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Evaluation of lumbopelvic stabilization in patellofemoral pain syndrome

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A R T I C L E I N F O

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A B S T R A C T

Background: Patellofemoral pain syndrome (PFPS) is a prevalent knee condition in physically active individuals, with a multifactorial etiology. This study aimed to assess the effectiveness of lumbopelvic stabilization in treating patients with PFPS.
Method: The study involved 28 PFPS patients and 28 healthy controls, all aged between 18 and 45 years. Sociodemographic data were collected, and measurements were taken using ultrasonography (USG) to assess muscle thickness of the transverse abdominis (TrA) and multifidus lumborum (ML), as well as static and dynamic endurance of the trunk muscles in both groups. Pain levels were evaluated using the Visual Analog Scale (VAS), and knee function was assessed using the Kujala Patellofemoral Rating Questionnaire (KPSQ).
Results: The TrA and ML muscle thicknesses were symmetrical and statistically similar in both the PFPS and control groups at rest and during contraction ($p > 0.05$). However, significant differences were found between the muscle thicknesses of the PFPS and control groups for both the right ($p < 0.01$) and left sides ($p < 0.01$), both at rest and during contraction. Additionally, significant differences were observed in the dynamic and static trunk endurance tests between the PFPS and control groups ($p < 0.001$). Pain levels and knee functionality also differed significantly between the two groups ($p < 0.001$).
Conclusion: The findings of this study indicate that individuals with PFPS exhibited differences in the thickness of the TrA and ML muscles compared to asymptomatic controls, suggesting potential lumbopelvic involvement in PFPS pathology.

Patellofemoral Pain Syndrome (PFPS) is one of the most common knee diseases, especially in the young population (15–45 ages), characterized by pain in the anterior region of the knee. It is seen two times more in women than in men (Boling et al., 2010; Robinson and Nee, 2007). The PFPS is responsible for 16–25% of knee injuries in sports clinics (O'Brien, 2001; Tecklenburg et al., 2006).

The most important problems of patients with PFPS are knee pain and limitation of functional activities. By limiting the functional status of the patients, the symptoms can negatively affect their daily living activities and social and professional lives. Pain around or behind the patella, especially during activities where the knee is in flexion position, is a typical symptom. (Green, 2005; Kurt et al., 2016). PFPS may develop due to many factors. These factors can be listed as follows: Quadriceps Femoris (QF) strength deficiency, trauma, increased femoral anteversion, wide pelvis, synovial fold, tension in the hamstrings and lateral retinacular tissue, changes in foot biomechanics, loss of proprioception, and psychological factors.

Although the etiology of PFPS remains unclear, experts believe that biomechanical changes significantly contribute to this disease. Recent studies have focused on biomechanical changes of the trunk in individuals with PFPS (Nakagawa et al., 2015; Powers et al., 2017).

Pelvic and trunk stabilization is needed for movement in all extremities (Shirazi et al., 2014). Previous studies showed a hip between muscle function and lower extremity injuries (Ireland et al., 2003). In general, the results of this review show that there are deficits in hip muscle strength in females with patellofemoral pain syndrome. Strong evidence was found for a decrease in hip external rotation, abduction, and extension strength; moderate evidence for a decrease in flexion and

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internal rotation strength; but no evidence for a decrease in hip adduction strength compared with healthy controls. Moderate evidence was found for a decrease in hip external rotation and abduction strength, but no evidence for a decrease in hip extension, flexion, adduction, and internal rotation strength compared with the unaffected side (Prins and Van der Wurff, 2009). Both daily and sportive activities are in the form of a kinetic chain. Body dynamic control provides the generation, transfer, control, and transfer of force to the distal segments in the chain. Stabilization of the trunk and pelvis is considered necessary for all movements of the extremities (Bouisset et al., 2000). The decrease in lumbopelvic control may affect physical performance by causing fatigue, a decrease in endurance, and injuries in individuals (Prins and Van der Wurff, 2009). Exercises that fatigue the lumbar paraspinal muscles have been reported to reduce QF muscle activation. Beattie et al. (2014). The TrA and ML work as co-contraction and control excessive anterior pelvic tilt, which is known to be associated with femoral internal rotation and adduction. Excessive femoral internal rotation produces relatively external rotation of the tibia. This may cause a larger QF angle and a significant increase in lateral retropatellar contact pressure. Repetitive activities can lead to retropatellar cartilage damage (Zazulak et al., 2007).

