JHSS
Journal of Health and Sport Sciences

ARAŞTIRMA MAKALESİ
E-ISSN: 2791-6847
JHSS 2025; 8(2): 93-108

# COMPARISON OF THE ACUTE EFFECTS OF SELF-MYOFASCIAL RELEASE AND STATIC STRETCHING ON THE PIRIFORMIS MUSCLE IN HEALTHY INDIVIDUALS*

**Emine İrem ŞAHİN[1**], Melahat MEHRİOĞLU[2], Tuğba ŞİMŞEK[3], Görkem KIYAK[4], Ahmet Said UYAN[5], Zeliha BAŞKURT[6], Sabriye ERCAN[7]**

Gönderim Tarihi: 02.05.2025 - Kabul Tarihi: 19.08.2025

## Abstract

**Objective:** The aim of the study was to investigate the acute effects of self-myofascial release (SMR) and static stretching (SS) on hip range of motion (ROM), hip muscle strength, flexibility, and pressure pain threshold.

**Methods:** The study was a crossover-randomized controlled trial. A total of 20 participants (mean age = 23.25 ± 1.97) took part in SMR (3 sets × 30 seconds), SS (3 sets × 30 seconds) and control sessions on three separate days, with a two-day interval between sessions. Hip ROM was measured using a goniometer, strengths were measured using a hand-held dynamometer, flexibility was assessed using a standard sit-and-reach test, and pressure pain threshold was measured using an algometer.

**Results:** A statistically significant difference was found in abduction ROM in the dominant lower extremity ($p<0.05$) in favour of SMR. The flexion and adduction ROM values were significantly higher in the nondominant lower extremity after SMR and SS interventions compared to the control session ($p<0.05$).

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* *This research was presented at 3rd International / 6th National Health Services Congress held in Suleyman Demirel University on 19-21 December, 2024.*

1 Doktora Öğrencisi, Süleyman Demirel Üniversitesi Sağlık Bilimleri Enstitüsü, Isparta / Türkiye, rmshnieai@hotmail.com, ORCID: 0000-0002-3635-8894
** Sorumlu Yazar

2 Doktora Öğrencisi, Süleyman Demirel Üniversitesi Sağlık Bilimleri Enstitüsü, Isparta / Türkiye, melahatmehrioglu@gmail.com, ORCID: 0000-0001-8088-3568

3 Doktora Öğrencisi, Sağlık Bilimleri Üniversitesi İstanbul Fatih Sultan Mehmet Sağlık Uygulama ve Araştırma Merkezi, İstanbul / Türkiye, tugbasimsek234@gmail.com, ORCID: 0000-0002-8607-3061

4 Arş. Gör., Süleyman Demirel Üniversitesi, Tıp Fakültesi, Dahili Tıp Bilimleri Bölümü, Spor Hekimliği Anabilim Dalı, Isparta / Türkiye, gorkemkiyak0@gmail.com, ORCID: 0000-0003-4780-8480

5 Dr. Arş. Gör., Süleyman Demirel Üniversitesi, Tıp Fakültesi, Dahili Tıp Bilimleri Bölümü, Spor Hekimliği Anabilim Dalı, Isparta / Türkiye, ahmetsaiduyan@gmail.com, ORCID: 0000-0002-0878-3877

6 Prof. Dr., Süleyman Demirel Üniversitesi Sağlık Bilimleri Fakültesi, Fizyoterapi ve Rehabilitasyon Bölümü, Isparta / Türkiye, zelihatulum@gmail.com, ORCID: 0000-0001-7488-9242

7 Doç. Dr., Süleyman Demirel Üniversitesi Tıp Fakültesi, Dahili Tıp Bilimleri Bölümü, Spor Hekimliği Anabilim Dalı, Isparta / Türkiye, sabriyeercan@gmail.com, ORCID: 0000-0001-9500-698X

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E-ISSN: 2791-6847
JHSS 2025; 8(2): 93-108

**Conclusion:** It was found that SMR was as effective as SS in increasing ROM in the acute period. It is thought that SMR intervention to the piriformis muscle can be used safely in warm-up programs of athletes who need more range of motion and flexibility, and in preparation for rehabilitation exercises for individuals who experience movement limitations. Further investigation of its effects and underlying mechanisms is recommended.

***Keywords:*** *Piriformis muscle, Muscle stretching exercises, Physical fitness*

## SAĞLIKLI BİREYLERDE SELF-MİYOFASYAL GEVŞETME VE STATİK GERMENİN PİRİFORMİS KASI ÜZERİNE AKUT ETKİLERİNİN KARŞILAŞTIRILMASI

### Öz

**Amaç:** Bu çalışma, **s**elf-miyofasyal gevşetme (SMG) ve statik germenin (SG), kalça eklem hareket açıklığı (EHA), kalça kuvveti, esneklik ve basınç ağrı eşiği üzerine akut etkilerini incelemek amacıyla yapılmıştır.

