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Acute Effects of Static Stretching, Dynamic Stretching, and Foam Rolling on the Range of Motion and Joint Position Sense of the Knee Joint in Adolescents

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Research Paper

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Abstract

Purpose: The purpose of the present study was to investigate the acute effects of static stretching, dynamic stretching, and foam rolling on knee range of motion and joint position sense in healthy male adolescents. **Method:** In a quasi-experimental study with a pretest–posttest design, 40 male adolescents (12–17 years) were randomly assigned to static stretching, dynamic stretching, foam rolling, and control groups. Knee ROM and JPS were measured before and immediately after the intervention. Data were analyzed using repeated-measures ANOVA. **Results:** No significant interaction effect was found between time and group for ROM ($p > 0.05$) or JPS ($p > 0.05$). Although a significant main effect of group was observed for ROM ($p < 0.001$), no significant changes were found in JPS. **Conclusion:** A single session of static stretching, dynamic stretching, and foam rolling did not significantly affect knee joint ROM or JPS in healthy adolescents.

Keywords: Static Stretching, Dynamic Stretching, Foam Rolling, Range of Motion, Proprioception, Knee

Introduction

Stretching exercises and foam rolling are widely used in warm-up routines, physical conditioning, and sports rehabilitation programs)Warneke et al., 2024; Warneke et al., 2025(. Their main goals are to increase flexibility and muscle length, improve joint range of motion, enhance sports performance, and prevent musculoskeletal injuries)Lewis A Ingram et al., 2025(. Despite the widespread use of stretching exercises, there is still no consensus regarding the type and extent of their effects on neuromuscular factors)Warneke et al., 2025(. One study reported that stretching may affect muscle performance differently)Chaabene et al., 2019(. Some research has shown that static stretching before activity can reduce muscle strength, power, and speed, and increase the risk of injury(Warneke & Lohmann, 2024). For example, Fowles et al. reported a significant decrease in the strength of the ankle flexor muscles after static stretching)Fowles et al., 2000(. Furthermore, Cramer et al. showed that performing stretching protocols at different times leads to a decrease in peak torque and muscle strength)Cramer et al., 2004(. In contrast, some studies have shown that stretching does not necessarily lead to a significant decrease in muscle performance; for example, Annino et al. reported that after performing static and dynamic stretching in professional basketball players, no significant change was observed in muscle strength and vertical jump power)Annino et al., 2017(. Furthermore, evidence shows that different types of stretching exercises can lead to an increase in joint range of motion)Esteban-García et al., 2024(. These conflicting findings have created ambiguity in selecting the appropriate type and timing of stretching exercises.

In this context, the knee joint, due to its key role in functional and athletic activities, is considered one of the most important joints in studies related to neuromuscular performance and injury prevention)Neumann, 2016(. Due to the ground reaction force passing through the medial compartment of the knee joint, significant mechanical pressure is imposed on the medial compartment of the knee, which can increase the risk of injuries and degenerative changes)J.-H. Kim et al., 2025(. On the other hand, knee injuries such as anterior cruciate ligament rupture, meniscus injury, and functional joint disorders have a high prevalence, especially among athletes in sports such as football and basketball)Martinez-Calderon et al., 2025(. Therefore, designing effective interventions to improve the function and health of the knee joint is of great importance.

One of the important factors in maintaining normal knee joint function is joint position sense (JPS))Chen et al., 2025(. JPS plays an important role in joint stability, motor coordination, and injury prevention).Yılmaz et al., 2024(Proprioceptive receptors in muscle, tendon, and connective tissues of the joint transmit information about limb position and movement to the central nervous system, and any functional impairment in this system can lead to reduced neuromuscular control and an increased risk of injury)Lallemend et al., 2025(. Given the sensitivity of muscle spindles to stretch and stretch velocity, it has been suggested that stretching exercises, both static and dynamic, may influence joint proprioception)Stephens et al., 2025(. Physiological studies have shown that during muscle stretching, the activity of muscle spindles increases and then decreases immediately after)Brokensha & Westbury, 1974.(However, the findings of clinical studies regarding the effect of stretching on JPS are conflicting; some studies have reported no significant change in JPS)Azevedo, Moreira, et al., 2025; Azevedo, Teixeira, et al., 2025(, while others have reported an improvement or decrease in knee JPS after stretching)Guede-Rojas et al., 2024; Simões et al., 2025(.