Therefore, according to the aforementioned, lumbopelvic control may affect different health parameters as lower extremity alignment. So, the weakness in lumbopelvic stability may result in patellofemoral pain syndrome. Based on this view, the aim of our study was to evaluate lumbopelvic stabilization in individuals with PFPS and to compare it with healthy individuals.

1. Methods

1.1. Study design

After being diagnosed by an orthopedist (>25 years of experience) at xxxx Orthopedics and Traumatology Clinic, patients diagnosed with PFPS were referred to the outpatient physiotherapy and rehabilitation service for assessment. Asymptomatic volunteer individuals from the working environment of researchers matched by age and gender participated in the study as a control group. This study was approved by the Local Ethics Committee of Acıbadem University (2021-01/25). Written and verbal consent was obtained from the individuals prior to the study. This study was conducted in accordance with the Declaration of Helsinki.

1.2. Participants

Twenty-eight individuals with PFPS and 28 asymptomatic individuals between the ages of 18 and 45 were included in the study. Inclusion criteria were as follows: (1) having atraumatic pain lasting at least 3 months; (2) having characteristic symptoms of PFPS (retropatellar pain, presence of cinematic signs, and positive patellar grinding test); (3) 18–45 years of age; (4) patellofemoral pain prolonged sitting, squatting, standing on knees, descending stairs, climbing stairs, and positive patellar grinding tests; (5) knee instability and absence of ligament or meniscus tear at grade 2–3 level (Briani et al., 2016; Kuriyama and Ito, 2005; Zazulak et al., 2007). Exclusion criteria were as follows: history of patellofemoral dislocation, subluxation, and osteoarthritis, History of previous knee surgery or presence of congenital deformity, Presence of neurological or rheumatologic disease, Inability to speak or understand to a degree that affects communication (Briani et al., 2016; Kuriyama and Ito, 2005; Zazulak et al., 2007).

1.3. Assessments

Age, height, weight, disease duration, dominant side, and painful knee side of the individuals included in the study were recorded.

1.4. Pain

The Visual Analogue Scale (VAS) (0–10 cm), which was found to be valid, reliable, and sensitive in patients with PFPS, was used for the pain assessment of individuals in both groups (Crossley et al., 2016).

1.5. Knee functional level

The KPSQ, a questionnaire specific to patellofemoral pain syndrome, was applied to determine the functional levels of the participants. The questionnaire developed has a total of 13 questions. This test evaluates the severity of symptoms related to patellofemoral pain syndrome with a scoring system. Scores range from 0 to 100. A score approaching 100 indicates an increase in the level of disease involvement (Kujala et al., 1993). The Turkish validity study of the KPSQ was conducted (Kuru et al., 2010).

1.6. Ultrasonographic assessment of TrA and ML muscles

The muscle thickness of TrA and ML, the primary muscles responsible for lumbopelvic control, were evaluated by the USG method using GE LOGIQ S8 Diagnostic Ultrasound System (GE Healthcare, Milwaukee, Wisconsin, USA) devices in B-mode. The probe was positioned at muscle level, parallel to the muscle. All USG assessments were provided by an experienced (>10 years) and blinded. Before USG, individuals were taught the "abdominal hallowing" maneuver, which provides muscle activation of the TrA and ML muscles. This maneuver activates the TrA, resulting in co-contraction of the ML muscle. In order for the movement to be performed successfully, individuals need to develop a sense of skill. For this purpose, the basic anatomy of the muscle was explained to the individuals by exemplifying it with a picture. The basic anatomy of other muscles was also mentioned, and the difference between TrA and other abdominal muscles was mentioned, and the individual was helped to understand the difference between trunk movement and "abdominal hallowing." The "abdominal hallowing" maneuver is the pulling of the belly upwards and inwards without any excessive movement in the superficial muscles. During the contraction, the individual was asked to concentrate on the lower abdominal part for full performance. Measurements of the right and left sides of the TrA muscle, during rest and contraction, in the supine hook position, parallel to the line that centered the lower ribs, exactly in the middle of the lowest rib and iliac crest with a 10 Mhz cap (Fig. 1). ML and USG measurements are 2.5 Mhz for the right and left sides at the level of L4-5 vertebrae in the prone position, both at rest and during contraction measured using a cap (Fig. 2). In measuring TrA and ML muscle thickness, three measurements were made during rest and contraction, and the average of these measurements was taken (Koppenhaver et al., 2009; Nabavi et al., 2014; Nakagawa et al., 2015).

