RESEARCH ARTICLE

Comparison of the Quadriceps Muscle Thickness and Function between Patients with Patellofemoral Pain Syndrome and Healthy Subjects using Ultrasonography: An Observational Study

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Abstract

Objectives: To compare the thickness and function of the quadriceps muscle in subjects with and without patellofemoral pain syndrome (PFPS) by ultrasonography.

Methods: Patients diagnosed with PFPS were included in the study. To measure the thickness of the rectus femoris (RF), vastus medialis longus and oblique (VML, VMO), vastus lateralis (VL) and vastus intermedius (VI), the ultrasonography was employed in rest and normal contraction modes and also the % rest-thickness normal as muscle function. For between-groups comparisons, the independent sample t-test was utilized.

Results: Sixty subjects (30 PFPS and 30 healthy) participated in this study. There were no significant differences between two groups with respect to demographic characteristics. No significant differences were observed between two groups regarding RF (P=0.07), VMO (P=0.38), VL (P=0.40) and VI (P=0.55) at rest. However, the rest thickness of VML (P=0.01) was significant between PFPS and healthy groups. No significant differences were found between two groups regarding RF (P=0.14), VML (P=0.68), VMO (P=0.11), VL (P=0.65), and VI (P=0.07) in contraction state. However, % rest-thickness normal were significant between groups for VML (P=0.03) and VMO (P=0.02) and were not significant for RF (P=0.56), VL (P=0.14) and VI (P=0.08).

Conclusion: In all parts of the quadriceps, % rest-thickness normal, as an indicator of its function, have been decreased in patients with PFPS. In patients with PFPF, ultrasonography should be cautiously used for muscle thickness comparisons.

Level of evidence: II

Keywords: Function, Knee pain, Patellofemoral pain syndrome, Thickness, Ultrasonography

Introduction

Patellofemoral pain syndrome (PFPS) is a prevalent musculoskeletal disorder[1,2] with an occurrence rate ranging from 20% to 28%. The PFPS affecting all individuals is particularly common among those aged 18 to 40.[3-6]

The clinical presentation of PFPS is anterior knee pain which exacerbates during activities, such as squatting, stair climbing and descending, and after long sitting time.[6] In addition, chondromalacia patellae, anterior knee pain syndrome, runner's knee, and patellofemoral tendon injuries, exhibit similar symptoms to PFPS, whether or not they coexist with other conditions (e.g., knee osteoarthritis).[6-8]

The exact cause of PFPS is still unclear and multifactorial. Biomechanical factors, such as engaging in activities that require the knee to bend beyond 60 degrees and structural malalignments which may increase knee valgus angulation, such as increased quadriceps angle; increased femoral

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anteversion, increased external tibial torsion, and increased foot pronation are considered as causes of PFPS.[6,9-11] Additionally, patella malalignment,[12,13] muscle imbalances, tendinopathy,[13,14] and quadriceps weakness may cause PFPS.[15,16] There is no consensus about selective atrophy of quadriceps in patients with PFPF. Some studies showed the imbalance between vastus medialis oblique (VMO) and vastus lateralis (VL) may cause patella lateralization and then PFPS, and others concluded that all portions of quadriceps may alter the patella position and cause PFPS.[10,17]

Objective assessment of muscle thickness by ultrasonography is a useful method for clinicians to determine the muscle changes in different conditions.[18] Moreover, muscle thickness changes have been studied between healthy subjects and patients in various contraction states. However, the ratio of muscle thickness changes or % rest-thickness-normal in rest and contraction mode is considered as an indirect way to evaluate muscle function.[18,19]

The findings of ultrasonography studies are controversial in patients with PFPS and knee disorders.[10,20-22] Some emphasize on muscle quality and others on muscle size as a main index of motor function in the quadriceps.[20,22] Furthermore, the muscle size was considered as thickness, volume or cross-section of all parts of quadriceps in ultrasonography studies.[20,21] Yet, to the best of the researchers knowledge, no study considered the thickness and specially the ratio of thickness changes in rest and contraction mode of all parts of quadriceps muscle in PFPS patients. Therefore, the present study aimed to compare the thickness and function of the rectus femoris (RF), VML (longus), VMO, VL, and vastus intermedius (VI) muscles in various states of rest and contraction using ultrasonography in two distinct groups of patients with PFPS and healthy individuals.