Joint range of motion (ROM) is also considered one of the important factors of musculoskeletal function and physical fitness, and limitation in ROM can increase the risk of injury and dysfunction)Garipi et al., 2025(. Flexibility throughout the full joint range of motion plays an important role in performing sports skills and preventing injuries)Garipi et al., 2025(. Various studies have reported the positive effect of stretching exercises on increasing ROM)Matsuo et al., 2025; Warneke et al., 2025(. Furthermore, the use of foam rolling as one of the modern methods of myofascial release has gained attention in recent years, and some studies have shown that this method can improve flexibility and muscle performance)Yang et al., 2025(. Nevertheless, there is insufficient evidence regarding the acute effect of foam rolling compared to static and dynamic stretching on knee joint ROM and JPS.

Despite the increase in studies related to stretching exercises and foam rolling, there are still significant gaps in this area. Most previous research has focused on adult populations, athletes, or individuals with musculoskeletal disorders, and limited information exists regarding the acute neuromuscular responses of healthy adolescents to these interventions. Adolescence is associated with rapid changes in the musculoskeletal system and the ongoing maturation of the neuromuscular system(Tumkur Anil Kumar et al., 2021), and these characteristics may lead to differences in proprioceptive responses and range of motion compared to adults. Furthermore, many previous studies have examined only one variable, either range of motion or joint position sense, and only a limited number of studies have simultaneously compared the acute effects of static stretching, dynamic stretching, and foam rolling within a single research design. Investigating these interventions in adolescents could provide a more precise understanding of their immediate effects on knee joint function during an important developmental period. Therefore, the aim of the present study was to investigate the acute effect of static stretching, dynamic stretching, and foam rolling on the ROM and proprioception of the knee joint.

Methods

Study Design

The present study was a quasi-experimental study with a pretest-posttest design, including a control group. In this study, the effect of three types of interventions—static stretching, dynamic stretching, and foam rolling—on knee joint ROM and JPS was investigated. The sample size was estimated using G*Power software, considering an effect size of 0.6, a significance level of 0.05, and a statistical power of 0.80, resulting in 36 participants. Due to the potential for participant dropout, a total of 40 individuals were ultimately recruited through convenience sampling and were randomly assigned to four groups: static stretching, dynamic stretching, foam rolling, and control.

Participants

The target population of the study consisted of boys aged 12 to 17 years in Tehran. A total of 40 individuals with a mean age of 14.02±1.09 years were selected using convenience sampling (based on the criteria) and were then randomly assigned to the groups. Inclusion criteria included age 12–17 years, male participants, absence of hamstring and quadriceps muscle shortness, general health, and the ability to participate in the tests. Exclusion criteria included a history of neuromusculoskeletal or systemic diseases; neurological or vestibular disorders; a history of lower limb injury during the past six months; a history of knee joint surgery; the presence of knee deformity or movement restriction; use of analgesic medications; alcohol or drug addiction; and unwillingness to continue participation at any stage of the study.

To describe the participants' demographic characteristics, body mass index (BMI) was calculated based on height and weight. The participants' physical activity levels ranged from light to moderate, and none of the subjects had a history of professional or regular structured strength or specialized training. Baseline flexibility was not directly measured; however, the inclusion criteria required the absence of muscle tightness and lower-limb range of motion limitations, which to some extent ensured sample homogeneity.

Measurement

Assessment of the knee ROM

To measure knee joint ROM, a range of motion measurement software with acceptable validity ($r = 0.85$ for the left knee and $r = 0.77$ for the right knee) was used)L. Kim et al., 2025(. During the assessment, the participant was placed in a supine position with the hip and knee positioned at 90 degrees of flexion. The examiner then passively extended the participant's knee, and the maximum knee extension angle was recorded.

