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Research Article

The Effect of Stretching, Foam Rolling, and FIFA 11+ Warm-ups on Performance and Pain in Athletes with Knee Pain

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Abstract

Background: Patellofemoral pain syndrome (PFPS) is the most prevalent disease of the knee. The purpose of this study was to compare the acute effects of various warm-up methods on several performance measures and pain intensity in athletes with and without PFPS.
Methods: This clinical trial study included 18 to 24-year-old professional female athletes with or without PFPS. Both groups performed warm-up protocols, including general stretching, foam rolling, and Federation Internationale de Football Association (FIFA) 11+ warm-up exercises in three test sessions simultaneously. The data collection procedure was implemented on three separate days in one week. Pain intensity was measured using the Visual Analogue Scale (VAS). Countermovement jump (CMJ) and squat jump (SJ) to measure the stretch-shortening cycle (SSC) and Landing Error Scoring System (LESS) were examined before and after each session.
Results: No significant difference was observed between the effect of different warm-ups in groups with and without PFPS regarding the use of the SSC ($P = 0.185$), while there were significant differences in the effect of various warm-up protocols on LESS ($P < 0.001$) and pain scores ($P < 0.001$).
Conclusion: Using the foam roller as a warm-up method can decrease the pain intensity in athletes with PFPS but may increase their LESS score. In addition, there was no difference in the effect of various warm-up methods on the SSC between athletes with and without PFPS. Finally, it seems that foam rolling should be used with more caution as a part of warming up in athletes with PFPS.

Keywords: Patellofemoral Pain Syndrome; Athletes; Warm-up Exercise; Pain; Athletic Performance

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Background

Patellofemoral pain syndrome (PFPS) is the most commonly diagnosed condition in people with knee problems (1). A general practitioner records five or six patients with PFPS annually, while women have a higher incidence than men (2). Although the incidence and the exact prevalence of PFPS are still unrevealed, it is the most common knee injury, and the rate has been estimated to be as high as 40% (3). Different treatments are suggested for knee pain (4, 5), and different sources can be involved in causing this pain. Research has demonstrated that decreased flexibility in the iliotibial band, quadriceps femoris, and hamstrings may be the risk factors for developing PFPS (6-8). Musculotendinous stiffness is also one of the main factors that may put mechanical pressure on the knee structures, causing pain (9). Therefore, decreasing muscle stiffness and increasing muscle flexibility are suggested as possible interventions to manage PFPS (10).

Warm-up is defined as a preliminary exercise period to enhance performance in training and competition (11). Warm-up is prescribed to raise blood flow, and consequently, it can increase muscle temperature and tissue flexibility (12, 13). Thus, the warm-up has been suggested as the preventive method for sports-related injuries (14). However, the warm-up program is influenced by the type of sport and the purpose of the exercise (8). Old warm-up techniques recently have been superseded by new ones, which allow for the use of various instruments, including foam rollers (13). Recently, foam rollers have become popular among athletes to reduce stiffness, enhance flexibility, and control pain (15). Previous studies showed that muscle stretching and foam rolling could improve muscle flexibility and joint stiffness (16). Foam rolling can reduce muscle stiffness and increase range of motion (ROM) when used in combination with dynamic stretching and active warm-up before a training session, and it also reduces delayed-onset muscle soreness (DOMS) (17). Furthermore, the result of a systematic review demonstrated that foam rolling and roller massage might be helpful therapies for improving joint ROM and muscle function before and after exercise (18).

Foam rolling is a method in which the target muscle is rolled and compressed (19). It has been shown that foam rolling may improve ROM, abate pain, accelerate the recovery period, and enhance performance (20). It seems that the warm-up by foam roller can reduce PFPS pain (8). There are not enough reliable and documented references that show us what specific sports can benefit from foam rolling warm-ups (13).

Another method of warm-up is Federation Internationale de Football Association (FIFA) 11+ program. The FIFA 11+ warm-up method is one of the latest methods that is used in the world of professional sports, especially football. This method is being considered to prevent injury (21). The FIFA 11+ injury prevention program is being formed of slow-speed running, active stretching, strengthening, jumping, speed running, and balance exercises. The FIFA 11+ has replaced the routine warm-up

program. It is easy to perform, and the duration is about 15 minutes (22). Nevertheless, there is no sufficient evidence to determine what type of warm-up method may be superior to others.