**Yöntem:** Bu çalışma çapraz randomize kontrollü çalışmadır. Toplam 20 katılımcı (ortalama yaş=23,25±1,97) ikişer gün arayla toplam 3 gün SMG (3 set x 30 saniye), SS (3 set x 30 saniye) ve kontrol uygulamalarına katılmıştır. Kalça EHA gonyometre, kas kuvveti ölçümleri el dinamometresi, esneklik standardize otur-uzan testi ve basınç ağrı eşiği algometre kullanılarak değerlendirilmiştir.

**Bulgular:** Dominant ekstremitede abduksiyon EHA açısından SMG lehine istatistiksel olarak anlamlı fark bulunmuştur (p<0,05). Nondominant alt ekstremitede fleksiyon ve adduksiyon EHA, kontrol ile karşılaştırıldığında SMG ve SG uygulamalarından sonra anlamlı olarak daha yüksek bulunmuştur (p<0,05).

**Sonuç:** Akut dönemde EHA'yı artırmada SMG'nin SS kadar etkili olduğu bulunmuştur. Piriformise SMR uygulamalarının daha fazla hareket açıklığı ve esnekliğe ihtiyacı olan atletlerin ısınma programlarında ve hareket limitasyonu olan bireylerde rehabilitasyon egzersizlerine hazırlık için güvenle kullanılabileceği düşünülmektedir. Etkilerinin ve altta yatan mekanizmaların daha fazla araştırılması önerilmektedir.

***Anahtar Kelimeler:*** *Piriformis kası, Kas germe egzersizleri, Fiziksel uygunluk*

**Atıf:** Şahin, E. İ., Mehrioğlu, M., Şimşek, T., Kıyak, G., Uyan, A. S., Başkurt, Z. & Ercan, S. (2025). Comparison of the acute effects of self-myofascial release and static stretching on the piriformis muscle in healthy individuals. *JHSS, 8*(2), 93-108. DOI: 10.71416/jhss.1668190

## Introduction

The piriformis muscle is a flat, isosceles triangle-shaped muscle of the gluteo-pelvic region (Larionov et al., 2022). The function of the muscle is abduction when the hip is in flexion, external rotation when the hip is in extension, and it stabilizes the femoral head in the acetabulum (Siddiq et al., 2017). The piriformis muscle is mostly composed of type 1 fibres, which tend to develop shortness and tension when the muscle is under stress (Kukadia et al., 2019).

When the piriformis muscle spasms, it causes pain, tingling and numbness, similar to the symptoms of sciatic nerve compression (Ahmad Siraj & Dadgal, 2022). Physiotherapy including static stretching (SS) can relieve pain by reducing tension in the piriformis muscle, surrounding structures, and the sciatic nerve, which is considered the main treatment for piriformis syndrome (Itsuda et al., 2024). Myofascial release (MFR) is one of the techniques applied to increase soft tissue flexibility, which reduces adhesions between fascial tissue layers. Self-myofascial release (SMR) is a specialized technique within MFR performed by the individuals themselves. In SMR, soft tissue is stretched by using special tools such as foam rollers of various sizes, massage balls, and by applying pressure to the tissue with the body weight, with reciprocating movements from the proximal to distal and vice versa (Sulowska-Daszyk & Skiba, 2022).

The most common tool used in SMR is the foam roller. SMR has a number of benefits among the general population and athletes, such as increased flexibility and accelerated recovery. SMR appears to acutely increase joint range of motion (ROM) without negatively affecting athletic performance. It can also be used prior to exercise sessions, training, or competitions (Beardsley & Skarabot, 2015). SMR and SS are frequently used in daily routine rehabilitation practice. In addition, athletes frequently uses these techniques before, during, and after physical activity for various purposes. Studies on the effects of SMR and SS on different performance parameters are part of sports medicine research (Konrad et al., 2021). However, a review of the literature indicates that the number of studies on the effects of the mentioned techniques on performance-related parameters following the interventions targeting the piriformis muscle is limited (Kukadia et al., 2019; Rajendran & Sundaram, 2020).

In this study, we hypothesized that immediate changes would occur in hip ROM, hip strength, flexibility, and pressure pain threshold (PPT) parameters following SMR intervention. This study aimed to investigate and compare the acute effects of SMR and SS interventions targeting the piriformis muscle on hip ROM, hip strength, flexibility, and PPT.

## Materials and Methods

### *Procedure and Study Design*

Ethical approval for the study was obtained from the Clinical Research Ethics Committee of Suleyman Demirel University Faculty of Medicine on December 29, 2023 (approval number: 372).