Assessment of knee JPS

To assess knee joint JPS, the knee joint angle replication test (using Goniometer Pro application) was employed ($ICC = 0.993$, $r = 0.992$))Melián-Ortiz et al., 2019(. In this method, the participant was seated, and the knee joint was passively placed at a 45-degree angle by the examiner to allow the individual to perceive the target angle. Then, after returning the limb to the initial position and removing visual feedback, the participant was asked to actively replicate the previous angle. The difference between the target angle and the replicated angle was recorded as the joint angle replication error. A smaller error indicated greater accuracy of JPS and better proprioceptive function of the knee)Busch et al., 2023(.

Intervention

After performing the pretest, participants received the respective interventions according to the designated grouping.

Static stretching

In the static stretching group, hamstring muscle stretching was performed. The participant lay in a supine position on a table, with the tested lower limb having an extended knee and the ankle in a neutral position. The examiner passively moved the limb from the hip joint in the direction of hip flexion until a tolerable stretch was felt in the hamstring muscles without causing pain. Meanwhile, the contralateral limb was kept in full extension on the table. The stretching angle was maintained at the participant's maximum tolerable range. Each stretching bout lasted 30 seconds, and the exercise was performed for 3 repetitions with 30 seconds of rest between repetitions)Reid & McNair, 2004(.

Foam rolling

In the foam rolling group, myofascial release of the hamstring muscles was performed using a foam roller. The participant sat in a seated position on the floor, and the foam roller was placed under the tested lower limb at the proximal region of the hamstring muscles, near the gluteal fold. The lower limb was positioned in full knee extension with the ankle in a neutral position. Then, leaning on the upper limbs and keeping the trunk in a suspended position, the participant moved their body forward and backward in a controlled manner so that the foam roller traveled from the proximal hamstring region to the posterior region of the knee. The applied pressure was within the participant's tolerable limit and without causing pain)Sağıroğlu et al., 2025(. The exercise protocol consisted of three 1-minute repetitions with 30 seconds of rest between repetitions. In this study, DTR foam rollers with an outer diameter of 10 cm and a thickness of 3 cm were used.

Dynamic stretching

In the dynamic stretching group, active hamstring muscle stretching was performed. The participant stood in a standing position and, while maintaining body balance, moved the tested lower limb with an extended knee and the ankle in a neutral position in a swinging motion in the direction of hip flexion. The range of motion was performed up to the maximum tolerable range without causing pain in order to create an appropriate stretch in the hamstring muscles. Each exercise bout lasted 30 seconds, and the protocol consisted of 3 repetitions with 30 seconds of rest between repetitions)Barbosa et al., 2020(.

The control group did not receive any intervention during the study period.

Statistical analysis

SPSS version 26 software was used to describe the data, and the significance level was set at $P < 0.05$. The normality of data distribution was examined using the Shapiro–Wilk test. Given the pretest-posttest design of the study, a one-way repeated measures ANOVA was used to compare groups and examine the effect of interventions.

Results

Table 1 shows the demographic characteristics of the participants in the four groups. No significant differences were observed in demographic characteristics among the groups. The results of the Shapiro–Wilk test indicated that the data followed an approximately normal distribution.

Table 1. Demographic characteristics of participants

Data	Group	Mean±SD	P-value
Age (years)	Static stretch	13.30 ± 0.21	0.05
	Dynamic stretch	13.90 ± 0.37	
	Foam rolling	14.40 ± 0.45	
	Control	14.50 ± 0.16	
Height (cm)	Static stretch	157.90 ± 0.01	0.060
	Dynamic stretch	162.60 ± 0.03	
	Foam rolling	171.60 ± 0.01	
	Control	165.00 ± 0.054	
Weight (kg)	Static stretch	48.10 ± 2.09	0.183
	Dynamic stretch	51.80 ± 3.85	
	Foam rolling	61.20 ± 3.07	

	Control	53.50 ± 6.53	
BMI (kg/m²)	Static stretch	19/21±1/75	0.560
	Dynamic stretch	19/53±3/66	
	Foam rolling	20/75±2/87	
	Control	18/86±3/73	

BMI; Body mass index (kg/m²)

