Journal of Musculoskeletal and Neuronal Interactions JMNI

Original Article

Hip Muscle Strength and Fear of Movement are Associated with Self-Reported Function in Women with Patellofemoral Pain

Osman Coşkun[1], Serdar Arslan[2], Engin Dinç[3], Gökmen Yapalı[2]

[1]Department of Anatomy, Faculty of Medicine, Istanbul University, Istanbul, Turkey;
[2]Department of Physiotherapy and Rehabilitation, Faculty of Nezahat Keleşoğlu Health Science, Necmettin Erbakan University, Konya, Turkey;
[3]Department of Sports Medicine, Konya City Hospital, Konya, Turkey

Abstract

Objectives: We aimed to investigate the relationship between self-reported lower extremity function, fear of movement, and quadriceps, hamstring, and hip stabilizer muscle strength in women with patellofemoral pain. **Methods**: Fifty-four women (age: 32.59±7.00) were included in the study. We assessed self-reported function with the Lower Extremity Functional Scale and fear of movement with the Tampa Scale for kinesiophobia. The strength of the quadriceps, hamstring, and hip stabilizer muscles was determined with a hand-held dynamometer. Relationships between variables were examined using Pearson correlation analysis and binary logistic regression analysis. **Results**: Self-reported function showed a moderate positive correlation with hip stabilizer muscle strength (r=0.408, p=0.002) and negative correlation with fear of movement (r=-0.500, p<0.01). **Conclusion**: The results of this study suggest that fear of movement and hip stabilizer muscle strength are factors associated with self-reported lower extremity function in women with patellofemoral pain.

Keywords: Anterior Knee Pain, Knee, Patient Reported Outcomes

Introduction

Patellofemoral pain (PFP) is a disorder characterized by localized pain around and/or behind the patella that is aggravated by at least one of the activities that require weight transfer to the flexed knee, such as squatting, going up and down stairs, and jumping[1]. Risk factors for PFP include exposure to activities that increase patellofemoral joint load, training errors, overpronation of the foot, dynamic knee valgus, and vastus medialis activation delay[2]. Additionally, quadriceps weakness, hip muscle weakness, and body composition may also contribute to the development of PFP[3,4]. The annual prevalence of PFP in the general population is 22.7%[5]. PFP restricts activities of daily living and impairs health-related quality of life[6,7].

PFP limits both objective and self-reported function, which led to curiosity about the factors associated with objective and self-reported function in this patient group[8-19]. Although some researchers have investigated factors that may affect measures of objective function (e.g., jumping and climbing stairs) in individuals with PFP, these studies are limited and have yielded contradictory findings[8-11]. Another area of research interest is the relationship between fear of movement, pain catastrophism, and lower extremity function. While PFP does not directly cause fear of movement or pain catastrophism, they may occur as a result of PFP[11]. Anterior Knee Pain Scale (AKPS) score has been associated with eccentric and concentric quadriceps strength, eccentric hip external rotation strength, and the ratio of eccentric quadriceps to concentric hamstring strength[12-14]. Isometric quadriceps, hip extension, hip abduction, and hip adduction strengths are correlated with Activities of Daily Living score[15]. In addition, the Tampa Scale for Kinesiophobia (TSK) score is

The authors have no conflict of interest.

Corresponding author: Serdar Arslan, Yaka Mah. Beyşehir Cad. D Blok no:281 Meram/KONYA
E-mail: etsarslan@gmail.com
ORCID: 0000-0002-5070-2524

Edited by: G. Lyritis
Accepted 29 July 2024

also related to the AKPS and Lysholm scores[9,16-18].

One of the tools that can be used to measure self-reported function in individuals with PFP is the Lower Extremity Functional Scale (LEFS)[19]. However, no previous study has examined the relationship between LEFS score, TSK score, and quadriceps, hamstring, and hip stabilizer muscle strength. Therefore, we aimed to evaluate correlations between these variables, as well as explore how regular medication use, abdominal surgery history, smoking, and working status influenced TSK scores.

Material and Method

Study design

A cross-sectional study was conducted in accordance with the Declaration of Helsinki and the REPORTing of quantitative PatelloFemoral Pain (REPORT-PFP) checklist[20].