Various warm-up protocols have been studied in many aspects. For instance, it has been shown that balance performance might be improved through static and dynamic stretching exercises (23). Furthermore, the result of a systematic review showed that the use of static stretching did not appear to improve overall injury rates. However, there is preliminary evidence that musculotendinous injuries may be diminished with static stretching (24). Still, there is a lack of studies that examined the effect of these methods on athletes with PFPS. Although most studies have concentrated on examining the possible effects of warm-up protocols on athlete injury prevention, there is still a lack of evidence to investigate the impact of warm-ups on athletes with existing injuries. Therefore, this study aimed to compare the immediate effect of selected warm-up methods on some performance indexes and pain in professional athletes with and without PFPS.

Methods

Participants: This clinical trial study included 18 to 24-year-old professional female athletes with or without PFPS in the Iranian League of Volleyball. Participants were recruited using advertisements. 16 athletes with PFPS and 14 athletes with no history of PFPS voluntarily participated in the study. To estimate the sample size, G*Power software (version 3.1) was used. The data of a previous study with presented effect size on the pain threshold changes after prescribing foam rolling (effect size: 0.76) were used (25). It was shown that it would require at least 21 volunteer participants in both groups to achieve 90% of statistical power at a 95% confidence interval (CI). However, 28 participants were recruited to eliminate the possible effect of dropouts on the results. Female athletes who met the following criteria were included in the study: having at least six years of regular exercise experience, weekly exercise of at least three sessions per week, a history of playing in the Iranian League of Volleyball, no history of injury in the lower extremity during the last three months (for the group without PFPS), obtaining a score of three and more based on Visual Analogue Scale (VAS) questionnaire, and having PFPS for more than three months. The exclusion criteria were as follows: a history of any pathological symptoms, fractures, surgery, and joint diseases in the lower extremity or spine, presence of significant postural malalignment in the trunk or lower extremities based on the New York Posture Rating, using drugs that affect the central nervous system (CNS) such as sedatives, inability to perform the protocol, feeling pain in any part of the body while performing the test, and Body Mass Index (BMI) less than 18 or more than 25 kg/m^2.

Preparation for Testing: First, a general description of the testing procedure was provided verbally and individually in writing as part of the introduction. Then the athletes completed the informed consent form and fulfilled the health questionnaire. All athletes were assured that all information obtained from their test would remain confidential, and they could leave the research any time they wanted. Both groups performed warm-up protocols in three test sessions simultaneously. The data collection procedure was implemented on three separate days at a one-week interval. On the first day of the test, participants performed three jump-landings from a 30-cm box, three squats, and three countermovement jumps (CMGs) as a pre-test at the beginning of the session. Then, the participants were asked to run a warm-up program of FIFA 11^+, and at the end, they re-ran all tests mentioned as post-tests. A week later, at the second session, they carried out the foam roller warm-up protocol, and after that, a post-test was done. Finally, in the third and final test session, athletes accomplished a pre-test and a simple warm-up protocol before the post-test.

Tools: Pain intensity was measured by VAS. The VAS is a self-reported pain scale that includes a vertical or horizontal line with extreme anchors ranging from "no pain" to "severe pain" (26). It is frequently depicted as a horizontal line 100 millimeters long. The VAS is the best tool for describing pain intensity because of its simplicity, dependability, validity, and ratio scale features (27). Participants (in the group with PFPS) with a VAS score of three and more and also those suffering from pain for less than three months were excluded from the study. According to a previous study, the reliability of VAS had been proved for knee pain examination (26).

The Landing Error Scoring System (LESS) is one of the most commonly used tools to assess motion quality during landing. The LESS examines 17 items or errors linked with anterior cruciate ligament (ACL) loading during landing (28). The LESS is a score that indicates the number of errors made by the individual during the jump-landing task (29). The reliability of the LESS is excellent [intra-class correlation coefficient (ICC) 2,1 = 0.91, ICC2, k = 0.84] (28). Furthermore, one study found that the total LESS score had good-to-excellent intra-rater, inter-rater, and intersession reliabilities (30). The LESS was used to evaluate the landing error. To perform this test, subjects were taught to jump from a 30-cm box and land on a line that was placed at 50% of their height away from the box. After landing, they immediately performed a maximum vertical jump. We used two digital cameras (model D300, Nikon Kabushiki-Kaisha, Japan) for the analysis of movement. One camera was used to capture movement in the frontal plane during the jump-landing procedure, while the other was used to capture movement in the sagittal plane (29). Each participant was scored using the LESS criteria.

In the current study, the difference between CMJ and squat jump (SJ) was used to measure the stretch-shortening cycle (SSC). A previous study established that the CMJ measurements used in this study were the most reliable field tests for the explosive strength of the lower extremities in athletes (31).

