

# The Comparison of Hip Abductors with Hip External Rotator Muscles Fatigue on Static Standing Balance in Subjects with and without Patellofemoral Pain Syndrome

Mehri Shakeri Nasab<sup>1\*</sup>, Javid Mostamand<sup>1</sup>, Nima Jamshidi<sup>2</sup>, Mohammad Ali Tahririan<sup>3</sup>

1. MSc, Musculoskeletal Research Center, Department of Physical Therapy, Rehabilitation Sciences Faculty, Isfahan University of Medical Sciences, Isfahan, Iran.

2. Assistant Professor, Department of Biomedical Engineering, Faculty of Engineering, University of Isfahan, Isfahan, Iran.

3. Assistant Professor, Department of Orthopedics, School of Medicine, Isfahan University of Medical Sciences, Isfahan, Iran.

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## ABSTRACT

**Purpose:** The patellofemoral pain syndrome (PFPS) is one of the most common musculoskeletal disorders of the knee joint. Hip muscles' weakness is one of the reasons for PFPS occurrence. The aim of this study was to recognize the effective muscle group in prevention and treatment of patients with PFPS.

**Methods:** This is a prospective and quasi-experimental study in which 30 participants (15 healthy/15 patients) who were aged between 18 and 38 years were recruited through non-probability simple sampling. Exhaustion process of hip abductors and hip external rotator muscles was performed using Delorme method in separate sessions with a rest interval of at least 48 hours. Then, the parameters of pressure center were measured on the anterior, internal-external plates using Force Plate System.

**Results:** Before the exhaustion process, parameters of the displacement length of the pressure center on the internal-external plate ( $P = 0.002$ ) and the sum of the pressure center displacement length on the internal-external plate ( $P=0.052$ ) were higher in the patients group. After the occurrence of fatigue in the abductor muscles of the control group, the sum of the pressure center displacement length on the internal-external plate ( $P = 0.001$ ) and the velocity of the pressure center displacement length on the anterior plate ( $P = 0.001$ ) and the internal-external plate ( $P = 0.016$ ) were significantly increased. But in the patients group, all of the above mentioned parameters were decreased after fatigue in both the rotator muscles ( $P = 0.005$ ,  $P = 0.054$ ,  $P = 0.038$ ) and the abductor muscles ( $P = 0.045$ ,  $P = 0.005$ ,  $P = 0.004$ ).

**Conclusion:** Before the induction of fatigue, patients had more postural swing than the control group. As the fatigue increased in the abductor and the external rotator muscles, the postural swing increased in the control group but decreased in the patients group. In healthy subjects, the fatigue of abductor muscles has a greater role in postural disturbance but there was no significant difference between the fatigue in abductor and rotator muscles in patients with PFPS.

## Key Words:

Patellofemoral Pain Syndrome,  
Hip Abductors and External Rotator Muscles Fatigue.

\* Corresponding Author:

Mehri Shakerinasab, MSc

Musculoskeletal Research Center, Department of Physical Therapy, Rehabilitation Sciences Faculty, Isfahan University of Medical Sciences, Isfahan, Iran.

Tel: +98916 372 7327

E-mail: mehrishakerinasab@yahoo.com

## 1. Introduction

**P**atellofemoral pain syndrome (PFPS) describes a variety of pathologic or anatomical abnormalities leading to a type of anterior knee pain [1]. Patellofemoral pain syndrome is one of the most common musculoskeletal disorders, especially affecting female athletes [2]. The prevalence of PFPS is 5.4% of all the injuries and 25% of all knee conditions that refer to sport clinics [1].

This syndrome is a multi-factorial condition. A growing body of evidences suggest that dysfunction at the hip junction is a contributing factor in PFPS [2]. Ireland et al. reported that individuals with PFPS demonstrate a 26% decrease in hip abduction and a 36% decrease in hip external rotation strength compared with similar healthy controls [3]. It is suggested that weak hip abductors and external rotators could lead to internal rotation and adduction of the hip during dynamic activities [4]. The increased knee valgus angle may cause increased lateral quadriceps muscle force on the patella, resulting in lateral tracking [5]. Fukuda et al. demonstrated greater improvement of pain and function in PFPS patients following simultaneous strengthening of hip and knee muscles compared to traditional treatments [6]. Other studies have also shown that physical therapy including hip muscular strengthening significantly decreases anterior knee pain in PFPS subjects [7-11].

