Balance and Isokinetic Strength of Lower Limb Muscles in Professional Female Volleyball Players with Patellofemoral Pain Syndrome

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Submitted: 2022-05-03; **Accepted**: 2022-09-11; **Doi:** https: doi.org.10.22037.jcpr.v7i4.44281

Abstract

Introduction: Patellofemoral pain syndrome (PFPS) is one of the prevalent musculoskeletal disorders of the knee, which subsequently causes joint changes in the knee. Investigating balance and muscle strength should be considered in the evaluation of these people. The present study aimed to compare balance and lower limb muscle strength in female volleyball players with PFPS and their healthy peers. **Materials and Methods:** In this cross-sectional study, 30 people (14 people with PFPS and 16 healthy peers) with mean±sd age of 24.33±3.12 years, height 178.72±0.06 cm, and Body Mass 67.76± 6.95 kg participated in this research. Biodex balance system was used to assess the balance as center of pressure (COP) displacement for anterior-posterior and medial-lateral directions in two open and closed-eye conditions. The evaluation of isokinetic strength of ankle, knee extensor, and hip abductor-external rotator muscles as peak torques and (PT) time-to-peak torque (TTPT) was measured by Cybex isokinetic dynamometer at a speed of 60 deg./s. The data were analyzed using MANOVA to compare two healthy and PFPS groups in SPSS software ver. 26 ($P<0.05$). **Results:** findings showed that the static balance in all tests conditions of female with PFPS was significantly decreased in compared to healthy ones ($P<0.05$). The strength of all evaluated muscles, except for the plantar flexor muscle group, was significantly lower in females with PFPS compared with healthy ones ($P<0.05$). **Conclusion:** The results demonstrated that static balance and muscle strength of lower limb in individuals with PFPS are weaker than in healthy ones, which can cause more injuries. Therefore, it is suggested that in the treatment and rehabilitation of this injury, strengthening the muscle and balance should also be considered for these people.

Keywords: Balance; Biomechanics; Knee; Patellofemoral Pain Syndrome; Volleyball

***Please cite this paper as*:** Khodarahmi S, Fatahi A, Sokhanguei Y. Balance and Isokinetic Strength of Lower Limb Muscles in Professional Female Volleyball Players with Patellofemoral Pain Syndrome. J Clin Physio Res. 2022; 7(4): e74. Doi: *https:.doi.org.10.22037.jcpr.v7i4.42731*

Introduction

Patellofemoral Pain Syndrome (PFPS) is one of the most prevalent injuries of the musculoskeletal system, which is very common in active young athletes (1). Due to skeletal and hormonal differences in women, PFPS is more common in women (2, 3). Patients with PFPS usually complain of dull aching pain in the front of their knee, progressively worsening. This pain is aggravated by increasing activity, squatting, walking, running, and going up and down stairs (4). That is why individuals' activities, especially their sports activities, are affected (1, 5).

Investigations have demonstrated that factors affecting the occurrence of PFPS include quadriceps weakness, especially the vastus medialis (VMO) muscle, quadriceps and hamstring muscle strength imbalance, stiffness, abnormal alignment of the lower limbs, patellar malalignment, or patellar subluxation (6). It has also been reported that these disorders influence sensory information speed that slow down the speed of message transmission, which can then negatively affect individual's muscle function, muscles dysfunction and pain are the main factors affecting balance and the sense of proprioception of these people (7, 8). In addition, most relevant research considers severe adduction and hip internal rotator in PFPS patients, which is usually associated with external rotator muscle weakness (9, 10). Strengthening the extensor muscles and stretching the anterior hip muscles relieve pain in patients with PFPS (11, 12). Some studies have found that muscle strengthening rather than balance empowerment is more effective in reducing pain and improving patients' performance (12-14).

In some studies conducted on balance in people with knee pain, it has been shown that the balance of these people is lower than their healthy peers. In these studies, the strength of hamstrings and quadriceps are associated with their balance (15, 16).

Since isokinetic strength assessments are the tests that provide reliable and objective assessment conditions with high reproducibility of muscle strength under natural body conditions, they are mainly used to control athletes' progress in exercise training or rehabilitation programs (17, 18). On the other hand, improving balance can be effective in reducing the symptoms of PFPS (19, 20). Therefore, the present study aimed to compare the balance and lower limb muscle strength in female volleyball players with PFPS and their healthy peers.