Materials and Methods

Study design and subjects

Subjects with and without PFPS in the Physiotherapy Ward of Poursina Hospital, Rasht, Iran, took part in the present study. Ethical Approval (IR.GUMS.REC.1399.258) was obtained from Guilan University of Medical Sciences. Age between 20-60 years, experiencing non-traumatic anterior knee pain, a minimum of three months pain duration, were the inclusion criteria. Furthermore, the criteria for PFPS included tenderness on medial and lateral border of patella during examiner palpation (patellar palpation test), prepatellar pain that intensifies when descending stairs or by prolonged sitting with flexed knees, squatting (squat test), isometric contraction of quadriceps (Clarke test), lateral patella depression, and adhering to distal femur (patellar tilt test).[23] The reliability and Clinical value of these tests were good to excellent.[23] Patients with a medical history of rheumatoid arthritis, second, third, and fourth-degree knee osteoarthritis (as determined by X-ray and the Kellgren-Lawrence classification), malignancies, prior knee surgeries, fractures, complete meniscus and cruciate ligament tears, genu valgus or varus exceeding 20 degrees, corticosteroid injections within the past six months, local infections, knee pain attributed to lumbar and hip conditions, and athletes, were excluded. Meanwhile, the healthy group consisted of individuals within the same age and body mass index (BMI) range who did not have PFPS. Eligibility assessments and examinations were conducted by an orthopedic surgeon with more than 10 years of experience through a comprehensive process of reviewing medical history, checking records, imaging, and physical examinations. The outcomes of the study included quadriceps muscle (RF, VML, VMO, VL, and VI) thickness in rest and normal modes and % rest-thickness-normal. The ratio of muscle thickness at normal contraction grade to that at rest was considered as % rest thickness-normal [Table 1].

Table 1. Determining the ratio of muscle thickness changes in contraction and rest states using ultrasonography

Raw muscle thickness	Ratio of thickness changes
Determining the thickness of the muscle in the contraction and rest state	(Muscle thickness in normal contraction - muscle thickness at rest/muscle thickness at rest) * 100

Data collection

Sampling was conducted using a simple non-probability method, with individuals voluntarily enrolling in the study and subsequently assigned to either the PFPS or healthy groups. The demographic variables were age, gender, height, weight, and BMI, and clinical variables were involvement side (right /left) and sonographic assessment. All parts of quadriceps muscle thickness at rest and normal contraction mode, % rest-thickness-normal were measured by ultrasonography. To ensure comparability, individuals in the healthy group were carefully matched with those in the PFPS group based on age and BMI.

Clinical examination

Patellar palpation test was performed by palpation of the medial and lateral border of the patella. Pain and tenderness on palpation sites were positive sign. [23] To perform the Clarke test, patients were instructed to lie supine with their knees extended. While the examiner held the base of the patella, patients were then requested to contract the quadriceps muscles. If the patient experienced pain in the patella during this action, it was documented as a positive test.[10,23] The squat test was positive if patient reported pain and discomfort on patella during 90º knee flexion.[23]

Ultrasonography evaluation

To measure the thickness of the RF, VML (longus), VMO (oblique), VL and VI at rest and contraction state, muscle ultrasonography (Chison, China, with a linear probe and 5-14 MHz) was employed. In this procedure, all subjects were positioned supine on a bed with their knees fully extended, and both lower limbs were relaxed. Initially, we measured the distance from the anterior superior iliac spine to the base of the patella using a meter as a reference point. From this reference point, specific distances for different muscles were calculated as 20% of this distance and 12.5% towards the inside for measuring the thickness of the VML,[24,25] 50% of this distance for both the RF and VI, and 12% outward for the VL. Additionally, 2 cm above the patella was measured to assess the VMO thickness [Figure 1]. Furthermore, the thickness of these muscles was then determined by measuring their upper and lower margins [Figure 2].[26,27]