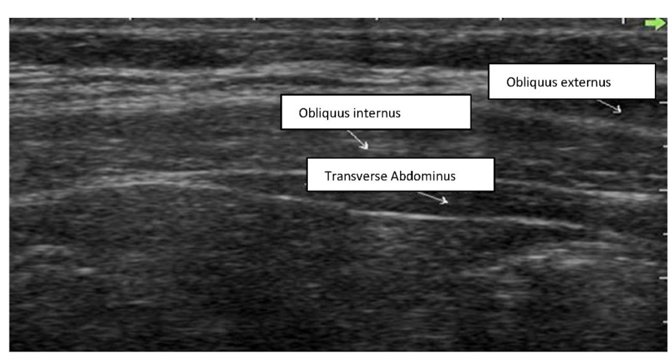

Fig. 1. USG imaging of the TrA muscle.

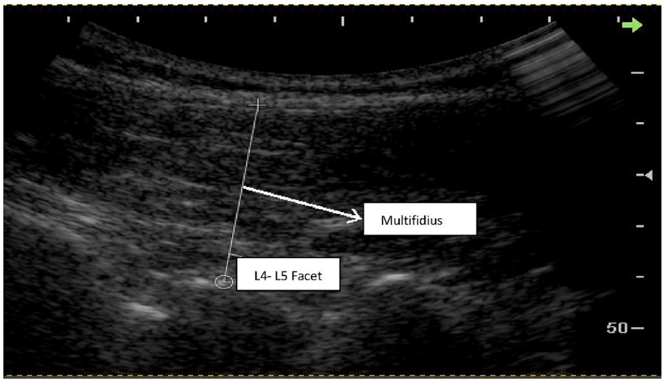

Fig. 2. USG imaging of the ML muscle.

1.7. Assessment of lumbopelvic stability

Lumbopelvic stability was evaluated statically and dynamically by the endurance of the trunk muscles. Static endurance of trunk muscles was measured by a trunk flexion endurance test, a trunk extension endurance test, and a right-left lateral bridge test. Measurements were made using a stopwatch, and the results were recorded in seconds. Each measurement was made twice, and the best measurement value was recorded. Tests were terminated when the patient's position deteriorated or the patient said he or she could not continue the test (McGill et al., 1999).

- *Trunk flexion endurance test (TFET):* The subjects were positioned with the trunk in 60° flexion position and the knees and hips in 90° flexion position. The physiotherapist who performed the evaluation fixed the feet on the ground by supporting them from the toes. The test was terminated when 60° trunk flexion was impaired and the time was recorded (McGill et al., 1999; Ropponen et al., 2005).

Trunk extension endurance test: With this test, the static endurance of the trunk extensors was evaluated. The subjects were positioned face down, with the pelvis, hips, and knees on the bed. Subjects were asked to extend their upper body straight forward from the edge of the table (McGill et al., 1999; Ropponen et al., 2005).

- *Lateral bridge test:* During the test, the subject was asked to turn on his side and raise his body on his forearm and toes and maintain this position. The measurement was repeated separately for the right and left sides (Leetun et al., 2004; McGill et al., 1999).

"Sit-ups" and "modified push-ups" tests were used to evaluate the dynamic endurance of the trunk muscles. Each test of the patients is 30 s. The number of times they could do it during the course was recorded (McGill et al., 1999; Ropponen et al., 2005).

- *Sit-ups test:* The patient was positioned with the knees flexed, the feet were fixed by the physiotherapist, and the patient was asked to do trunk flexion (McGill et al., 1999; Moreland et al., 1997).

Modified push-up test: The patient was placed in a prone position, with hands at shoulder level and elbows flexed next to the body. The patient was asked to lift the head, shoulders, and trunk off the ground with the elbows in full extension. During the test, the knees were positioned in flexion (McGill et al., 1999; Moreland et al., 1997).