### *Participants*

The study included 20 healthy individuals, 10 females and 10 males aged between 18 and 30 years, who volunteered. Participants were selected on a voluntary basis from the students studying at the Department of Physiotherapy and Rehabilitation, Faculty of Health Sciences, Suleyman Demirel University. An informed consent form was obtained from each participant in accordance with the Declaration of Helsinki.

The exclusion criteria were as follows: 1) having a lower extremity injury in the last 6 months, 2) having surgery for a lower extremity injury in the last 1 year, having piriformis syndrome, having any neurological or developmental musculoskeletal disorder, being younger than 18 years or older than 30 years.

***Outcome Measures***

After the volunteers signed the informed consent form, they were examined by a physician to rule out any pathology related to the piriformis muscle. Demographic and health-related information (gender, age, height, body weight, body mass index, dominant extremity, regular exercise habit) and lower extremity function level were recorded in the data collection form.

For hip ROM measurement, 6 different movements of the hip (flexion, extension, abduction, adduction, internal rotation, and external rotation) were measured with a goniometer (Baseline, Stainless Steel, USA) after the interventions to both extremities of the participant. Hip strength was assessed using a Jamar hydraulic hand dynamometer (Sammons Preston, Bolingbrook, IL, USA) for six movements: flexion, extension, abduction, adduction, internal rotation, and external rotation. For each assessment, participants were positioned as follows: 1) flexion: in the sitting position, 5 cm proximal to the proximal edge of the patella; 2) extension: in the prone position, 5 cm proximal to the proximal edge of the medial malleolus (posterior calf complex); 3) abduction: in the supine position, 5 cm proximal to the lateral malleolus; 4) adduction: in the supine position, 5 cm proximal to the medial malleolus; 5) internal rotation: in the sitting position, 5 cm proximal to the proximal edge of the lateral malleolus; 6) external rotation: in the sitting position, 5 cm proximal to the proximal edge of the medial malleolus. During each measurement, participants were asked to push the dynamometer using maximal hip force (Thorborg et al., 2010). Results were recorded in kg.

Flexibility was assessed separately for the right and left extremity according to the sit-and-reach test protocol. The participants were first asked to sit on the floor, with one knee flexed and the sole of the foot touching the floor, while the other foot and knee were stretched and the sole of the foot contacted the sit-and-reach table. Each participant was asked to stretch by pushing the bar on the sit-and-reach table with both hands forward, using their fingertips. Participants were allowed to make a trial as a warm-up. Then the test was performed three times and the mean values were recorded in cm. The test was then repeated for the other extremity.

An algometer (Force Dial FDK 20, Wagner Instruments, USA) was used for pressure pain threshold measurement. To locate the piriformis muscle, a line was drawn from the posterior superior iliac spine to the greater trochanter and another line from the anterior superior iliac spine to the ischial tuberosity. The piriformis muscle was identified at the intersection of the lines (Keskula & Tamburella, 1992). The pressure applied to the participant's hip area was recorded in kg at the moment they first felt the pain during the pressure was applied with an algometer.

The Lower Extremity Functional Scale (LEFS) was used to assess lower extremity function.

The Turkish validity and reliability study of the scale was conducted by Cankaya et al. in 2019 (Çankaya et al., 2019). It is a five-point Likert-type scale consisting of 20 questions that evaluates the individual's activities of daily living depending on the impairment in the lower extremity. Higher scores indicate better lower extremity function.

### *Procedures*

After the relevant information was obtained in the data collection form, 20 participants were included in the SMR, SS and control interventions for 3 days, two days apart, in accordance with cross randomization (Figure 1).