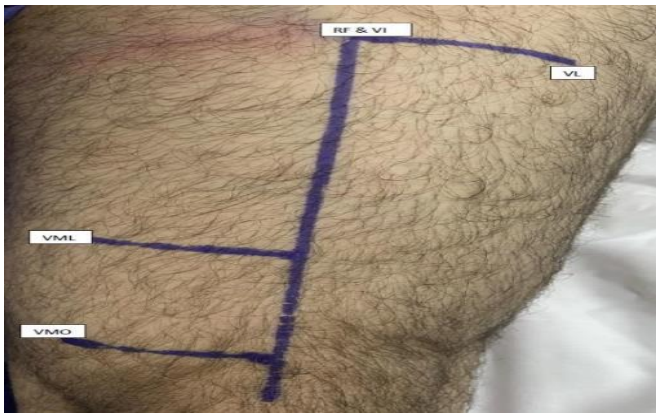

Figure 1. Locations of ultrasonography measurements on the anterior thigh

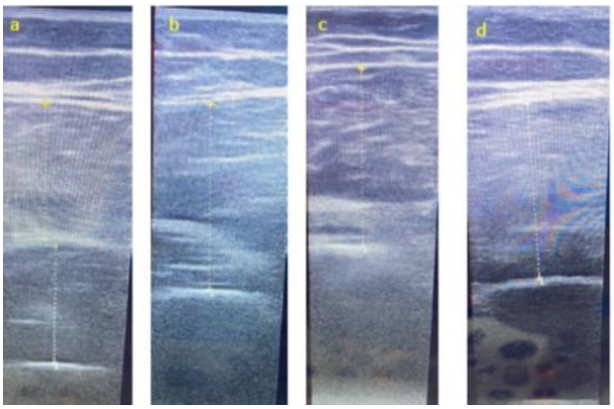

Figure 2. Locations of ultrasonography measurements on the anterior thigh

To measure the thickness of the quadriceps muscles during a normal contraction, the patient assumed a seated position with the thigh fully supported, and the legs hanging off the bed. The patient contracts the quadriceps muscle against therapist resistance and maintained a straight knee position. The examiner instructed the subject to perform the knee extension to an angle of 60° and then maintain it for 5s. There was a rest time of 120 s between each contraction. The process for marking the specific points remained consistent with the previous section.[28]

All assessments were conducted without applying any pressure to the skin, and to maintain this, a thin layer of gel was applied between the transducer and the skin.[29] During ultrasonography, all records were measured three times, and their average was recorded as the actual measurement.[17] The formula below was applied to compute the percentage of muscle thickness both at rest and during normal contraction [Table 1]. The same investigator (K. E.) with nine years of experience and practice in musculoskeletal ultrasonography performed all scans. The intra-session and inter-session reliability of thickness measurement were assessed for 15 subjects prior to the study. The intra-session and inter-session reliability were good to excellent (intraclass-correlation coefficients, ICC2, 1, were 0.86 to 0.94 for all parts of quadriceps, unpublished data).

Sample size

The sample size for this study was determined based on the research conducted by Jan et al. in 2009.[25] The mean and standard deviation in the PFPS patient group was 1.8 (SD=1.5), while in the healthy group, they were 2.2 (SD=3). Utilizing the G*Power software and maintaining a one-to-one sample ratio, a total of 27 participants per group was initially calculated. However, to account for a potential 10% drop in each group and considering three variables for assimilation, the final sample size was determined to be 60 individuals.