1.8. Statistical analysis

The obtained data were analyzed by IBM's SPSS software (version 22). In this study, the G*Power 3.1.9.4 package program was used to determine the number of individuals to be included in the study (Heinrich Heine University, Düsseldorf, Germany) (Faul et al., 2007). The incidence of PFPS in the community is high (Smith et al., 2018). According to this, in order to obtain 80% power from the study at a significance level of $p < 0.05$ at an effect size of |r:0.8|, 28 individuals were included in each group. The distribution of the data obtained in the study was tested with the Kolmogrov-Smirnov test, and the skewness-kurtosis values were examined, and as a result, parametric analysis tests were applied since the skewness-kurtosis values of the data were in the range of ±1. While the independent *t*-test was used to compare the scores of the PFPS and control groups from the measurements between the groups, the paired *t*-test was used for comparison within groups. Significance level was accepted as $p < 0.05$.

2. Results

This study was completed with a total of 56 individuals, 28 in the PFPS group and 28 in the control group. The socio-demographic characteristics of the cases are shown in Table 1.

Table 2 shows the right and left TrA and ML muscle thicknesses, trunk static and dynamic endurance test scores, and VAS, KPSQ scores of the PFPS group and the control group at rest and during contraction.

The right and left side muscle thicknesses of the control group individuals during rest and contraction of the TrA and ML muscles were symmetrical, and no statistically significant difference was found ($p > 0.05$) (Table 3).

The right and left side muscle thicknesses of the TrA and ML muscles at rest and during contraction of the PFPS group individuals were symmetrical, and no statistically significant difference was found ($p > 0.05$) (Table 3).

There were statistically significant differences between the right and left TrA and ML muscle thicknesses measured during rest and contraction in the PFPS and control groups ($p < 0.05$) (Table 4).

Statistically significant differences were found between the trunk dynamic and static endurance test scores of the individuals in the PFPS group and the control group in the direction of the individuals in the control group ($p < 0.001$) (Table 4).

3. Discussion

According to the results of our study, we determined that the TrA and ML muscles, which are primarily responsible for lumbopelvic stability, were negatively affected when the individuals in the PFPS group were compared with the individuals in the control group. When the trunk static and dynamic endurance tests of the individuals in the PFPS group

Table 1
Socio-demographic characteristics of individuals in the control group and PFPS group.

	Control group (n = 28)	PFPS group (n = 28)	p
Sex n (%)			0.818
Female	20 (71.4)	21 (75.0)	
Male	8 (28.6)	7 (25.00)	
Dominant Extremity n (%)			0.713
Right	19 (67.9)	24 (85.7)	
Left	9 (32.1)	4 (14.3)	
Age (year)			0.618
Min-Maks.	21.00–34.00	21.00–33.00	
X± SD	26.29 ± 3.51	26.75 ± 3.43	
BMI (kg/m^2)			0.965
Min-Maks.	19.20–24.20	19.60–24.30	
X± SD	21.73 ± 1.65	21.71 ± 1.33	

n: Number of individuals, PFPS: Patellofemoral Pain Syndrome, %: percentile, Min: minimum, Max: Maximum, X: Mean, SD: Standard deviation BMI: Body Mass Index.

Table 2
Right and left TrA and ML muscle thicknesses, trunk static and dynamic endurance test scores, VVAS, and KPSQ scores of the control group and PFPS group individuals at rest and during contraction.

	Control group (n = 28)		PFPS group (n = 28)	
	Min-Max.	X± SD	Min-Max.	X± SD
TrAR Right (mm)	2.80–4.90	3.92 ± 0.47	2.60–4.40	3.34 ± 0.34
TrAC Right (mm)	3.60–6.40	5.11 ± 0.70	3.10–5.20	4.02 ± 0.61
TrAR Left (mm)	3.20–5.50	4.00 ± 0.58	2.50–4.80	3.36 ± 0.51
TrAC Left (mm)	4.00–6.60	5.19 ± 0.69	3.00–6.00	4.17 ± 0.74
MLR Right (mm)	29.00–42.00	33.59 ± 4.21	19.50–35.90	25.87 ± 4.84
MLC Right (mm)	28.20–43.50	35.40 ± 4.67	20.70–40.10	29.79 ± 5.26
MLR Left (mm)	30.00–39.70	33.15 ± 2.98	21.20–37.10	26.64 ± 4.16
MLC Left (mm)	24.40–44.00	34.66 ± 4.92	22.50–41.60	30.21 ± 5.54
Sits-up test	17.00–30.00	23.32 ± 4.48	11.00–24.00	15.32 ± 3.93
Modified Push-up test	15.00–30.00	20.32 ± 4.84	10.00–21.00	13.00 ± 3.42
TFET (sec)	26.03–50.12	38.02 ± 5.94	15.99–40.12	27.19 ± 5.86
TEET (sec)	22.15–52.24	42.70 ± 6.17	16.91–41.20	28.80 ± 7.71
RLBT (sec)	17.97–34.28	23.66 ± 4.43	10.31–24.16	16.00 ± 3.66
LLBT (sec)	13.31–30.18	19.90 ± 4.31	9.11–22.18	13.23 ± 3.13
VAS (cm)	0.00–0.00	0.00 ± 0.00	4.00–6.00	4.89 ± 0.88
KPSQ (point)	100.00–100.00	100.00 ± 0.00	68.00–84.00	77.25 ± 5.20