Participants

Fifty-four women with PFP with an average age of 32.59±7.00 years were included in the study. Inclusion criteria were: being a woman between the ages of 18 and 40 years; having PFP for at least 3 months; reporting a Visual Analog Scale (VAS) pain score of 3 or higher during the past week; and experiencing pain in at least two relevant activities (e.g., climbing or descending stairs, jumping, running, prolonged sitting, squatting, and kneeling) and at least one clinical test (patellar compression or palpation of the patellar facets). Exclusion criteria were: having clinical, radiographic, or MRI findings of meniscus, ligament, cartilage injury, osteoarthritis, epiphysitis, knee joint effusion, or recurrent patellar subluxation or dislocation; having hip or back pain that prevents exercise; having a history of knee surgery; using nonsteroidal anti-inflammatory drugs or cortisone; having a history of knee trauma; and receiving physiotherapy or other treatment for PFP in the previous 3 months. Informed consent was obtained from all participants at the beginning of the study (Figure 1).

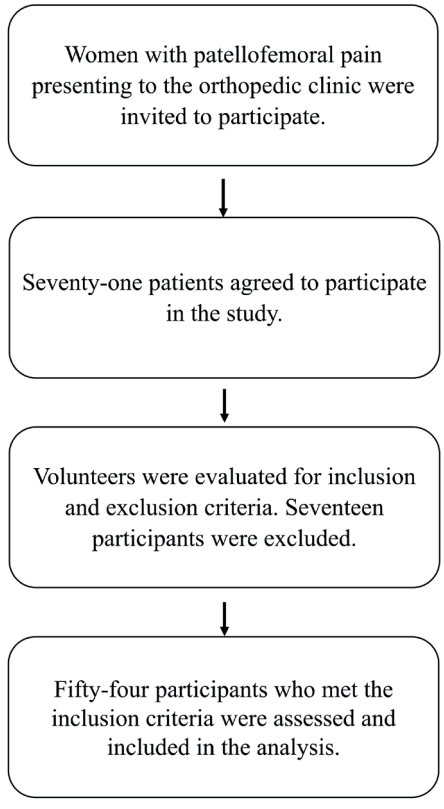

Figure 1. Flow chart of participant selection.

Table 1. Demographic data of participants.

Variables		n (%)
Affected limb	Dominant	33 (61.1)
	Nondominant	21 (38.9)
Employed		16 (29.6)
Surgical history		23 (42.6)
Regular medication use		16 (29.6)
Smoking		18 (33.3)

Outcomes

We recorded the participants' age, height, weight, symptom duration, pain severity, and affected extremity (dominant or non-dominant). We also noted their employment, surgical history, regular medication use, and smoking habits. The participants' subjective lower extremity function, fear of movement, and quadriceps, hamstring, and hip stabilizer muscle strength were measured as described below.

Pain severity was evaluated on a 10-cm VAS where 0 corresponded to no pain and 10 to intolerable pain. All participants were instructed to mark the level of pain felt at rest and during activities[1].

Self-reported lower extremity function was measured with the LEFS. Binkley and colleagues developed this scale in 1999 to determine the functional status of patients with lower extremity musculoskeletal dysfunction. The LEFS contains 20 items, each of which is scored between 0 and 4. The highest score is 80, and a higher score indicates better functional status[22]. The advantage of the LEFS over other knee-specific scales is that it can distinguish pain and function[23]. The LEFS Turkish version is a valid and reliable scale for patients with different types of knee dysregulation[24].

Fear of movement was assessed using the TSK and reported in terms of TSK score. This scale was created by Miller, Kori, and Todd in 1991 to measure fear of reinjury and

Table 2. Relationships between self-reported lower extremity function, muscle strength, and fear of movement.

		Mean (SD)	1		2		3		4	
			r	p	r	p	r	p	r	p
1	LEFS score	56.926 (13.827)	-							
2	Hip stabilizer strength	1.682 (0.448)	0.408**	0.002	1					
3	Hamstring strength	0.835 (0.237)	0.203	0.142	0.590**	<0.001	1			
4	Quadriceps strength	1.250 (0.334)	0.243	0.077	0.630**	<0.001	0.635**	<0.001	1	
5	TSK score	37.963 (7.854)	-0.500**	<0.001	-0.358**	0.008	-0.137	0.323	-0.345*	0.011

*LEFS: Lower Extremity Functional Scale, TSK: Tampa Scale for Kinesiophobia. **p<0.01, *p<0.05*

Table 3. Results of linear regression analysis of selected demographic variables as predictors of kinesiophobia.