First, subjects performed an SJ and recorded the height of the jump, then performed a CMJ and recorded the height as well; after that, the value of the CMJ was subtracted from the SJ. This value was used as an indicator for the SSC. A marker was attached to the anterior superior iliac spine (ASIS) to measure the height of the jump more accurately. The jump was recorded from the sagittal plane by a camera. Subsequently, the jump height was measured through Kinovea software using following formula: SSC = CMJ height ($CMJH$) – SJ height (SJH)/$SJH \times 100$.

Warp-up Protocols

Foam Roller Protocol: Foam rolling was done with a Perform Better Bio-Foam Roller (15.24 cm diameter, 30.48 cm length) (Perform Better Inc., Cranston, RI, USA). The foam roller's average pressure has been calculated to be 33.4 ± 6.4

kPa. In this study, a six-minute foam-rolling protocol for the lower extremity muscles was prescribed. Rolling was done for the hamstring muscles group, calf and soleus muscles, gluteal muscles, iliotibial band, and quadriceps femoris muscles. Each section had a time limit of sixty seconds. The foam rolling was performed as follows: left and right gluteal muscles (30 seconds on each side), hamstring muscles group (60 seconds), quadriceps femoris (30 seconds each side), left and right hamstrings (30 seconds on each side), calf and soleus (60 seconds), and iliotibial band (30 seconds each side) (32). A numerical rating scale (0 = no discomfort, 10 = maximal discomfort) with a range of six to seven was used to standardize the amount of exerted pressure.

General Stretching Exercise: This exercise included 5 minutes of walking and 5 minutes of static stretching and focused on the lower body. The participants walked at a moderate pace for five minutes before performing ten static stretches. A stretching application includes a sequence of stretches, each lasting 30 seconds. We performed stretching in the following order: sitting with feet together, sitting with feet apart, sacral stretch in supine position, leg lift with towel in supine position, and calf stretch with towel in sitting position. All other stretches were performed for 30 seconds on both the left and right sides.

FIFA 11⁺ Protocol: FIFA 11^+ is a comprehensive warm-up program that includes running exercises at the beginning and in the end. The exercises consist of core stabilization, eccentric thigh muscle training, proprioceptive training, dynamic stabilization, and plyometric exercises, all performed with proper postural alignment (33). All of these are divided into three levels based on the difficulty of providing variety and progression. It takes around 20 minutes to finish and just requires a few basic tools (34). The first part takes 8 minutes, the second one 6 minutes, and the last part two minutes (19). Before starting the study, the subjects were informed about the procedure of warm-up in the 11^+ method, and also, a tutorial video and a Persian guideline for the exercises were provided.

Statistical Analysis: Data were processed using the SPSS software (version 22.0, IBM Corporation, Armonk, NY, USA). The mean and standard deviation (SD) were used to summarize all the data. The normality of the data distribution was examined using the Shapiro-Wilk test. Data were analyzed using one-way repeated measures analysis of variance (ANOVA). Statistical significance was set at $P < 0.05$.

Results

All included participants completed the study. Study participants' demographics are summarized in table 1.

Table 1. Demographic characteristics of the study participants

Variable	PFPS (n = 15)	Without PFPS (n = 15)
Age (year)	24.00 ± 2.64	19.66 ± 1.50
Height (cm)	168.67 ± 4.16	169.78 ± 1.56
Weight (kg)	72.16 ± 2.25	60.11 ± 7.97
BMI (kg/m²)	25.17 ± 1.07	20.81 ± 2.32

Data are presented as mean ± standard deviation (SD)
PFPS: Patellofemoral pain syndrome; BMI: Body mass index

Data analysis showed no significant difference in the effects of different warm-up protocols on the use of SSC in groups with and without PFPS (P = 0.185), while there were significant differences in the effect of various warm-up protocols on LESS (P < 0.001) (Table 2) and pain scores (P < 0.001) (Table 3). The least significant difference (LSD) post-hoc test showed that the LESS score increased significantly in athletes with PFPS that had warm-up with foam roller compared to the pre-test. In addition, foam roller warming-up reduced pain in athletes with PFPS, whereas the pain was increased by general stretching exercise.

Discussion

This research showed that the LESS score increased and pain intensity decreased significantly in athletes with PFPS after using a foam roller. But various warm-up protocols showed no different effect on the SSC between both groups.

This study showed no significant difference in the effect of various warm-up protocols on the usage of the SSC between athletes with and without PFPS. Although previous studies showed that different exercises, including stretching, could affect the SSC (35, 36), there is no evidence to compare the effects of these exercises on athletes with and without PFPS. The SSC is a sequence of muscle eccentric, isometric amortization, and concentric activities that help the muscle to increase force output (37). The current study does not provide evidence to support using any type of warm-up that may positively affect the SSC in athletes with PFPS.