One of the most important factors of daily activities in PFPS patients is postural control or maintaining the balance. Balance is a complex function that involves maintenance of the vertical projection of the center of gravity (COG) within the base of support [12]. In patients with PFPS, static balance on the symptomatic side is significantly less than the asymptomatic side [13]. Rezazadeh et al. reported different balance factors in athletes with PFPS compared with healthy athletes [14].

Muscle fatigue, which is defined as decrease in force generation after repeated muscle contractions [15, 16], impairs proprioception and disturbs postural control [17-19]. Increased fatigability followed by muscle weakness is one of the primary symptoms of patients with different musculoskeletal disorders [20]. Since there has been no study to compare the role of hip abductor and hip external rotator muscles in the balance of PFPS patients, in this study by comparing the effect of fatigue in these

groups of muscles on the static balance of patients with PFPS, it would define that the fatigue of which group causes more balance disorder in both of the case and the control groups; hence with more focus on the more effective muscle group, this syndrome could likely be prevented in the healthy group and be treated more sufficiently in the patients.

## 2. Methods

30 participants [15 healthy and 15 patients) who were aged from 18 to 38 years [3, 21, 22] entered the study after filling a written informed consent; each group contained 10 female and 5 male subjects. Patients with PFPS from Physical Therapy and orthopedic clinics of Isfahan were included if they had the following criteria:

Having frontal or interior knee pains that were not caused by any impact and lasted for more than 6 months [23], experiencing pain by touching or pressuring the patellar articular surface [24], and having pain while doing at least two of these activities: long sittings with bent knees, doing squats, kneeling, running, jumping, and going up and down the stairs [24, 25].

Any of the following criteria would lead to exclusion from the study: having arthritis, patellar tendinitis, or patellar dislocation [26], clinical records of tendon, meniscal, or ligament injury [24, 26], history of defects in nervous system [26], having arthroscopic or any surgery on the knee [26], limp length discrepancy [26], flat foot or any other primary anatomical disorder [27], other joints involvements that would lead to lower limb or loin damage in the past year [28], and consumption of drugs that would disrupt balance.

All the participants were asked not to involve in any heavy exercises from two days before the test and keep a similar diet before all the test sessions as much as possible. In patients who had PFPS in both side, the side with more pain and impairment were assumed as the injured side. To evaluate pain and disability, all patients completed visual analogue scale (VAS) and Kujala Patellofemoral Scale (KPS) [29], respectively. Additionally, in order to match the activity level of patients and healthy subjects, the Tegner activity rating scale [30] was completed by both of the study groups. Both groups were matched regarding demographic data such as age, gender, height, weight, and activity level.

After gathering the demographic data, resistance determination process (the amount of weight) was conducted using Delorme method [31-35]. In this method, that 10 RMs (the amount of weight that could be lifted and lowered exactly 10 times) are used for progressive strengthening of patients, specific resistance of each patient would be defined as the amount of weight they could move back and forth for 10 times through the full range in a given time [36]. In this study, 10 RMs were assigned for each of the abductor and external rotator muscle groups; then to induce fatigue, each participant was asked to get into the appropriate position (side-lying for abductors and sitting with knees bent at 90 degrees for external rotators) and move the weight that was hooked to their extremities through the defined range until it was not possible for them to complete the full range any more (figure 1). Each muscle group was tested in a separate session so that one's exhaustion would not affect the other. Therefore, each participant was tested in 3 different sessions with 48 hours intervals: the first

one was for introduction to the process and defining the specific resistance of each muscle group, and the other two were for testing the muscles. Before testing at each session, static balance of each participant was measured by standing on both feet using the Kistler force plate. Then, the exhaustion process was conducted on the side that was randomly selected; and right after that the static balance was measured again. After a 30 minute rest, the same process was conducted on the other side. To improve the reliability and validity of observations, at each stage the static balance was measured 6 times, each lasting for 60 seconds. There was a 60 seconds interval between measurements. The participant's position during the balance measurement was as participants were standing holding their head straight and eyes open, arms beside the body with barefoot during the measurement of the balance [28]. Also, 3 pressure center points with 100 hertz frequency were used. The force plate's signal was filtered using a butterworth low pass filter which filtered frequencies lower than 10 hertz [37, 38].