	B	SE	Beta	t	p	95% CI	
						Lower	Upper
Constant	34.454	2.090		16.484	0.000	27.166	43.930
Employment	0.237	0.405	0.080	0.586	0.561	-5.107	4.719
Abdominal surgery	5.566	2.131	0.357	2.612	**0.012***	0.992	9.875
Regular medication use	-0.084	0.510	-0.023	-0.166	0.869	-1.050	1.008
Smoking	0.567	2.256	0.035	0.255	0.800	-4.116	5.035

*R=0.348, R^2=0.121, F=3.503, p=0.038. SE: Standard error, CI: Confidence interval. Dependent variable: Tampa Scale for Kinesiophobia score. *p<0.05*

movement and was published by Vlaeyen et al. in 1995[24]. It includes 17 questions and uses 4-point Likert-type scoring. The lowest possible score is 17 and the highest is 68. A higher score indicates greater fear of movement and re-injury[25]. The test-retest reliability of the Turkish version of the scale is excellent[26].

We measured isometric quadriceps and hamstring strength using a hand-held dynamometer (Nicholas Manuel Muscle Tester, Lafayette Indian Instruments, Lafayette, Indiana, USA). Before the study, we had the hand-held dynamometer calibrated by the manufacturer's authorized technical service. Before collecting the study data, we also piloted the measurement protocol on 10 healthy people using the calibrated hand-held dynamometer. Prior to measurement, the participants warmed up for 5 minutes with range-of-motion and isometric exercises. Quadriceps strength was measured in sitting position and hamstring strength in prone position. Three measurements were made for each direction with a 30-second rest between measurements. The average of the three measurements was recorded as the test score. We performed quadriceps strength measurement first, followed by a 5-minute break, and then performed hamstring strength measurement[27]. Hand-held dynamometer measurements are reliable and provide similar results to those made with an isokinetic dynamometer. It is an effective method for clinical use due to its portability, ease of use, and low cost[28].

We assessed the strength of the hip stabilizer muscles using the HipSIT test. This test involves measuring isometric hip posterolateral muscle strength in the clam exercise position. For the test, the participant laid on her side with the measured extremity on top. The hips were positioned in 45° flexion and knees in 90° flexion. The participant was instructed to lift the knee to abduct her leg to 20° while keeping the heels together. The dynamometer was placed 5 cm above the knee joint line. We then asked the participant to lift her leg with maximum force against the dynamometer. Three repetitions were made with a 30-second resting period between repetitions. The average of the three measurements was recorded as the test score. The HipSIT test provides detailed information about hip stabilizer muscle strength and has proven validity and reliability[29].

Statistical analysis

Sample size was calculated with G*Power software for 95% predicted power with an alpha value of 0.05 and an expected correlation coefficient of 0.53 based on the results of Glaviano et al.[15] We used the correlation between isometric quadriceps strength and the Activities of Daily Living Scale for calculation and determined that at least 34 participants were needed.

Data were analyzed using SPSS for Windows version 21 (IBM Corp., Armonk, NY, USA). The data were tested for normal distribution using visual (histogram and probability graphs) and analytical methods (Shapiro-Wilk test; skewness and kurtosis coefficients). Continuous variables are presented as mean ± standard deviation and categorical variables as number and percentage. Relationships between variables were evaluated by Pearson correlation analysis. Correlation coefficients were interpreted as weak (0.0-0.4), moderate (0.4-0.7), or strong (0.7-1.0)[15]. Binary logistic regression was used to determine the predictive value of selected variables for fear of movement. Statistical significance level was accepted as $p<0.05$.

Results

The study participants' mean age, height, and weight were 32.59±7.00 years, 161.80±6.00 cm, and 74.02±14.78 kg, respectively. The mean VAS score was 4.24±2.59 and pain duration was 14.06±17.62 months. Other demographic variables are shown in Table 1.

Self-reported lower extremity function was positively correlated with hip stability and negatively correlated with fear of movement ($p<0.01$ for both, Table 2). Fear of movement also showed a weak negative correlation with quadriceps strength and hip stability ($p<0.05$ and $p<0.01$, respectively, Table 2).