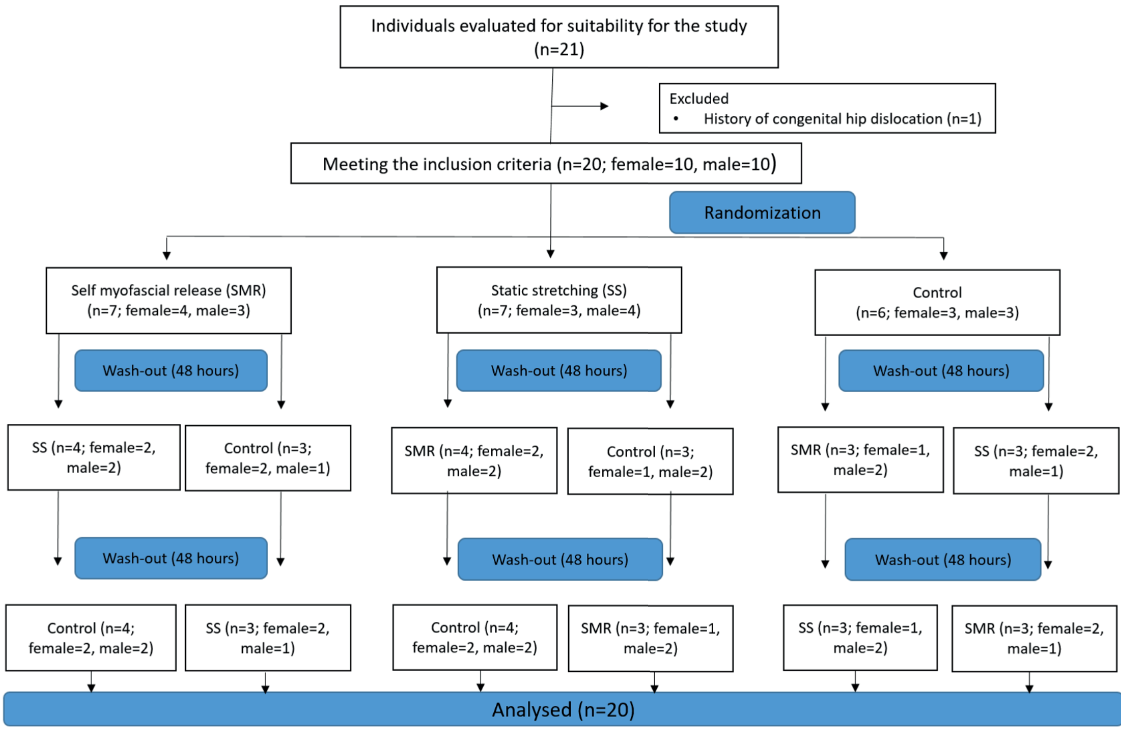


**Figure 1.** Flow chart

### *Self-Myofascial Release*

During the SMR, the foam roller was asked to be positioned on the participant's hip area, and the ankle of the same side positioned above the knee of the opposite extremity to increase the piriformis muscle activation (Figure 2a). In this way, the technique was performed 3 sets x 30 seconds for each piriformis muscle according to the literature (Behm et al., 2023; Chaabene et al., 2019; Su et al., 2017).

### *Static Stretching*

During the SS, the participant was asked to assume a supine position, and the stretching process towards the buttocks with the opposite knee was applied for 3 sets x 30 seconds (Figure 2b)

(Behm et al., 2023; Chaabene et al., 2019; Su et al., 2017). It was stated that the procedure could be stopped if the participant felt any discomfort.

After the SMR and SS techniques were applied to one extremity, the tests were started and the same technique was performed for the other extremity after the tests.

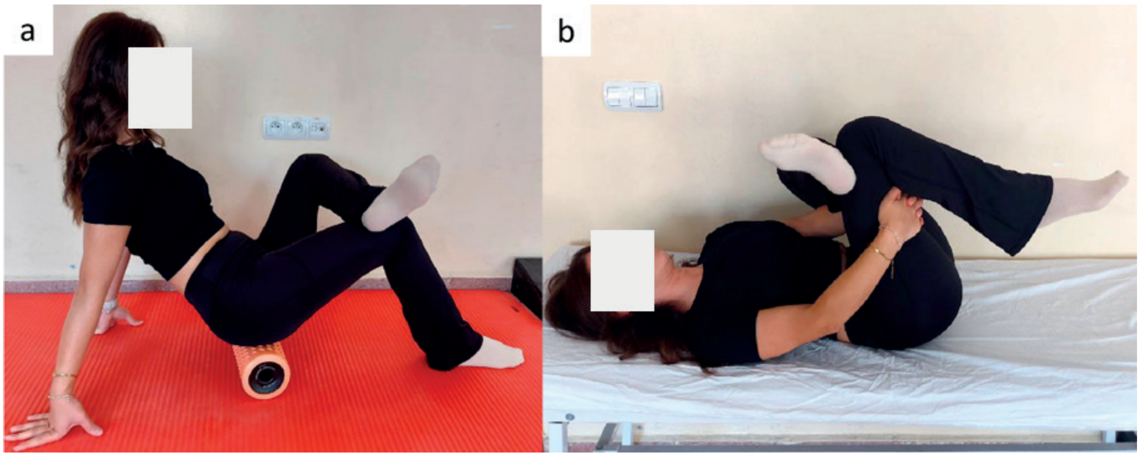


**Figure 2.** a) self myofascial release, b) static stretching

***Control***

On the control day, tests were performed without any intervention.

***Statistical Analysis***

G-Power (version 3.1.9.6, Germany) power analysis method was used to calculate the sample size. The sample size was calculated as at least 18 with 95% power based on the reference study with an effect size of 0.56 for the degree of external rotation (noncentrality parameter δ=3.3660, Critical t=1.6909, Df=34, Power (1-β err prob)=0.95 and α err prob=0.05) (Rajendran & Sundaram, 2020).