PHYSICAL TREATMENTS

**Figure 1.** A) exercise position for exhausting the external rotator muscles, B) exercise position for exhausting abductor muscles, C) position of quiet standing on the force plate

The following parameters were used for the final analysis [39]:

1. Path Length x (PLx) and Path Length y (PLy)(mm)

The displacement of the pressure center on x and y coordinate axes:

$$PLx (mm) = \sqrt{(x_{i+1} - x_i)^2}$$

$$PLy (mm) = \sqrt{(y_{i+1} - y_i)^2}$$

2. Sum Path Length x (SPLx) and Sum Path Length y (SPLy)(mm)

The sum of the displacement length of the pressure center on x and y coordinate axes, which is a resultant of the participant's general balance:

$$SPLx (mm) = \sum_{i=1}^{n-1} \sqrt{(x_{i+1} - x_i)^2}$$

$$SPLy (mm) = \sum_{i=1}^{n-1} \sqrt{(y_{i+1} - y_i)^2}$$

3. Velocity x (Vx) and Velocity y (Vy)(mm/min)

The rate of displacement of the pressure center on x and y coordinate axes:

$$V_x \text{ (mm/min)} = \frac{\sum^{n-1} \sqrt{(x_{i+1} - x_i)^2}}{t}$$

$$V_y \text{ (mm/min)} = \frac{\sum^{n-1} \sqrt{(y_{i+1} - y_i)^2}}{t}$$

At the end, the mean of all the mentioned parameters were measured for each participant through 6 tests. SPSS 16 was used for statistical analysis to compare both groups. To evaluate the conformity of numeric vari-

ables with the theoretical normal distribution, the Kolmogorov-Smirnov statistical test was used. Independent t-test was used to determine the similarity of both groups at the beginning of the study and also to compare the balance parameters of both groups before the induction of fatigue. Then, a mixed model of variance analysis as 2\*2\*2\*2 (2 groups of participants, 2 fatigue conditions, 2 muscle groups, and 2 lower limbs) (ANOVA) was used to assess the balance parameters after exhaustion. Alpha level was set at 0.05.

3. Results

The results of Kolmogorov-Smirnov statistical test showed that all of the studied variables had normal distribution. Independent t-test showed that at the beginning of the study variables of age, height, weight, and the level of activity had no significant difference between both groups (table 1).

Table 1. Mean ± SD of the demographic and functional characteristics of all the participants

Demographic Characteristic	Control Group	Case Group	P-value
Age (year)	25 ± 4.62	24.5 ± 5.71	0.81
Weight (kg)	65.7 ± 11.21	63.5 ± 10.13	0.54
Height (cm)	172.3 ± 10.11	170.47 ± 9.65	0.62
Level of Activity	4.1 ± 1.15	3.87 ± 1.50	0.73
Kujala Score	-	73.07 ± 8.73	-
Pain Score	-	5.14 ± 1.20	-

PHYSICAL TREATMENTS

The results of independent t-test showed that before the induction of exhaustion, the parameters of imbalance in patients with PFPS was more than healthy subjects (P = 0.002 and P = 0.052 for PL<sub>y</sub> and SPL<sub>y</sub>, respectively).