In this study, our primary hypothesis was that static balance and muscle strength of ankle, knee, and hip in female volleyball players with PFPS differ from healthy female volleyball players.

Materials and Methods

Participants

The research method was a cross-sectional study. The study's population included 30 elite female volleyball players of Iran national team over 20 years old (16 players with PFPS and 14 healthy players). A sample size of 15 people per group was determined using G*Power software with a statistical power of 80%, type I error rate of 0.05, and effect size of 0.80. All procedures were explained to the individuals before the measurements. All the subjects fulfilled the personal information questionnaires and the process of the research tests was described for them, completely.

The inclusion criteria for the PFPS group included pain in the anterior part of the knee for at least three months to a maximum of two years, no history of ankle sprains or fractures in the lower limbs over the past six months, no history of surgery, especially in the lower limbs over the past year, and no diseases affecting performance (*e.g.*, walking, balancing). On the other hand, the exclusion criteria included pain caused by non-PFPS, fluid accumulation in the joint, and overweight.

Ethical consideration was considered according to the ethics committee of the Islamic Azad University Central Tehran Branch, with the ethics code of SSRI.REC-2207-1768.

Measurement tools

Background characteristics of individuals including job, history of regular physical activity, history of injury, duration of injury, side of injury, were recorded through a questionnaire. The height parameters were measured using an Esca height meter made in Germany with an accuracy of 1 mm. The subjects' weight was also determined using a Bearer digital scale with an accuracy of 0.1 kg made in Germany.

Biodex balance system

A Biodex balance system (Shirley co., Canada) was used to measure static balance, a powerful tool for measuring all types of balance with high validation(21). The Biodex dynamometer is composed of a plane base connected to the device. It is a circular part on which a person is placed and moves freely in the anterior-posterior (AP) and medial-lateral (ML) directions. It can adjust the tilt to 20 degrees relative to the horizontal surface, which is efficient in dynamic balance assessment. The device's stability levels range from 1 to 12, with "one" representing the most unstable and "twelve" the most stable. The balance index is the variance of the center of pressure (COP) displacement in both anterior-posterior and medial-lateral directions in a constant time. The higher the index, the weaker the balance. A number above 500 indicates poor balance. The standard deviation (SD) obtained from Biodex implies a close range of values from which the mean is computed. Therefore, it is always better to set it on a relatively low scale.

Cybex Isokinetic Dynamometer

The Cybex isokinetic dynamometer allows for eccentric and concentric movements and continuous passive motion. The subjects' data is entered into the computer, then the rehabilitation or range of motion program is tested. The test for strength of ankle, knee, and hip muscles was carried out at 60 deg./s, and the contraction type is eccentric/concentric. Participants performed five maximum repetitions after fully understanding the assessment process. The data was stored in the computer software, and the average peak torque for each subject was known as an index of muscle strength. The lumbar and seat angles are 85˚, and the knee and hip angles are 90˚. During testing, the examiner ensured that the hip was in complete contact with the dynamometer seat and fixed it firmly with a strap. The dynamometer's range of motion was set to 30 degrees of external rotation. The dynamometer's axis of rotation was aligned with the longitudinal axis of the femur. For tests conducted by isokinetic dynamometer, variables of peak torque (PT) and time-to-peak torque (TTPT) were extracted and analyzed.

Balance test

For the balance test, the person stood barefoot on the platform, other knee was straight, and the arms were crossed over the chest (22). Each subject should maintain this position for 30 seconds with eyes closed and opened. Every subject was given 5 minutes to practice and understand the test, there was a 20-second (each subjects performed the test three times with open eyes and three times with closed eyes and average of the three was considered as the balance index in each condition) rest between each attempt, and an average of three attempts was recorded as an index of balance (each subjects performed the test three times with open eyes and three times with closed eyes and average of the three was considered as the balance index in each condition)**.** It is noteworthy that there was no verbal encouragement during the test. However, in isokinetic strength testing, subjects were verbally encouraging.