The results of linear logistic regression indicated that history of abdominal surgery was associated with greater fear of movement ($p<0.05$, Table 3). Being employed, using medication regularly, and smoking were not related to fear of movement ($p>0.05$, Table 3).

Discussion

The results of this study suggest that isometric quadriceps muscle strength is not associated with self-reported lower extremity function. Quadriceps weakness is considered one of the most important risk factors for PFP[2], and some studies have shown that quadriceps weakness may be an indicator of self-reported function[12-15]. Guney et al. reported that both concentric and eccentric quadriceps strength were negatively correlated with AKPS score[12], while Nakagawa reported a positive relationship between eccentric quadriceps strength and AKPS score[13]. Guney et al. also reported that the ratio of eccentric quadriceps to concentric hamstring strength correlated with the Kujala score[14], and Glaviano et al. found that isometric quadriceps strength was associated with the Activities of Daily Living Scale score[15]. Our results may differ from those in the literature because we used different tools used to measure strength and self-reported function. However, to our knowledge, this is the first study to provide evidence regarding the relationship between the commonly used LEFS score and isometric quadriceps strength in individuals with PFP. Therefore, the current study can contribute to the literature.

Our results also demonstrated a positive correlation between hip stabilizer muscle strength measured with the HipSIT test and self-reported lower extremity function. The HipSIT is a functional test developed based on the clam exercise, which is the exercise with highest gluteal muscle activation[29]. It provides information about hip extension, abduction, and external rotation strength[29,30]. Human movements are non-isolated movements that occur in all three planes[31]. Therefore, measuring isolated hip extension, abduction, and external rotation forces will not fully reflect functional strength. The HipSIT test was developed to evaluate the stabilization of the hip during functional movements[30]. The fact that it is a functional test suggests that it may also be related to subjective function level. To our knowledge, the current study is the first to provide information regarding the relationship between the HipSIT test and self-reported function in individuals with PFP. However, a special interest in hip strength is also evident in the PFP literature. It is known that interventions to increase hip muscle strength, especially those that strengthen the gluteus medius, increase objective and self-reported function in individuals with PFP[32]. This information suggests that there may be a relationship between hip strength and self-reported function. The results of several studies investigating the correlation between hip strength and self-reported function also support this claim. Nakagawa reported a strong positive correlation between eccentric hip external rotation strength and AKPS[13]. Glaviano et al. also reported that AKPS score showed moderate to strong positive correlations with isometric hip abductor, adductor, and extensor muscle strength[15]. Despite some methodological differences, the current study supports the results of the two studies mentioned above.

In our study, there was a moderate negative correlation between fear of movement scores and self-reported lower extremity function. A few previous studies have also evaluated this relationship in individuals with PFP[9,11,16]. De Oliveira Silva et al. reported a moderate negative correlation between AKPS and TSK scores[9]. Pazzinatto et al. investigated whether physical function and fear of movement were risk factors for the development of PFP in women in their study with a 2-year prospective follow-up. They reported that fear of movement was not a risk factor for the development of PFP, but the development of PFP was associated with reduced performance in the step-down and single-leg hop for distance tests, even in the early stages[11]. Domenech et al. reported a moderate negative correlation between Lysholm and TSK scores[16]. Rethman et al. stated that there was a moderate correlation between self-reported function and fear of

movement in their meta-analysis[17]. The findings of the current study support the relationship between fear of movement and self-reported function reported in the literature. These results point to the potential role of psychological factors in PFP[33]. Recent evidence suggests that fear of movement may increase sensitivity to pain by causing some changes in the central nociception process[34]. For these reasons, methods that reduce fear of movement, such as knee braces, may improve physical function in individuals with PFP. This may also enable more comfortable implementation of exercise therapy, thereby increasing its effectiveness[35].

The finding that surgical history was a predictor of fear of movement score was another interesting result of the current study that is novel to the literature. We determined that women with a surgical history were 6 times more likely to experience fear of movement than those without. However, there are many cross-sectional studies showing that different knee surgeries cause fear of movement[36,37]. Interestingly, the participants in our study reported a history of abdominal surgery, which is not directly related to the knee but was statistically associated with fear of movement. Surgery may lead to changes in the central or peripheral mechanisms related to pain[38]. Thus, pain sensitivity may increase and function level may decrease. On the other hand, the negative impact of abdominal surgery on core stabilization may be another explanation for this relationship[39]. Impaired core stabilization may have negatively affected lower extremity alignment, causing increased patellofemoral reaction forces, pain, and functional impairment[40]. Future studies should explore the relationship between abdominal surgery history and subjective and objective physical function in individuals with PFP.