Statistical analysis

Quantitative variables were characterized using measures of central tendency and dispersion, while descriptive variables were presented using absolute and relative frequency values. To assess the distribution of numerical and continuous variables about the theoretical normal distribution, the Shapiro-Wilk statistical test was employed. For between-groups comparisons, the independent sample t-test was used. Data analysis was performed using SPSS (version 21), and a $P < 0.05$ was considered statistically significant.

Results

Sixty subjects (30 PFPS and 30 healthy) participated in this study. There were not significant differences between two groups with respect to demographic characteristics [Table 2].

Table 2. Demographic variables in patients with PFPS and healthy groups

Variable	PFPS group (n=30)		Healthy group(n=30)		P-value
Gender (Female/Male)	18:12		20:10		0.09
	Mean	**SD**	**Mean**	**SD**	
Height (cm)	162.39	6.94	167.20	7.94	0.11
Weight (kg)	77.95	12.46	74.84	18.75	0.51
Age (year)	54.85	6.78	49.48	7.97	0.38
BMI (kg/m2)	29.3	6.34	26.5	5.21	0.08

PFPS: Patellofemoral pain syndrome, SD: Standard deviation, BMI: Body mass index

The results of independent t-test for rest thickness of quadriceps muscle indicated no significant differences between two groups regarding RF (P=0.07), VMO (P=0.38), VL (P=0.40), and VI (P=0.55). However, the rest thickness of VML (P=0.01) was significant between PFPS and healthy groups [Table 3].

The normal contraction thickness of quadriceps muscle revealed no significant differences between two groups regarding RF (P=0.14), VML (P=0.68), VMO (P=0.11), VL (P=0.65), and VI (P=0.07) [Table 4]. However, % rest-thickness normal was significant between groups for VML (P=0.03), and VMO (P=0.02), and was not significant for RF (P=0.56), VL (P=0.14), and VI (P=0.08) [Table 5].

Table 3. Thickness of the quadriceps muscles at rest for both PFPS and healthy groups

Group /Muscle	PFPS group (n=30)		Healthy group (n=30)		P-value
	Mean	SD	Mean	SD	
Rectus femoris	18.56	3.77	20.11	4.11	0.07
Vastus medialis longus	31.24	8.36	35.77	8.08	0.01
Vastus medialis oblique	23.03	6.44	24.38	7.57	0.38
Vastus lateralis	17.74	4.35	18.48	3.82	0.40
Vastus intermedius	13.60	4.75	14.19	4.49	0.55

PFPS: Patellofemoral pain syndrome, SD: Standard deviation, P-values less than 0.05 are in bold

Table 4. Thickness of the quadriceps muscle in normal contraction for both PFPS and healthy groups

Group /Muscle	PFPS group (n=30)		Healthy group (n=30)		P-value
	Mean	SD	Mean	SD	
Rectus femoris	21.78	5.89	23.64	5.76	0.14
Vastus medialis longus	30.76	7.81	31.44	7.80	0.68
Vastus medialis oblique	20.97	5.92	23.27	7.29	0.11
Vastus lateralis	18.50	4.85	18.08	3.84	0.65
Vastus intermedius	13.08	3.69	14.49	3.46	0.07

PFPS: Patellofemoral pain syndrome, SD: Standard deviation, P-values less than 0.05 are in bold

Table 5. Quadriceps muscle % rest-thickness- normal by ultrasonography in healthy and patient groups

Group /Muscle	PFPS group (n=30)		Healthy group (n=30)		P-value
	%rest-thickness normal	SD	%rest-thickness normal	SD	
Rectus femoris	-0. 21	0.24	-0.18	0.20	0.56
Vastus medialis longus	-0.01	0.26	0.11	0.24	0.03
Vastus medialis oblique	-0.01	0.39	0.00	0.34	0.02
Vastus lateralis	-0.06	0.23	0.00	0.18	0.14
Vastus intermedius	0.03	0.23	-0.07	0.30	0.08

PFPS: Patellofemoral pain syndrome, SD: Standard deviation, P-values less than 0.05 are in bold