Statistical analyses were performed using SPSS version 25 (IBM SPSS Statistics; IBM Corporation, Armonk, NY, USA) software. The conformity of the data to normal distribution was evaluated by Shapiro Wilk test. Comparisons for the three interventions were made with Friedman's test. If there was a statistical difference between the three interventions, pairwise comparisons were made by Wilcoxon Signed Rank Test. Statistical significance value was accepted as $p<0.05$.

## Results

A total of 20 individuals, 50% (n=10) females and 50% (n=10) males, with an average age of 23.25±1.97 years and a body mass index of 22.79±3.72 kg/m$^2$ participated in the study and their results were included in the analyses. Right extremity was dominant for 95% (n=19) and left extremity was dominant for 5% (n=1) of the participants. In addition, 80% (n=16) did not have regular exercise habits. The mean score of the participants on the Lower Extremity Function Scale was 78±2.80. Demographic and health-related variables are shown in Table 1.

**Table 1.** Demographic and health-related characteristics of the participants

| Variables | Mean ± SD or n (%) |
|---|---|
| **Age** *(year)* | 23.25 ± 1.97 |
| **Gender** | |
| *Female* | 10 (50) |
| *Male* | 10 (50) |
| **BMI** *(kg/m²)* | 22.79 ± 3.72 |
| **Dominant extremity** | |
| *Right* | 19 (95) |
| *Left* | 1 (5) |
| **Regular exercise habits** | |
| ***Yes*** | 4 (20) |
| *Year* | 1.87 ± 2.09 |
| *Day/Week* | 3 ± 1.41 |
| *Hour/Day* | 0.87 ± 0.25 |
| ***No*** | 16 (80) |
| **LEFS score** | 78 ± 2.80 |

LEFS: The Lower Extremity Functional Scale, kg: Kilograms, m²: square metres, SD: Standart deviation, BMI: Body mass index

A statistically significant difference was found between SMR, SS and control in terms of abduction ROM in the dominant lower extremity. Abduction ROM was significantly higher in SMR than in SS and control ($p<0.05$) (Table 2). No significant change was found in other dominant lower extremity ROM measurements.

**Table 2.** Intergroup comparison of range of motion for the dominant limb

| | SMR Mean±SD | SS Mean±SD | Control Mean±SD | p |
|---|---|---|---|---|
| **Flexion** | 117.10±7.37 | 116.90±7.36 | 116.10±5.93 | 0.186[a] |
| **Abduction** | 42±5.41 | 39±6.60 | 38.10±7.15 | **0.013[a] *** |
| *SMR-SS:* | | | | ***0.016[b] **** |
| *SMR-Control:* | | | | ***0.007[b] **** |
| *SS-Control:* | | | | *0.204[b]* |
| **Adduction** | 1215±2.73 | 12.40±2.81 | 11.75±2.73 | 0.112[a] |

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JHSS 2025; 8(2): 93-108

| | | | | |
|---|---|---|---|---|
| **Internal rotation** | 33.55±5.62 | 33.75±5.32 | 33.65±5.85 | 0.983[a] |
| **External rotation** | 30.45±5.17 | 30.35±3.45 | 29.25±6.12 | 1.000[a] |
| **Extension** | 10.55±1.53 | 10.55±1.27 | 10.60±1.56 | 0.717[a] |

Friedman test[a] Wilcoxon signed-rank test[b] $p<0.05$*; SMR: Self-miyofasyal release, SS: Static stretching, SD: Standart deviation

A statistically significant difference was found between SMR, SS and control in terms of flexion and adduction ROM in the nondominant lower extremity. Flexion and adduction ROM were significantly higher in SMR and SS than in control ($p<0.05$) (Table 3). No significant change was found in other nondominant lower extremity ROM measurements.

**Table 3.** Intergroup comparison of range of motion for the nondominant extremity

| | **SMR Mean±SD** | **SS Mean±SD** | **Control Mean±SD** | **p** |
|---|---|---|---|---|
| **Flexion** | 117.85±7.11 | 117.85±7.82 | 115.15±5.65 | **0.014[a] *** |
| *SMR-SS:* | | | | *0.891[b]* |
| *SMR-Control:* | | | | ***0.016[b]*** |
| *SS-Control:* | | | | ***0.026[b]*** |
| **Abduction** | 40.75±6.93 | 38.70±6.33 | 40.25±5.25 | 0.381[a] |
| **Adduction** | 12.05±2.50 | 12.50±2.83 | 11.30±2.88 | **0.018[a] *** |
| *SMR-SS:* | | | | *0.355[b]* |
| *SMR-Control:* | | | | ***0.026[b]*** |
| *SS-Control:* | | | | ***0.011[b]*** |
| **Internal rotation** | 34.35±7.61 | 34.05±5.09 | 33.50±6.30 | 0.522[a] |
| **External rotation** | 30.75±3.53 | 30.25±5.72 | 29.45±5.79 | 0.705[a] |
| **Extension** | 10.40±1.35 | 10.60±1.27 | 10.60±1.56 | 0.779[a] |

Friedman test[a] Wilcoxon signed-rank test[b] $p<0.05$*; SMR: Self-miyofasyal release, SS: Static stretching, SD: Standart deviation

No statistically significant difference was found between SMR, SS and control in terms of PPT for dominant and nondominant lower extremities, hip extension, abduction, adduction, flexion, external and internal rotation strengths, sit and reach test maximum and mean values ($p>0.05$) (Table 4).