The study has some limitations. Although we took care to prevent compensation while measuring isometric muscle strength, some overlooked compensatory movements may have affected the results. In future research, muscle strength can be measured with methods such as an isokinetic dynamometer, where compensatory movements can be better prevented. Additionally, the use of muscle strength measurements reflecting other contraction types may offer a more complete picture. Secondly, although participants filled out the scales used for subjective measurements under our supervision, they may not have responded with adequate care and consideration, which may have compromised the reliability of the subjective measurements. Future studies that use both subjective and objective measurements together may provide more detailed results.

Conclusion

Self-reported lower extremity function was moderately negatively correlated with fear of movement and positively correlated with hip stabilizer muscle strength in women with PFP. A history of abdominal surgery was associated with fear of movement and may offer a tool that can be used to predict fear of movement.

Ethics approval

The research was carried out by the Declaration of Helsinki and received ethical compliance according to the decision numbered 2023/527 and dated 06/09/2023 from Health Sciences Scientific Research Ethics Committee of Necmettin Erbakan University.

Consent to participate

All participants were informed about the study, and then written informed consent was obtained.

Authors' contributions

All authors contributed to the design, conceptions and implementation of the study. Data collection was performed by Serdar Arslan and Engin Dinç. Data analysis was performed by Osman Coşkun, Gökmen Yapalı. Serdar Arslan wrote the first draft of the manuscript, and research process supervision and manuscript proofreading were carried out by Osman Coşkun and Engin Dinç. All the authors have read and approved the final manuscript.

References

1. Crossley KM, Stefanik JJ, Selfe J, et al. 2016 patellofemoral pain consensus statement from the 4th International Patellofemoral Pain Research Retreat, Manchester. Part 1: terminology, definitions, clinical examination, natural history, patellofemoral osteoarthritis and patient-reported outcome measures. Br J Sports Med 2016;50(14):839-843.
2. Sisk D, Fredericson M. Update of Risk Factors, Diagnosis, and Management of Patellofemoral Pain. Curr Rev Musculoskelet Med 2019;12(4):534-541.
3. Neal BS, Lack SD, Lankhorst NE, Raye A, Morrissey D, van Middelkoop M. Risk factors for patellofemoral pain: a systematic review and meta-analysis. Br J Sports Med 2019;53(5):270-281.
4. Ferreira AS, Mentiplay BF, Taborda B, Pazzinatto MF, de Azevedo FM, de Oliveira Silva D. Overweight and obesity in young adults with patellofemoral pain: Impact on functional capacity and strength. J Sport Health Sci. 2023;12(2):202-211.
5. Glaviano NR, Kew M, Hart JM, Saliba S. Demographic and epidemiological trends in patellofemoral pain. Int J Sports Phys Ther 2015; 10(3): 281-290
6. Smith BE, Moffatt F, Hendrick P, Bateman M, Rathleff MS, Selfe J, Smith TO, Logan P. The experience of living with patellofemoral pain—loss, confusion and fear-avoidance: a UK qualitative study. BMJ Open 2018;8(1): e018624.
7. Coburn SL, Barton CJ, Filbay SR, Hart HF, Rathleff MS, Crossley KM. Quality of life in individuals with patellofemoral pain: a systematic review including meta-analysis. Phys Ther Sport 2018;33:96-108.
8. Priore LB, Azevedo FM, Pazzinatto MF, Ferreira AS, Hart HF, Barton C, de Oliveira Silva D. Influence of kinesiophobia and pain catastrophism on objective function in women with patellofemoral pain. Phys Ther Sport 2019;35:116-121.
9. de Oliveira Silva D, Barton CJ, Briani RV, Taborda B,