Furthermore, the results showed that there was a significant difference in the effect of different warm-up protocols on the LESS score of athletes with and without PFPS. It is demonstrated that the LESS score increases significantly after foam rolling in athletes with PFPS. Regarding the positive effects of foam rolling on an athlete's movement pattern, recent studies have shown that use of foam rolling improves athlete's function (38), ROM (39), and lunge movement (40). Nevertheless, there is not any study that investigated the effects of different warm-ups on LESS scores in athletes with PFPS. Recent studies indicated that the LESS was a reliable tool that could predict future injuries in athletes (30, 41). It is important to note that athletes with PFPS, unlike the athletes without PFPS, may be at increased risk of injury after using foam rolling. To explain the possible mechanism of reduction of injury risks in athletes without PFPS, we can refer to the prior studies showing that foam rolling may result in improving proprioception (42) and tissue flexibility (43, 44).

Nevertheless, it seems that tissue adaptations to PFPS may have a protective effect on the lower extremity. Therefore, it can be suggested to use foam rolling with more caution in athletes with PFPS.

Table 2. The effects of various warm-up protocols on groups with and without patellofemoral pain syndrome (PFPS) regarding usage of the stretch-shortening cycle (SSC) and Landing Error Scoring System (LESS)

Variable	Group	Time	11^+	Warm-up	Foam rolling	F	P-value	Power	Effect size
SSC	PFPS	Pre-test	1.51 ± 0.30	1.37 ± 0.70	1.99 ± 1.30	1.744	0.185	0.350	0.061
		Post-test	3.61 ± 0.37	1.17 ± 1.92	3.71 ± 2.10				
	Without PFPS	Pre-test	0.42 ± 1.30	0.45 ± 1.33	0.68 ± 1.44				
		Post-test	2.17 ± 2.12	1.45 ± 2.27	2.40 ± 1.80				
LESS	PFPS	Pre-test	8.38 ± 0.65	8.69 ± 1.10	8.38 ± 1.04	9.840	< 0.001	0.978	0.267
		Post-test	6.46 ± 0.87	7.61 ± 0.76	9.69 ± 1.31				
	Without PFPS	Pre-test	8.43 ± 1.09	8.50 ± 1.36	7.81 ± 1.93				
		Post-test	6.87 ± 1.20	7.37 ± 1.02	5.93 ± 2.74				

Data are presented as mean ± standard deviation (SD)
SSC: Stretch-shortening cycle; PFPS: Patellofemoral pain syndrome; LESS: Landing Error Scoring System

Table 3. Statistical data analysis of pain intensity

Variable	Group	Time	11+	Warm-up	Foam rolling	F	P-value	Power	Effect size
Pain intensity	PFPS	Pre-test	2.88 ± 0.41	2.76 ± 0.56	2.92 ± 0.49	32.761	< 0.001	0.999	0.732
		Post-test	2.89 ± 0.65	3.76 ± 0.78	1.73 ± 0.63		< 0.001	0.999	0.732

Data are presented as mean ± standard deviation (SD)
PFPS: Patellofemoral pain syndrome

Furthermore, the results showed that pain intensity reduced significantly after prescribing foam rolling. Numerous studies showed that foam rolling could reduce pain intensity in several musculoskeletal pain disorders, such as knee pain (45) and low back pain (46). However, to the best of our knowledge, this is the first study that compares the acute impacts of these different warm-up methods on athletes with and without PFPS. The decrease in pain may be due to the increased pressure pain threshold (47) and force sense changes (48) in the body tissues. Therefore, it seems that foam rolling might be preferable compared to the FIFA 11+ or general warm-up exercises for athletes who are suffering from PFPS.

Our study has certain limitations. First, the FIFA 11+ warm-up method, as it is known, is a specific method for football, and it might not be usable for sports such as volleyball, which involves lots of jumping and landing. Second, it proved that the LESS score decreased after prescribing foam rolling for athletes with PFPS, but the possible impact of decreasing the LESS score on future sport-related injuries remained unclear. Lastly, although foam rolling reduces pain intensity immediately after exercise, the long-term effects of this method on pain are still unknown.

Conclusion

Using the foam roller as a warm-up method can decrease the pain intensity in athletes with PFPS but may increase their LESS score. In addition, there was no difference in the effects of various warm-up methods on the SSC of athletes with and without PFPS. Finally, it seems that foam rolling should be used with more caution as a part of warm-up program in athletes with PFPS.

Conflict of Interest

The authors declare no conflict of interest in this study.

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