n: Number of individuals, Min: Minimum, Max: Maximum, mm: milimeter, X: Mean, SD: Standard deviation, TrAR: Musculus Transverse Abdominus Rest, TrAC: Musculus Transverse Abdominus Contraction, MLR: Musculus Multifidus Lumborum Rest, MLC: Musculus Multifidus Lumborum Contraction, TFET: Trunk Flexors Endurance Test, TEET: Trunk Extensors Endurance Test, RLBT: Right Lateral Bridge Test, LLBT: Left Lateral Bridge Test, VAS: Visual analog scale, KPSQ: Kujala Patellofemoral Scoring Questionnaire.

were compared, a statistically significant difference was found in favor of the control group. It was found that the right and left TrA and ML muscle thicknesses of the PFPS and control group individuals were symmetrical at rest and contraction.

When the literature was examined, no studies were found that measured the thickness of the muscles responsible for lumbopelvic stability during rest and contraction in patients with PFPS. Studies on this subject are mostly related to low back pain. In a study comparing subjects treated with stabilization exercises performed with rhythmic personal stimuli due to low back pain with individuals in the control group, when the muscle thicknesses of the TrA and ML muscles were examined both at rest and during contraction before treatment, it was found that the TrA and ML muscle thicknesses of the individuals in the treatment control group were similar (İba, 2018). In addition, other studies have reported that the TrA muscle does not show asymmetry in terms of muscle thickness in patients with low back pain (Hides et al., 2008; Teyhen et al., 2009). In our study, the right and left muscle thicknesses of the TrA and muscles of the individuals in the PFPS and control groups, both at rest and during contraction, were measured symmetrically. These measurements were made with B-mode USG. This imaging option is a proven technique used in the literature to measure TrA and ML muscle thickness (Hosseinifar et al., 2013; Rasouli et al., 2011). In this respect, our study is compatible with the literature.

In addition to local muscles, superficial muscles also play an important role in providing lumbopelvic stability. In cases where the local muscles are weakened, the superficial muscles are responsible for providing compensation. However, in long-term weakness of the lumbopelvic region, the stability deteriorates as the superficial muscles will get tired after a while. Although the validity and reliability of the USG method are high in the evaluation of TrA and ML, which are primarily responsible for lumbopelvic control, static and dynamic endurance tests including superficial muscle groups can be used in some clinics where USG is not available (Palmer and Uhl, 2011; Tong et al., 2014). In our study, we planned to increase the reliability of the results to be obtained in the study by using the trunk static and dynamic endurance tests of the individuals in the PFPS and Control group, in addition to measuring the TrA and ML at rest and contraction on the right and left in the individuals in the PFPS group and the Control group, under the guidance of USG (Christophe et al., 2008; Moreland et al., 1997; Nabavi et al., 2014).

In a study examining the differences in TrA, ML, and Musculus Rectus Abdominis muscle thickness and contraction rates between female PFPS individuals and an asymptomatic control group, no difference was found between the thickness and contraction rates of the muscles (Briani et al., 2016). However, in our study, when the muscle thickness of the TrA and ML muscles of the PFPS group and control group individuals was examined both at rest and during contraction, it was found that there was a significant difference between the groups. The reason for this is that TrA and ML muscle thicknesses were measured at rest and during contraction in our study. Additionally, in that study, muscle thickness was obtained from the body mass index ratio (Briani et al., 2016). In addition, while male and female individuals were included in our study in accordance with the literature, only female individuals were included in that study (Boling et al., 2010; Briani et al., 2016). We thought that the reasons for the difference with the other study were due to the differences in the inclusion criteria and the

Table 3
Right and left side symmetry evaluation of TrA and ML muscle of PFPS and control group individuals.