The results of repeated measures ANOVA for ROM (Table 2) showed that the time effect on knee joint range of motion was not significant ($F = 0.044$, $p = 0.835$). The time by group interaction was also not significant ($F = 0.612$, $p = 0.612$). However, the main effect of groups was significant ($F = 16.009$, $p = 0.001$), indicating the presence of differences between groups in knee range of motion. The results of repeated measures ANOVA for JPS (Table 2) also showed that the time effect on the variable under study was not significant ($F = 0.669$, $p = 0.419$). The time by group interaction was not significant either ($F = 0.146$, $p = 0.931$). Furthermore, the main effect of groups was not significant ($F = 1.963$, $p = 0.137$), indicating no differences between groups in this variable.

Table 2. ANOVA test results

Variable	Group	Stage	Mean ± SD	Effect	F	P
ROM	Static stretch	Pre-test	27.13±4.46	T	0.44	0.835
		Post-test	28.96±7.48	G	16.00	P<0.001
	Dynamic stretch	Pre-test	42.23±4.92	T×G	0.612	0.612
		Post-test	41.39±4.78			
	Foam rolling	Pre-test	30.89±5.23			
		Post-test	30.46±3.62			
	Control	Pre-test	33.09±5.71			
		Post-test	33.16±5.19			
JPS	Static stretch	Pre-test	7.74±4.86	T	0.669	0.419
		Post-test	6.96±8.92	G	1.96	0.137
	Dynamic stretch	Pre-test	5.83±4.99	T×G	0.146	0.931
		Post-test	5.76±5.03			
	Foam rolling	Pre-test	4.76±3.97			
		Post-test	4.06±4.78			
	Control	Pre-test	4.80±2.81			
		Post-test	2.70±1.78			

ROM: Range of Motion; JPS: Joint Position Sense; T: Time; G: Group

Discussion

The results of the present study showed that a single session of static stretching, dynamic stretching, and foam rolling did not induce significant changes in knee joint ROM and JPS in healthy adolescents. Although the main effect of groups was observed for the range of motion variable, the time effect and the time × group interaction were not significant, indicating that the changes induced after the intervention were not statistically significant.

One of the main mechanisms resulting from stretching exercises is a reduction in stiffness and an increase in soft tissue stretch tolerance)L. A. Ingram et al., 2025(. However, it seems that in this study, the duration of the interventions was insufficient to induce significant changes in the viscoelastic properties of soft tissue (stretches: three 30-second repetitions; foam rolling: three 1-minute repetitions). In this regard, systematic review studies have shown that significant effects of stretching are usually observed in protocols with longer durations)Panidi et al., 2023(. Studies have shown that the rapid increase in ROM after stretching is mainly due to increased stretch tolerance and perceptual changes of the nervous system rather than structural changes in the muscle or fascia)Konrad et al., 2025(. Furthermore, sustained mechanical changes in the musculotendinous unit typically occur in response to interventions with long duration and high training volume, not a single short-term training session)Panidi et al., 2023(. This could explain the lack of significant changes in the present study. Although some studies, such as the study by Walsh et al. have reported that both acute static and dynamic stretching can improve knee joint proprioception)Walsh, 2017(, The findings of our study are not consistent with these results. These discrepancies can be attributed to differences in intervention protocols and the characteristics of the study samples. The adolescent participants in this study, due to the absence of muscle shortness and having a relatively favorable level of flexibility at baseline, had limited capacity to produce further changes in range of motion.