Ferreira AS, Pazzinatto MF, Azevedo FM. Kinesiophobia, but not strength is associated with altered movement in women with patellofemoral pain. Gait Posture 2019; 68:1-5.
10. De Oliveira Silva D, Willy RW, Barton CJ, Christensen K, Pazzinatto MF, Azevedo FM. Pain and disability in women with patellofemoral pain relate to kinesiophobia, but not to patellofemoral joint loading variables. Scand J Med Sci Sports 2020;30(11):2215-2221.
11. Pazzinatto MF, Barton CJ, Willy RW, Ferreira AS, Azevedo FM, de Oliveira Silva D. Are Physical Function and Fear of Movement Risk Factors for Patellofemoral Pain? A 2-Year Prospective Study. J Sport Rehabil 2022;32(1):24-30.
12. Guney H, Yuksel I, Kaya D, Doral MN. The relationship between quadriceps strength and joint position sense, functional outcome and painful activities in patellofemoral pain syndrome. Knee Surg Sports Traumatol Arthrosc 2016;24(9):2966-2972.
13. Nakagawa TH, de Marche Baldon R, Muniz TB, Serrão FV. Relationship among eccentric hip and knee torques, symptom severity and functional capacity in females with patellofemoral pain syndrome. Phys Ther Sport 2011;12(3):133-9.
14. Guney H, Yuksel I, Kaya D, Doral MN. Correlation between quadriceps to hamstring ratio and functional outcomes in patellofemoral pain. Knee 2016;23(4):610-5.
15. Glaviano NR, Saliba S. Relationship Between Lower-Extremity Strength and Subjective Function in Individuals With Patellofemoral Pain. J Sport Rehabil 2018;27(4): 327-333.
16. Domenech J, Sanchis-Alfonso V, López L, Espejo B. Influence of kinesiophobia and catastrophizing on pain and disability in anterior knee pain patients. Knee Surg Sports Traumatol Arthrosc 2013;21(7):1562-8.
17. Rethman KK, Mansfield C, Moeller J, De Oliveira Silva D, Stephens JA, Di Stasi S, Briggs M. Kinesiophobia Is Associated with Poor Function and Modifiable through Interventions in People with Patellofemoral Pain: A Systematic Review with Individual Participant Data Correlation Meta-Analysis. Phys Ther 2023;103(9): pzad074.
18. Pazzinatto MF, Silva DO, Willy RW, Azevedo FM, Barton CJ. Fear of movement and (re)injury is associated with condition specific outcomes and health-related quality of life in women with patellofemoral pain. Physiother Theory Pract 2022;38(9):1254-1263.
19. Watson CJ, Propps M, Ratner J, Zeigler DL, Horton P, Smith SS. Reliability and responsiveness of the lower extremity functional scale and the anterior knee pain scale in patients with anterior knee pain. J Orthop Sports Phys Ther 2005;35(3):136-46.
20. Barton CJ, De Oliveira Silva D, Morton S, Collins NJ, Rathleff MS, Vicenzino B, van Middelkoop M, Crossley KM, Callaghan MJ, Selfe J, Holden S, Lack S, Macri EM, Bazett-Jones DM, Earl-Boehm JE, Riel H, Powers CM, Davis IS, Morrissey D. REPORT-PFP: a consensus from the International Patellofemoral Research Network to improve REPORTing of quantitative PatelloFemoral Pain studies. Br J Sports Med 2021;55(20):1135-1143.
21. Binkley JM, Stratford PW, Lott SA, Riddle DL, North American Orthopaedic Rehabilitation Research Network. The Lower Extremity Functional Scale (LEFS): scale development, measurement properties, and clinical application. Phys Ther 1999;79(4):371–383.
22. Pua YH, Cowan SM, Wrigley TV, Bennell KL. The Lower Extremity Functional Scale could be an alternative to the Western Ontario and McMaster Universities Osteoarthritis Index physical function scale. J Clin Epidemiol 2009;62(10):1103–1111.
23. Citaker S, Kafa N, Hazar Kanik Z, Ugurlu M, Kafa B, Tuna Z. Translation, cross-cultural adaptation and validation of the Turkish version of the Lower Extremity Functional Scale on patients with knee injuries. Archives of orthopaedic and trauma surgery 2016;136:389-395.
24. Vlaeyen JWS, Kole-Snijders AMJ, Boeren RGB, van Eek H. Fear of movement/(re)injury in chronic low back pain and its relation to behavioral performance. Pain 1995; 62(3):363-372.
25. Vlaeyen JWS, Linton SJ. Fear-avoidance and its consequences in chronic musculoskeletal pain: a state of the art. Pain 2000;85(3):317-332.
26. Yilmaz O, Yakut Y, Uygur F, Ulug N. Turkish version of the Tampa Scale for Kinesiophobia and its test-retest reliability. Turkish Journal of Physiotherapy Rehabilitation-Fizyoterapi Rehabilitasyon 2011;22(1): 44-9.
27. Schaeffer M, Abbruzzese LD, Tawa Z, Schultz K, Binney J, Boyle J, Bronner S. Inter- and Intra-Rater Reliability of Handheld Dynamometry for Lower Extremity Strength Testing in Pre-Professional Dancers. J Dance Med Sci 2021;25(2):86-95.
28. Toonstra J, Mattacola CG. Test-retest reliability and validity of isometric knee-flexion and -extension measurement using 3 methods of assessing muscle strength. J Sport Rehabil 2013;22(1):1-5.
29. Almeida GPL, das Neves Rodrigues HL, de Freitas BW, de Paula Lima PO. Reliability and Validity of the Hip Stability Isometric Test (HipSIT): A New Method to Assess Hip Posterolateral Muscle Strength. J Orthop Sports Phys Ther 2017;47(12):906-913.
30. Selkowitz DM, Beneck GJ, Powers CM. Which exercises target the gluteal muscles while minimizing activation of the tensor fascia lata? Electromyographic assessment using fine-wire electrodes. J Orthop Sports Phys Ther 2013;43(2):54-64.
31. Reznick E, Embry KR, Neuman R, Bolívar-Nieto E, Fey NP, Gregg RD. Lower-limb kinematics and kinetics during continuously varying human locomotion. Sci Data 2021; 8(1):282.
32. Na Y, Han C, Shi Y, Zhu Y, Ren Y, Liu W. Is Isolated Hip Strengthening or Traditional Knee-Based Strengthening More Effective in Patients With Patellofemoral Pain