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**Table 4.** Comparison of pressure pain threshold, strength and sit-and-reach test between groups

| Pressure Pain Threshold | | | | |
|---|---|---|---|---|
| | **SMR Mean±SD** | **SS Mean±SD** | **Control Mean±SD** | **p** |
| **Dominant** | 12.42±3.53 | 11.64±3.18 | 11.38±2.93 | 0.262[a] |
| **Non-dominant** | 12.36±3.08 | 12.48±3.00 | 11.80±3.20 | 0.112[a] |
| **Strength** | | | | |
| **DOMINANT EXTREMITY** | **SMR Mean±SD** | **SS Mean±SD** | **Control Mean±SD** | **p** |
| **Extension** | 44.25±14.23 | 47.80±14.39 | 46.30±14.82 | 0.289[a] |
| **Abduction** | 33.70±11.06 | 34.60±10.24 | 35.95±12.71 | 0.478[a] |
| **Adduction** | 29.40±8.50 | 29.95±9.41 | 29.85±11.96 | 0.904[a] |
| **Flexion** | 66.45±24.41 | 65.80±22.58 | 65.35±23.35 | 0.771[a] |
| **External Rotation** | 34.40±12.87 | 33.95±12.68 | 36.60±16.42 | 0.828[a] |
| **Internal rotation** | 43.05±17.42 | 39±11.98 | 41.60±18.88 | 0.833[a] |
| **NONDOMINANT EXTREMITY** | **SMR Mean±SD** | **SS Mean±SD** | **Control Mean±SD** | **p** |
| **Extension** | 44.70±14.95 | 45.20±12.77 | 41.50±13.87 | 0.244[a] |
| **Abduction** | 34.50±11.68 | 35±11.41 | 34.10±11.48 | 0.901[a] |
| **Adduction** | 31.15±15.69 | 29.10±9.98 | 29.50±11.11 | 0.616[a] |
| **Flexion** | 62.90±19.35 | 59.70±24.67 | 65.05±25.05 | 0.338[a] |
| **External Rotation** | 33.10±11.71 | 32.60±10.66 | 34.30±12.48 | 0.863[a] |
| **Internal rotation** | 41.20±12.46 | 39.45±9.82 | 39.85±15.53 | 0.352[a] |
| **Sit-and-Reach Test** | | | | |
| | **SMR Mean±SD** | **SS Mean±SD** | **Control Mean±SD** | **p** |
| **Dominant** | | | | |
| SRT maximum | 20.64±6.35 | 20.32±7.08 | 19.07±6.40 | 0.182[a] |
| SRT mean | 19.45±6.17 | 19±6.86 | 17.72±6.20 | 0.316[a] |
| **Non-dominant** | | | | |
| SRT maximum | 20.26±6.36 | 19.99±6.77 | 18.91±6.24 | 0.307[a] |
| SRT mean | 19.08±6.32 | 18.52±6.53 | 17.57±6.37 | 0.764[a] |

Friedman test[a] p<0,05*; SMR: Self-myofasyal release, SD: Standart deviation, SS: Static stretching, SRT: Sit-and-reach test.

## Discussion

In our study, we investigated the effects of SMR and SS applied to the piriformis muscle on hip ROM, hip strength, flexibility, and PPT in healthy young adults. SMR, SS and control were applied to all participants on different days by cross randomization.

Significant changes were observed in some ROM values after SMR, SS interventions and control. In the literature, Perez et al. (2016) showed that SMR applied to hamstring and quadriceps muscles had no effect on muscle strength and fatigue, while SMR had a similar significant effect on hip ROM as SS. In addition, it was reported that SMR and SS applied to the gastrocnemius and hamstring muscles increased the ROM, but there was no significant difference between them. It was found that the combined application of the two techniques provided the highest increase in ROM (Mohr et al., 2014; Halperin et al., 2016). Rajendran and Sundaram (2020), who studied the piriformis muscle in isolation like our study, applied MFR and SS to individuals with piriformis syndrome for 4 weeks. At the end of the study, no significant difference was found between the groups in ROM and pain. However, unlike our study, participants in this study underwent prolonged stretching and individuals with piriformis syndrome were selected as participants (Rajendran & Sundaram, 2020). In addition, in another study where SMR was applied to the piriformis muscle, the flexibility of the piriformis muscle was evaluated with the Chaitow technique and it was shown that flexibility increased (Sulowska-Daszyk & Skiba, 2022).