Discussion

In our study, ultrasonography findings have revealed a reduction in the thickness of the VM muscle at rest in patients diagnosed with PFPS when compared to healthy subjects. Consequently, alterations in muscle strength and non-contractile tissue may play a vital role in patellar malalignment.[10,20] Given that the VMO muscle is anatomically connected to the patella, some researchers attested that deficiencies, inhibitions, or atrophy of this muscle could be a contributing factor to the development of PFPS.[10,21]

In a study conducted by Pattyn et al. (2011), it was noted that individuals with PFPS exhibited shorter lengths in their RF and VL muscles in comparison to their healthy counterparts. In addition, patients showed VMO atrophy compared to the healthy group. In a study carried out by Pattyn et al., muscle thickness measurements were acquired using MRI. However, the relatively small sample size was one limitation of their research, which was successfully addressed in the present study by employing a larger sample size. In the present study, ultrasonography was employed to gauge muscle thickness, and no significant differences were observed in the thickness changes of the VL and RF muscles

between patients with PFPS and healthy individuals. It is worth noting that variations in measurement locations and differences in the methodologies employed for measuring muscle thickness between MRI and ultrasonography may have played a role in influencing the disparate findings in our results.[10] Jan et al. (2009) found significant alterations in the morphology of the VMO muscle in individuals with PFPS when compared to those without the condition. Their research suggested that these morphological changes played a crucial role in the disease development. In contrast, in our study, no significant differences were found in the thickness of the VMO muscle in rest and contraction mode. However, the ratio of rest-thickness -contraction of VMO indicated significant differences between two groups.[25] Moreover, Giles et al. showed that the thickness of all portions of the quadriceps muscle in PFPS patients were not smaller than healthy subjects. Although similar to our study, they performed all measurements with ultrasonography at rest; they did not assess muscle thickness in contraction mode and did not estimate the ratio of rest-thickness -contraction.[17]

According to our findings, the quadriceps muscle % rest-thickness normal, as an indicator of its function, have been decreased in all parts in patients with PFPS [Table 5]. However, these changes were significant in VML and VMO between two studied groups.[18,19] It seems that muscle thickness may not be appropriate for detecting the alteration in quadriceps morphology in patients with knee disorders.[20] Therefore, it is better to evaluate the ratio of rest-thickness-contraction of the muscles for further studies.[19] Chopp-Hurley et al. (2020) found that muscle quality rather than muscle thickness should be considered in evaluating motor performance in women with knee osteoarthritis.[20] Furthermore, Lin et al. found that the VMO insertion level, insertion ratio and volume were associated with patellar alignment. Nevertheless, the angle of the knee was different between sonographic and radiologic measurements. In addition, they did not consider the thickness and its changes of this muscle in functional positions.[21] Recently, Jakovacz et al. (2024) claimed that there is no relationship between the presence and frequency of knee crepitation and quadriceps muscle thickness in patients with PFPS. They concluded that muscle thickness may not be a sensitive tool for knee crepitation.[20]

Limitations

The patellar alignment was not assessed in patients with PFPS and healthy subjects. The probe placement in contraction mode was not stabilize by devices. The subcutaneous fat thickness and muscle echogenicity, which are important potential factors in knee chronic disorders were not evaluated in our subjects. Additionally, only isometric contraction of the quadriceps was evaluated. The concentric or eccentric contractions should be considered in the future studies. Our study target population had 20-60 years of age and their results cannot be generalized to other populations. Although we did not match the participants according to the activity levels, the professional athletes were excluded.

Conclusion

The quadriceps % rest-thickness normal, as an indicator of its function, was decreased in all parts in patients with PFPS. However, only the VML and VMO were significant between two studied groups. In patients with PFPF, ultrasonography should be used cautiously for between group comparisons of muscle thickness.

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Declaration of Informed Consent: There is no information in the submitted manuscript that can be used to identify patients.

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