The strength of ankle dorsiflexor and plantarflexor muscles

The test was performed in the supine position. The examinee's leg (dominant leg for healthy subjects and the leg with more pain for PFPF subjects) was placed on a cushion whose height could be adjusted, so that the knee was in 60 degrees of flexion. The sole of the examinee's foot was placed on the plate that exerts force on it, and with the help of a strap, the examinee's foot was fixed to the Cybex isokinetic dynamometer from the hip and waist areas (to prevent unwanted movements in other joints). Before the test, the participants were asked to ride a stationary bike for 7 minutes, perform soft resistance movements for one minute in the direction of dorsiflexion-plantarflexion and eversion-inversion using a theraband, and at the end for 30 seconds in each of the above-mentioned four directions, give an active stretch to the ankle joint (23). The device was set in the 25 degrees of plantarflexion position, 10 degrees of dorsiflexion, 35 degrees of inversion, and 25 degrees of eversion, and the dynamometer was locked in this position (24). The individuals performed five submaximal contractions as a trial to get familiar with the device and its function. The rest period between two tests was considered to be one minute. Then, to perform the test, we asked the examinee to perform three repetitions with the maximum intensity. We asked participants to look at the monitor screen if possible since seeing the higher height of the recorded wave can encourage the test taker to exert maximum effort.

The strength of ankle evertor and invertor muscle

To perform eversion and inversion, the amount of tilt, rotation, height of dynamometer, and angle patient's position on the bed were changed in such a way that the examinee's leg can perform 35 degrees of inversion and 25 degrees of eversion easily. Then, the leg was fixed by two straps tied crosswise on the leg. The examinee moved the leg to inversion and started the inversion movement with researcher's command.

The strength of knee extensor muscles

The examinee sat in such a way that the knee, hip and torso had 90 degree angles to each other. The femur was fixed by a strap. The movement was done from 90 degree knee flexion to extension.

The strength of hip and external rotator muscles

Lumbar and seat angles were 85 degrees and both knee and hip angles were 90 degrees. During the test, the examiner made.

Procedure

Assuring that the thigh was in full contact with the dynamometer seat and fixed it firmly with a strap. The range of motion of the dynamometer was set at 30 degrees of external rotation. The rotation axis of the dynamometer was aligned with the longitudinal axis of the femur.

Statistical Analysis

For data normality assessment a Shapiro-Wilk test was used.. The MANOVA at the significance level of P<0.05 was also used to obtain the difference between the PFPS and healthy groups. The statistical data analysis was carried out using SPSS v.20.

Results

The data of 15 people with PFPS and 14 healthy people were analyzed. One participant was excluded in the healthy group due to high BMI. The mean and standard deviation of demographic characteristics are presented in Tables 1, with no significant different between two healthy and PFPS groups. The normality results showed that the distribution of all data was normal (P<0.05).

Table 2 shows that COP displacements in anterior-posterior and medial-lateral directions with both eyes-closed and eyes-opened conditions were significantly increased in PFPS individuals compared with healthy ones(P<0.05). That means the balance in individuals with PFPS in the eyes-closed condition was significantly decreased compared to healthy subjects.

Table 3 and Figures 1 and 2 show that Peak Torque (PT) and Time to Peak Torque (TTPT) parameters in hip abductor-external rotator, knee extensor, ankle invertor, and ankle dorsiflexor was significantly decreased in PFPS individuals compared with healthy ones (P<0.05). There was no significant different between two groups in PT and TTPT of ankle plantar flexor (P>0.05). For ankle evertor, there was a significant different between two groups in PT (P=0.000), but not for TTPT (P=0.72).