	Group		Side	n	X±SD	t	p
TrA	**Control**	**Rest**	Right	28	3.92 ± 0.47	−1.016	0.319
			Left	28	4.00 ± 0.58		
		Contraction	Right	28	5.11 ± 0.70	−1.011	0.321
			Left	28	5.19 ± 0.69		
	PFPS	**Rest**	Right	28	3.20 ± 0.42	−0.326	0.747
			Left	28	3.36 ± 0.51		
		Contraction	Right	28	4.02 ± 0.61	−1.293	0.207
			Left	28	4.17 ± 0.74		
ML	**Control**	**Rest**	Right	28	33.59 ± 4.21	0.979	0.336
			Left	28	33.15 ± 2.98		
		Contraction	Right	28	35.40 ± 4.67	2.006	0.055
			Left	28	34.66 ± 4.92		
	PFPS	**Rest**	Right	28	25.87 ± 4.84	−1.694	0.102
			Left	28	26.64 ± 4.16		
		Contraction	Right	28	29.79 ± 5.26	−0.659	0.515
			Left	28	30.21 ± 5.54		

TrA: Transerve abdominus, ML: Multifidius Lumborum, PFPS: Patellofemoral Pain Syndrome, X: Mean, SD: Standard Deviation.

Table 4
Comparison of TrA and ML muscle thickness values and trunk static and dynamic endurance values of PFPS and control group.

	Grup	n	X±SD	t	p	Mean Difference (95%CI)
TrAR Right(mm)	Control	28	3.34 ± 0.34	5.347	<0.001	0.6 (0.3–0.9)
	PFPS	28	3.92 ± 0.47			
TrAC Right(mm)	Control	28	4.02 ± 061	6.144	<0.001	1.1 (0.6–1.6)
	PFPS	28	5.11 ± 070			
TrAR Left(mm)	Control	28	3.36 ± 051	4.376	<0.001	0.7 (0.3–1.1)
	PFPS	28	4.00 ± 0.58			
TrAC Left(mm)	Control	28	4.17 ± 0.74	5.378	<0.001	1.1 (0.5–1.7)
	PFPS	28	5.19 ± 0.69			
MLR Right(mm)	Control	28	25.87 ± 4.84	6.362	<0.001	12.6 (8.2–17.1)
	PFPS	28	33.59 ± 4.21			
MLC Right(mm)	Control	28	29.79 ± 5.26	4.222	<0.001	6.5 (4.6–8.4)
	PFPS	28	35.40 ± 4.67			
MLR Left(mm)	Control	28	26.64 ± 4.16	6.730	<0.001	7.1 (5.9–8.3)
	PFPS	28	33.15 ± 2.98			
MLC Left(mm)	Control	28	30.21 ± 5.54	3.180	0.02	4.5 (2.9–7.1)
	PFPS	28	34.66 ± 4.92			
Sits-up test	Control	28	15.32 ± 3.93	7.106	<0.001	8.1 (5.1–11.2)
	PFPS	28	23.32 ± 4.48			
Modified Push-up test	Control	28	13.00 ± 3.42	6.538	<0.001	7.5 (5.5–9.6)
	PFPS	28	20.32 ± 4.84			
TFET (sec)	Control	28	27.19 ± 5.86	6.864	<0.001	11.0 (8.2–13.8)
	PFPS	28	38.02 ± 5.94			
TEET (sec)	Control	28	28.80 ± 7.71	7.445	<0.001	14.2 (9.9–18.5)
	PFPS	28	42.70 ± 6.17			
RLBT (sec)	Control	28	16.00 ± 3.66	7.056	<0.001	7.5 (5.1–9.9)
	PFPS	28	23.66 ± 4.43			
LLBT (sec)	Control	28	13.23 ± 3.13	6.620	<0.001	6.7 (4.1–9.3)
	PFPS	28	19.90 ± 4.31			
VAS (cm)	Control	28	0.00 ± 0.00	8.123	<0.001	4.8 (2.4–7.1)
	PFPS	28	4.89 ± 0.88			
KPSQ (point)	Control	28	100.00 ± 0.00	7.986	<0.001	23.1 (17.0–29.2)
	PFPS	28	77.25 ± 5.20			