From a neurophysiological perspective, stretching is expected to affect JPS by altering the activity of muscle spindles and Golgi tendon organs (GTO))Konrad et al., 2025(. Muscle stretching can temporarily reduce the sensitivity of muscle spindles and consequently alter the accuracy of joint angle replication)Budini et al., 2020(. However, In the present study, no significant changes in JPS were observed following the interventions. This finding is consistent with the study by Larsen et al., which reported that three bouts of 30-second static stretching of the hamstring and quadriceps muscles had no significant effect on knee JPS in healthy individuals)Larsen et al., 2005(. Furthermore, the study by Torres et al. showed that a single session of quadriceps stretching had no effect on JPS, sense of force, or threshold for detection of passive movement. The researchers of this study stated that acute stretching likely does not create a considerable change in the activity of muscle spindles and GTO)Torres et al., 2012(. In contrast, the results of the present study are inconsistent with those of the study by Ghaffarinejad et al. They reported that static stretching improves the accuracy of knee JPS at 45 degrees of flexion and attributed this improvement to increased afferent input from muscle receptors and enhanced kinesthetic awareness)Ghaffarinejad et al., 2007(. The participants in the present study were healthy adolescents, whereas some previous studies were conducted on active individuals or athletes, who may have different neuromuscular responses to stretching. It seems that the central nervous system in healthy adolescents can compensate for the temporary changes induced by stretching through the process of sensory reweighting, such that the accuracy of JPS is maintained at a relatively stable level)Mallau et al., 2010(. Furthermore, since proprioceptive function is the result of integrating information from multiple receptors, including muscle spindles, joint, ligamentous, and cutaneous receptors, a limited change in one afferent source may not be sufficient to produce a measurable change in JPS)Proske, 2024(.

Regarding the mechanism of foam rolling, although some studies have reported an increase in ROM)Hirose et al., 2025; Pinto et al., 2026(, the exact mechanism of action remains unknown. Hypotheses such as increased tissue temperature, changes in muscle viscoelastic properties, reduced neuromyofascial activity, improved blood flow, and pain modulation have been proposed)Warneke et al., 2024(. However, many studies emphasize that these changes are short-term and transient and do not necessarily lead to improved neuromuscular function)Bartik & Pacholek, 2025; Martínez-Aranda et al., 2024(. Therefore, the lack of a significant change in proprioception and range of motion following the use of foam rolling in the present study is not unexpected.

Overall, the findings of this study indicate that a single session of static stretching, dynamic stretching, or foam rolling in healthy adolescents has no significant acute effect on knee ROM and JPS. It seems that to induce significant changes in neuromuscular and mechanical function, longer protocols or chronic interventions are necessary. Furthermore, examining these interventions in individuals with movement limitations, injuries, or professional athletes could provide a more precise perspective on the actual effects of these methods.

It is recommended that future studies investigate the long-term effects of static stretching, dynamic stretching, and foam rolling on knee ROM and JPS. Furthermore, conducting studies in different groups, such as professional athletes, older adults, individuals with limited flexibility, and patients with muscular disorders, could provide a more precise perspective on the effects of these interventions. Finally, the use of more advanced tools such as 3D motion analysis systems and EMG could help to better understand the mechanical and neurological changes.

Study limitations

The present study has several limitations that should be considered when interpreting the results with caution. First, the study design was acute and based on a single intervention session; therefore, no definitive conclusions can be drawn regarding the long-term effects of static stretching, dynamic stretching, and foam rolling on knee joint ROM and JPS. Second, the study sample consisted of healthy adolescents without movement limitations or musculoskeletal disorders, which may have resulted in a ceiling effect and potentially limited the study's ability to detect intervention-induced changes. Third, the relatively small sample size may reduce the generalizability of the findings and limit the statistical power to detect significant differences between interventions. In addition, the variables were assessed using smartphone-based software tools, which, although reported to have acceptable validity and reliability, may still be subject to measurement error and operator-related variability during testing. Finally, potential learning effects or familiarity with the testing procedures may also have influenced the results.

Conclusion

The findings of the present study showed that a single session of static stretching, dynamic stretching, and foam rolling had no significant effect on knee ROM and JPS in healthy adolescents. Based on these findings, it appears that a single acute application of these interventions does not lead to meaningful improvements in neuromuscular function of the knee joint in this age group. Therefore, coaches and sports science practitioners should consider that the effects of these methods are likely dependent on the type of protocol, intervention duration, and participant characteristics, and they should not be regarded as primary tools for immediate improvements in neuromuscular control in healthy adolescents. Finally, future research is recommended to examine the chronic effects of these interventions, as well as their impact in athletes, individuals with movement limitations, and different age groups.

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Conflicts of Interest:

The author declares no conflict of interest.

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