The results of variance analysis showed that in the patients group, the parameters of imbalance decreased as the exhaustion increased (P = 0.003, P = 0.006, and P = 0.013 for PL<sub>y</sub>, PL<sub>x</sub>, and SPL<sub>x</sub> respectively). But in the control group, these parameters were increased with exhaustion (P = 0.049, P = 0.030, and P = 0.012). (Table 2)

Also in the control group, the exhaustion of abductor muscles has increased the imbalance parameters (P = 0.001, P = 0.001, P = 0.016 for SPL<sub>y</sub>, V<sub>x</sub>, and V<sub>y</sub> respectively). While in the case group, both the exhaustion of external rotator muscles (P = 0.038, P = 0.054, and P =

0.052) and the abductor muscles (P = 0.004, P = 0.005, and P = 0.045) decreased the imbalance parameters. (Figure 2)

4. Discussion

Humans and many other species are still not able to stand with disturbance. While standing their bodies go through unwanted motions, even if they focus on preventing these motions. This phenomenon is usually called the disability of central nervous system in maintaining the balance through the feedback which is sent by the sensor signals to control the ground reaction force [40]. Nowadays, authors mention the variability of vital functions of the body in their writings and believe that it depends on other cognitive behaviors [41].

**Table 2.** Mean ± SD of balance parameters in different measurement conditions

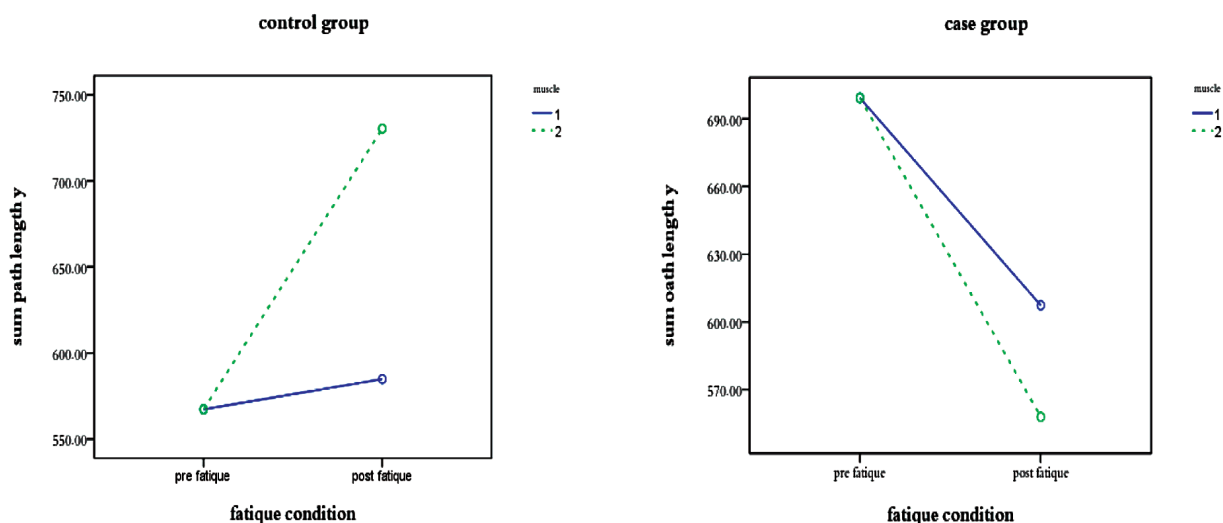
		V <sub>y</sub>	V <sub>x</sub>	SPL <sub>y</sub>	SPL <sub>x</sub>	PL <sub>y</sub>	PL <sub>x</sub>	
Case group	Before Exhaustion	1398.6±438.38	1124.3±310.29	699.29±219.19	562.14±155.14	0.34±0.21	0.22±0.14	
	After Exhaustion	A with PFPS	1118.7±238.36	937.04±163.78	559.34±119.18	468.52±81.89	0.21±0.14	0.16±0.09
		A without PFPS	1112.7±211.51	953.17±168.31	556.34±105.75	476.58±84.16	0.22±0.13	0.16±0.08
		B with PFPS	1193.9±280.19	959.74±169.76	596.97±140.09	479.87±84.88	0.23±0.13	0.16±0.06
		B without PFPS	1235.4±319.20	1020.8±212.20	617.68±159.60	510.39±106.10	0.18±0.10	0.15±0.05
Control Group	Before Exhaustion	1202.4±367.50	1004.5±227.25	567.26±124.67	502.24±113.63	0.14±0.05	0.15±0.09	
	After Exhaustion	A with PFPS	1410.6±278.51	1207.4±285.04	705.31±139.25	603.72±142.52	0.20±0.09	0.22±0.10
		A without PFPS	1467.9±333.19	1244.6±249.12	755.23±182.94	622.32±124.56	0.20±0.10	0.18±0.05
		B with PFPS	1168.2±255.58	1007.7±194.72	584.12±127.79	606.43±414.87	0.27±0.17	0.16±0.09
		B without PFPS	1171±267.22	988.35±170.25	585.50±133.61	494.17±85.13	0.20±0.08	0.18±0.08