n: Number of individuals, Min: minimum, Max: Maximum, X: Mean, SD: Standard deviation, PFPS: Patellofemoral Pain Syndrome, mm: milimeter, TrAR: Musculus Transverse Abdominus Rest, TrAC: Musculus Transverse Abdominus Contraction, MLR: Musculus Multifidus Lumborum Rest, MLC: Musculus Multifidus Lumborum Contraction, TFET: Trunk Flexors Endurance Test, TEET: Trunk Extensors Endurance Test, RLBT: Right Lateral Bridge Test, LLBT: Left Lateral Bridge Test, VAS: Visual Analog Scale, KPSQ: Kujala Patellofemoral Scoring Questionnaire, CI: Confidence Interval.

assessments of muscle thicknesses. Although not related to PFPS, our other study found that increased hindfoot protonation and collapse of the medial longitudinal arch negatively affected the TrA and ML, which are primarily responsible for lumbopelvic stability (Kararti et al., 2021). In the same study, it was found that the increase in hindfoot protonation and the collapses in the medial longitudinal arch negatively affected TrA and ML, which are primarily responsible for lumbopelvic stability (Kararti et al., 2021). The results of this study indirectly support our study, as they are an effective factor in the etiology of PFPS. To the best of our knowledge, there is no other study on this subject. There is a need for comprehensive and widely participated studies on this subject.

As a result of a cross-sectional study examining the difference in trunk flexor and trunk extensor endurance tests between individuals with PFPS and a healthy control group, a significant difference was found between the PFPS group and the control group in favor of the control group (Yilmaz Yelvar et al., 2017). Additionally, individuals with PFPS were found to have significantly lower hip abductor, trunk extensor, and ankle plantar flexor endurance than healthy control individuals (Van Cant et al., 2017). In another study comparing trunk muscle strength in individuals with PFPS and healthy control groups, an 18% decrease was found in trunk extension strength in the PFPS group (Nakagawa et al., 2015). However, another study found that increasing the endurance of trunk muscles in patients with PFPS did not prevent compensatory trunk movements during weight-bearing activities (Baldon et al., 2015). One important result of our study is the first study in which trunk dynamic and static endurance tests and muscle thickness measurements in USG were analyzed together in patients with PFPS. In this respect, our study is compatible with the literature.

There are some limitations of this study that should be discussed. First, in this study, the thickness of the TrA and ML muscles, lumbopelvic stability, knee functionality and pain of asymptomatic individuals and individuals with PFPS were compared. Due to the cross-sectional design of the study, this situation was likely to negatively affect the distribution of the data obtained in the study on the PFPS and control groups. Second, the small number of cases included in the study was a factor that may reduce the reliability of the data in the study. Third, only the TrA and ML muscles were evaluated in this study. In addition to these muscles, the oblique abdominals and rectus abdominus should have been evaluated. Finally, the fact that trunk muscle strength was not measured in the study.

4. Conclusion

In conclusion, lumbopelvic stability was negatively affected in individuals with PFPS compared to asymptomatic individuals. Therapeutic approaches that increase or support lumbopelvic stability in cases with PFPS may be applied as part of treatment programs. Further studies with larger participation are needed to investigate the relationship and effect between PFPS and trunk muscles.

CRediT authorship contribution statement

Yusuf Mücahit Turan: Writing – original draft, Validation, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Öznur Büyükturan:** Supervision, Project administration, Methodology, Conceptualization. **Mehmet Çavuş:** Resources, Methodology, Data curation. **Bertan Cengiz:** Software, Resources, Data curation. **Buket Büyükturan:** Methodology, Data curation. **Mehmet Hanifi Kaya:** Data curation. **Sinan Karaoğlu:** Resources, Methodology, Data curation.

Declaration of competing interest

Ethical approval: This study was performed in line with the principles of the Declaration of Helsinki. Approval was granted by the Ethics Committee of Acibadem University, Türkiye (Date February 21, 2021/ No. 2021-08/22) Informed consent: Informed consent was obtained from the individual participant included in the study

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