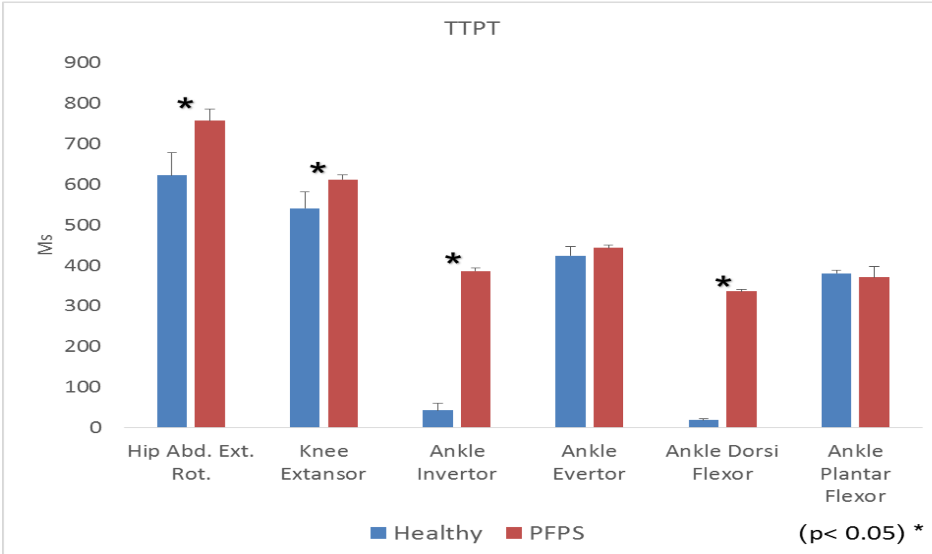

Figure 2. Time-to-peak torque (TTPT) of lower limb muscles between healthy and PFPS groups

Table 1. Mean (SD) of Demographic characteristics of individuals

Groups	Index	Age	Height (m)	Body Mass (kg)
Healthy (n=14)	Mean (SD)	22.07 (3.67)	1.76 (0.04)	67.3 (7.03)
	P-value	0.330	0.321	0.123
PFPS (n=16)	Mean (SD)	21.9 (2.73)	1.78 (0.06)	70.01(6.76)
	P-value	0.501	0.323	0.423

Table 2. Mean, standard deviation (SD), normality, and MANOVA results of balance parameters in two healthy and PFPS groups

Variable		Groups	Test conditions	Mean (SD)	Normality results	Comparison condition	*P*-value (comparison between two groups)
The rate of cop oscillations	AP direction	Healthy	Eye open	2.17 (2.1)	0.508	Eye open	0.01*
			Eye close	4.05 (6.13)	0.112		
		PFPS	Eye open	3.32 (2.71)	0.602	Eye close	0.04*
			Eye close	5.41 (3.24)	0.201		
	ML direction	Healthy	Eye open	4.03 (1.53)	0.864	Eye open	0.03*
			Eye close	5.42 (3.61)	0.102		
		PFPS	Eye open	1.34 (2.1)	0.106	Eye close	0.01*
			Eye close	2.12 (1.14)	0.512		

**P<0.05, AP: anterior-posterior, ML: medial-lateral*

Table 3. Mean (SD) of parameters related to muscles strength, normality, and MANOVA results for PT and TTPT in healthy and PFPS individuals

Muscles	Parameters	Healthy	Normality results (healthy)	PFPS	Normality results (PFPS)	*P*-value (comparison between two groups)
Hip Abd, Ext Rot	PT	218.4 (57.22)	0.692	168.5 (28.1)	0.732	0.001*
	TTPT	621.1 (5.55)	0.820	757.3 (17.8)	0.446	0.037*
Knee Extensor	PT	256.7 (41.57)	0.127	187.7 (11.6)	0.867	0.000*
	TTPT	541.00 (0.08)	0.721	9.612 (0.91)	0.344	0.04*
Ankle Invertor	PT	85.5 (18.00)	0.212	70.7 (7.7)	0.315	0.017*
	TTPT	42.90 (0.08)	0.059	386 (80.1)	0.07	0.03*
Ankle Evertor	PT	46.4 (21.65)	0.412	31.9 (6.99)	0.650	0.000*
	TTPT	452.00 (55.8)	0.119	444.0 (14.8)	0.120	0.95
Ankle Dorsi Flexor	PT	40.5 (2.5)	0.221	35.6 (4.6)	0.999	0.007*
	TTPT	19.08 (0.03)	0.168	336.0 (108.0)	0.16	0.008*
Ankle Plantar Flexor	PT	127.58 (7.5)	0.211	126.3 (27.6)	0.620	0.080
	TTPT	381.00 (0.97)	0.168	370.9 (0.1)	0.100	0.959

*PT: peak torque, TTPT: time-to-peak torque, *P<0.05*

Discussion

This study aimed to compare the balance and isokinetic strength of the hip, knee, and ankle muscles between female volleyball players with PFPS and their normally peers.