In the present study before the exhaustion process, the imbalance parameters of patients with PFPS were more than control subjects which is similar to the findings of Citaker et al. and Rezazadeh et al. regarding static balance of PFPS patients and they all have related this balance deficit to the decreased proprioception of these subjects [13, 14].

Also in the present study, the effect of the muscle fatigue on the both case and control group were different (figure 2). In the control group, the imbalance parameters have increased as the exhaustion increased, as it has been demonstrated in the previous studies [20, 42-44].

But in the case group, the parameters of imbalance have decreased as exhaustion increased which is contrary to previous studies [45, 46].

Unlike previous approaches, Carpenter et al. in their study showed that postural fluctuations could be an exploratory mechanism of the central nervous system for facing continuous signals of multiple sensory systems [40]. In other words, increased disturbance or disruption in balance does not always mean a decline in physical functioning and pathology. An increase in variability could have a functional role in postural control; aging and neurologic diseases could decrease this variability [47].



**Figure 2.** The graph of the changes in the mean of SPL<sub>y</sub> of the external rotator muscles (1) and the abductor muscles (2) before and after exhaustion in both the case and the control group

In a study by Meshkati et al., it was revealed that karate athletes in comparison to healthy subjects, both with open eyes and closed eyes, experience more postural fluctuations; therefore it would question this old belief that increased motion performance would decrease postural fluctuations [48]. Also, Salavati et al, reported that patients with lower back pain experience less postural fluctuations compared to healthy subjects and these fluctuations would be decreased with increased cognitive and perceptual activities; and both groups of healthy and patient subjects in sensory difficult conditions like hard surfaces or closed eyes, experience increased postural fluctuations [49]. Hence, increment of fluctuations or postural defects in patients with lower back pain depends on the condition they are tested in [50]. Also, Mok et al. in a study conducted on patients with lower back pain and healthy subjects reached similar results. After analyzing the pressure center, they realized that patients in lower back pain in comparison to healthy subjects, show less hip strategy in more visual-dependent activities and can not start and control an hip strategy very well [51].

Some of the studies reported that exhaustion of thigh muscles (proximal) would cause disruption in balance while standing on one foot more than exhaustion of ankle muscles (distal) [43, 45]. While Reimer et al. mentioned no difference between the effects of exhaustion of distal and proximal muscles on the dynamic balance [42]. In another study, Negahban et al. compared the effect of exhaustion of thigh abductor muscles and knee extensor muscles and concluded that the exhaustion of thigh abductor muscles has a greater effect on disruption of balance than the exhaustion of knee extensor muscles [52].

## 5. Conclusions

In the present study, the imbalance factors in healthy subjects and subjects with PFPS were compared before and after the exhaustion of abductor and external rotator muscles. Before exhaustion, patients had more postural fluctuations than healthy subjects. In healthy subjects after exhaustion of abductor muscles, postural fluctuations were increased, which probably indicates their greater role in maintaining the static balance of healthy subjects. But in the patients group, the exhaustion of both the abductor and the external rotator muscles decreased postural fluctuations, which could indicate that in PFPS patients both of these muscle groups lose their appropriate

functionality; therefore in the rehabilitation program of these patients, both balance and strengthening exercises should be considered.

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