A review by Kalichman and David (2017) showed that the use of SMR, especially with foam rollers, significantly increased ROM without any detrimental effect on neuromuscular force production. De Souza et al. (2019) found that SMR acutely increased the ROM of both hip flexion and ankle dorsiflexion (de Souza et al., 2019). A systematic review by Bryant et al. (2023) included 18 studies and all studies showed that static stretching increased ROM. As can be seen, recent studies have proved that SMR and SS have effects on ROM. It reported that the increase in ROM after SMR using foam rollers was due to a change in the thixotropic property of the fascia surrounding the muscle. This property is due to the fact that fascia is composed of colloidal substances and becomes more gelatinous when stressed by heat and mechanical stress. In addition to the changes in the thixotropic properties of fascia, sustained and strong pressure applied to soft tissues can overload skin receptors, inhibit or minimize the sensation of pain, thus increasing tolerance to stretching. Pressure applied through the SMR is thought to alter the viscosity of the fascia, making it more gelatinous. This occurs due to the stimulation of type III and IV interstitial receptors, which respond to a light touch, and Ruffini endings when a deep and sustained pressure occurs. Additionally, the response of the central nervous system to localised pressure involves stimulation of the Golgi tendon organ and inhibition of muscle spindles, which leads to decreased muscle tone and possibly contributes to increased ROM (de Souza et al., 2019). When the literature was reviewed, no studies were found examining the acute effects of stretching exercises targeting the piriformis muscle in healthy individuals. As a result of our study, we see that stretching exercises affect ROM. We think that piriformis muscle stretching should be included in the rehabilitation process of individuals with limitation in hip ROM.

Perez et al. (2014) applied MFR and SS to hamstring and quadriceps muscles combined with a foam roller. As a result of muscle strength measurement with isokinetic device, it was found that the intervention had no acute effect on muscle strength (Perez et al., 2014). According to a review, there is no evidence that foam roller SMR is effective in improving muscle strength or performance, and it cannot be recommended as a warm-up routine before strength or performance-enhancing activities (Kalichman & David, 2017). Similarly, in a systematic review by Cheatham et al. (2015), it was reported that short-term foam roller (1 session for 30 seconds) or roller massage (1 session for 2 minutes) applied to the lower extremity before activity did not improve muscle performance. In parallel with these studies, in our study, control, SMR and SS interventions were not found to be superior to each other in terms of strength parameters.

In our study, there was no significant difference between SMR, SS, and control interventions in terms of flexibility parameter. In Keys' study (2014), the effetcs of SS applied to the hamstring and MFR using foam rollers were compared using the sit-and-reach test. Participants divided into SMR and SS groups were applied these stretches for 3 days with 48 hours intervals. According to the sit-and-reach test results, although there was an increase in both groups, the interventions were not found to be superior to each other in terms of flexibility (Keys, 2014). Tomas et al. (2021) compared the effects of foam rollers and SS on the flexibility of rowers. As a result of stretching applied to the gastrocnemius, hamstring, piriformis, lumbar and dorsal muscles, the results in the sit-and-reach test were similar between the two groups (Penichet-Tomas et al., 2021). Roylance et al. (2013) investigated the effects of applying SMR, SS and postural alignment exercises with foam rollers to lower extremity muscles, including the piriformis muscle, on muscle flexibility using the sit-and-reach test. They showed that acute treatment with foam rollers, when combined with postural alignment exercises or SS, significantly increased ROM in participants with below-average ROM (Roylance et al., 2013). Queiroga et al. (2021) applied MFR using a myofascial stick to the hamstring, gastrocnemius, soleus, and quadriceps muscles. According to the results obtained, MFR increased sit-and-reach distance, left hip extension and plantar flexion ROM (Queiraga et al., 2021). In studies in which stretching was applied on different muscles, an increase in the sit-and-reach test was generally observed, but there was no significant change between SS and MR in parallel with our study. In the studies, stretching was applied ~~on~~ to the muscles that would affect the sit-and-reach test the most, especially the hamstrings (Mookerjee & McMohan, 2014). In our study, we suggest that the reason why the SMR and SS interventions were not superior to the control measurement may be due to these interventions were solely targeting the piriformis muscle.