The statistical findings of COM data revealed that individuals with PFPS had poorer balance than healthy subject. Citaker *et al.* (15) investigated the balance factor affecting PFPS and healthy subjects. They found a significant difference between healthy and affected subjects in their balance, which is consistent with our study. The results of Erdoganoglu *et al.* (7) study showed that in people suffering from PFPS pain due to inappropriate kinematics of the lower limbs, their dynamic balance was also decreased compared to healthy ones. Zamboti *et al.* (16) reported that women with PFPS exhibited worse functional capacity and body balance than control group. These studies confirm the finding of our study. The presence of pain sense is one of the factors of decreasing static and dynamic balance in patients suffering from PFPS (25). On the other hand, previous studies demonstrated that balance exercises can help improve patellofemoral pain by improving postural stability (19, 26, 27). Balance exercises by correcting muscle disorders such as Q angle can be effective in improving the symptoms of PFPS (27). Also, balance exercises on one leg can strengthen the hip abductor and external rotator muscles and increase neuromuscular coordination in the hip, knee and ankle joints.

According to the results of present study, isokinetic performance in concentric/concentric contraction of hip abductor-external rotator, knee extensor, ankle invertor, and ankle dorsiflexor muscles, except plantar flexors, was significantly higher in healthy players. Malalignment in the hip joint such as severe adduction and internal rotation, as well as malalignment in the ankle joint and leg such as severe ankle pronation and tibia internal rotation, as one of possible causes of femur internal rotation, can be related to PFPS. Piazza stated that when the foot is in pronation, the tibialis anterior must actively counteract the ankle pronation. As a result, it loses an important part of its function as a foot invertor (28). So, PFPS can be related to dorsiflexor and invertor muscle weakness of ankle (28). Snook (29) investigated the concentric/eccentric strength of the muscles around the ankle and reported a decrease in plantar flexor strength in people with pronated feet, and attributed its reason to a decrease in the strength of the ankle and foot arch structure as a result of a decrease in plantar flexor torque in these people. Silva Boitrago *et al.* (30) in the isometric comparison of hip muscle strength between healthy female and those suffering from PFPS found that there was a direct relationship between hip mechanics disorders and PFPS. These disorders were reported more often in femoral abduction and external rotator in PFPS patients. The findings of present study is in a line with the study of McKenzie (2010) stated that females with PFPS compared with healthy controls descend stairs with the knee in a more flexed position and had the hip in a more adducted and internally rotated position at foot contact during stair stepping at a comfortable speed (31). Findings of our study is in consistent with similar ones. On the other hand, since increasing the strengthening of the hip muscles reduces patellofemoral pain, hip muscle strengthening exercises are helpful in reducing this pain.

Considering that the strength of the lower limb muscles was higher in the healthy group, it is recommended to empowering the strength of these muscles in people with PFPS. It is also suggested to pay more attention to the combined exercises that include all the joints of the lower limb, and avoid just focusing on the knee joint in the treatment of this syndrome.

Conclusion

The results demonstrated that static balance and muscle strength of lower limb in individuals with PFPS are weaker than in their healthy peers, which can cause more injuries. Therefore, it is suggested that in the treatment and rehabilitation of this injury, strengthening the lower limb muscles should also be considered for these people.

Acknowledgments
The authors would like to express their thanks to the volleyball players of the Iran National women team as well as Iran National Volleyball Federation.

Ethical considerations
This study was approved by the research ethics committee of sport sciences research institute according to compliance with ethical standards in the research ministry of science, research and technology with the code IR.SSRI.REC.1401.1768

Practical application of the study
Strengthening lower limb muscles to avoid injuries in volleyball players susceptive to Patellofemoral syndrome should be considered as a vital component.

Conflict of interest
None.

Funding support
None.

Authors' contributions
Sara Kodarahmi: the initial design of study. Ali Fatahi: the initial design of study, writing and paper revision. Yahta Sokhagui: paper revision

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