Syndrome? A Systematic Review With Meta-analysis. Orthop J Sports Med 2021;9(7):23259671211017503.
33. Maclachlan LR, Collins NJ, Matthews MLG, Hodges PW, Vicenzino B. The psychological features of patellofemoral pain: a systematic review. Br J Sports Med 2017;51(9): 732-742.
34. Barber Foss KD, Slutsky-Ganesh AB, Diekfuss JA, Grooms DR, Simon JE, Schneider DK, Jayanthi N, Lamplot JD, Hill D, Pombo M, Wong P, Reiter DA, Myer GD. Brain Activity During Experimental Knee Pain and Its Relationship With Kinesiophobia in Patients With Patellofemoral Pain: A Preliminary Functional Magnetic Resonance Imaging Investigation. J Sport Rehabil 2022; 31(5):589-598.
35. Priore LB, Lack S, Garcia C, Azevedo FM, de Oliveira Silva D. Two Weeks of Wearing a Knee Brace Compared with Minimal Intervention on Kinesiophobia at 2 and 6 Weeks in People With Patellofemoral Pain: A Randomized Controlled Trial. Arch Phys Med Rehabil 2020;101(4):613-623.
36. Bullock GS, Sell TC, Zarega R, Reiter C, King V, Wrona H, Mills N, Ganderton C, Duhig S, Räisäsen A, Ledbetter L, Collins GS, Kvist J, Filbay SR. Kinesiophobia, Knee Self-Efficacy, and Fear Avoidance Beliefs in People with ACL Injury: A Systematic Review and Meta-Analysis. Sports Med 2022; 52(12): 3001-3019.
37. Brown OS, Hu L, Demetriou C, Smith TO, Hing CB. The effects of kinesiophobia on outcome following total knee replacement: a systematic review. Arch Orthop Trauma Surg 2020;140(12):2057-2070.
38. Voscopoulos C, Lema M. When does acute pain become chronic?. British journal of anaesthesia 2010; 105(suppl_1): i69-85.
39. Malavde R, Rayjade A. Effect of Trunk Extensor Muscle Fatigue on Postural Stability in Women Undergone Lower Segment Cesarean Section. Medico-Legal Update 2020;20(4):489-494.
40. De Blaiser C, De Ridder R, Willems T, Vanden Bossche L, Danneels L, Roosen P. Impaired Core Stability as a Risk Factor for the Development of Lower Extremity Overuse Injuries: A Prospective Cohort Study. Am J Sports Med 2019;47(7):1713-1721.