In a study, PPT was assessed using an algometer in 30 healthy people and 30 people diagnosed with piriformis syndrome. The algometer was found to be reliable for measuring PPT for the piriformis muscle (Tabatabaiee et al., 2020). For this reason, algometer was used in our study. According to the results obtained from the study by Jung et al. (2017), it was reported that SMR applied to the hamstring muscle for 3 days reduced myofascial pain according to the results obtained with the algometer. Nehring et al. (2021) also applied MFR technique to the hamstring for 30-120 seconds and found no significant change in myofascial pain. Rajendran and Sundaram

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E-ISSN: 2791-6847
JHSS 2025; 8(2): 93-108

(2020) applied SS and MFR to individuals with piriformis syndrome for 4 weeks. At the end of the study, although there was an increase in ROM and a decrease in pain, the groups were not found to be superior to each other (Rajendran & Sundaram, 2020). It is known that the constant and strong pressure applied to the soft tissues as a result of stretching can prevent or minimize the sensation of pain by overloading the skin receptors (de Souza et al., 2019). In the aforementioned studies of Jung et al. (2017) and Rajendran and Sundaram (2020), long-term intervention was performed on the hamstring and its effect on PPT was observed. As a result of our stretching interventions, there was no significant difference between SMR, SS and control in terms of PPT. Since our study investigated the acute effects of SMR and SS, similar changes may have been observed between the groups. We suggest that chronic effects should be investigated in future studies.

Nowadays, the acute effects of different types of stretching are a common research topic, especially in the field of sports sciences (Behm et al., 2023). The warm-up period, an essential part of any exercise session, prepares the body for more demanding activities by regulating outputs such as flexibility and strength, and is also important for improving performance during activity. Current literature offers complicated findings regarding the effects of the types of stretching applied during this phase on parameters such as flexibility, strength, power, and injury risk. Furthermore, foam roller technique has been reported to be more effective than other types of stretching in improving the quadriceps and hamstring flexibility. Therefore, its use is recommended during warm-up periods for both healthy young people and those performing sports that require flexibility (Su et al., 2017).

Considering both healthy individuals and individuals with musculoskeletal pathologies, the methods applied during pre-exercise preparation can alter the effects of training or rehabilitation. They can also reduce an athlete's risk of injury during competition, improve performance, or shorten recovery time (Su et al., 2017). For example, SMR with foam rolling is gaining prominence today for reducing soft tissue restrictions, accelerating recovery, and increasing range of motion (Su et al., 2017). However, there is no consensus on the acute effects of different stretching techniques on physical fitness parameters. With the very limited literature, information on the acute effects of foam rolling on performance is also limited.

To our knowledge, the acute effects of SMR and SS on the piriformis muscle have not been investigated before in healthy young adults, and our study is the first to investigate this topic in the literature. The small sample size and limited age range are factors that hinder the generalizability of our results. Another limitation of our study is that the effects of SMR and SS on piriformis were analysed only in the acute period and long-term results were not evaluated. It is recommended that long-term effects should be analysed in future studies. It is thought that our study will be a guide for future studies. Considering that SMR applied to the piriformis can be used as an alternative method to SS to increase ROM in both the acute and chronic periods, we suggest that future studies should be conducted in this direction.

## Conclusion

SMR was found to be as effective as SS in increasing ROM in the acute period. It is thought that it can be used safely in warm-up programs of athletes who need more range of motion and flexibility, and in preparation for rehabilitation exercises for individuals who experience movement limitations, whether or not any pathology is present. We think that the effects and underlying mechanism of SMR applied to the piriformis on different variables such as muscle pain, balance, energy consumption, flexibility, ROM and strength should be re-examined in healthy and vulnerable populations.

## Ethical Approval

This study was approved by the Clinical Research Ethics Committee of Süleyman Demirel University Faculty of Medicine at its meeting dated December 29, 2023, and numbered 372.

## Conflict of Interest

The authors reported no conflict of interest related to this article.

## Author Contribution Rate


| No | Full Name | ORCID | Contribute* |
|---|---|---|---|
| 1 | Emine İrem ŞAHİN | 0000-0002-3635-8894 | 1, 2, 3, 4 |
| 2 | Melahat MEHRİOĞLU | 0000-0001-8088-3568 | 1, 2 |
| 3 | Tuğba ŞİMŞEK | 0000-0002-8607-3061 | 1, 4 |
| 4 | Görkem KIYAK | 0000-0003-4780-8480 | 1, 2, 4 |
| 5 | Ahmet Said UYAN | 0000-0002-0878-3877 | 1, 2, 4 |
| 6 | Zeliha BAŞKURT | 0000-0001-7488-9242 | 1, 5 |
| 7 | Sabriye ERCAN | 0000-0001-9500-698X | 1, 3, 5 |
| *Write the number(s) corresponding to the related explanation in the Contribution section. | | | |
| 1.Designing the study<br>2.Collecting the data<br>3.Analysis and interpretation of the data<br>4.Writing the manuscript<br>5.Critical revision | | | |


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