RESEARCH ARTICLE

Association of Physical Function and Pain with Lower Muscle Strength and Trunk Muscle Endurance in Subjects with Patellofemoral Pain Syndrome

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Abstract

Objectives: This study investigated the relationship between knee pain severity and functional performance, as well as hip and knee muscle strength and trunk endurance, in individuals with patellofemoral pain syndrome (PFPS).

Methods: This cross-sectional study included 50 participants diagnosed with PFPS. An 11-point visual analog scale (VAS) was used to assess the severity of knee pain, and the Anterior Knee Pain Scale (AKPS) was used to quantify functional ability. Hip extensors, abductors, medial and lateral rotators, and knee extensors were tested for strength using a handheld dynamometer. Trunk endurance was assessed through plank tests in anterior, posterior, and lateral positions.

Results: A significant inverse relationship was identified between pain intensity and functional performance ($r = -0.504$, $p < 0.001$). Body mass index (BMI) exhibited a negative relationship with performance ($B = -7.459$, $p = 0.021$). Knee extensor strength ($B = 0.156$, $p < 0.0001$) and lateral plank endurance ($B = 1.457$, $p = 0.002$) showed a positive relationship with functional performance.

Conclusion: Higher pain levels and BMI were related to poorer function in individuals with PFPS. In contrast, greater quadriceps strength and increased lateral core endurance were correlated with better functional outcomes.

Level of evidence: III

Keywords: Patellofemoral pain syndrome, Physical function, Trunk muscle endurance

Introduction

Patellofemoral pain syndrome (PFPS) is a highly prevalent musculoskeletal disorder characterized by anterior knee pain,[1] which is exacerbated by activities such as running, jumping, stair climbing, or prolonged sitting with the knees bent.[2] Chronic pain associated with PFPS significantly impacts an individual's quality of life and physical performance, disrupting work, exercise routines, and daily activities.[3] Since PFPS may predispose individuals to knee arthritis later in life,[4] effective prevention and treatment strategies are essential. While short-term treatments often yield positive results,[5] pain and symptoms frequently recur in many individuals over time.[6] Long-term dissatisfaction with treatment may arise from a limited understanding of the factors contributing to PFPS. Although this syndrome is multifactorial, biomechanical dysfunction resulting from muscle function deficits is one of the most significant contributors to pain in affected individuals.[7] In many cases, quadriceps weakness and decreased muscle torque during eccentric contractions are observed.[8] Furthermore, proximal muscles—including the femoral abductor, external rotator, and extensor muscles—are weaker in individuals with PFPS compared to healthy controls.[1] Impaired hip and pelvic control leads to abnormal alignment during movement. This misalignment, such as pelvic drop on the opposite side, results in increased adduction and internal rotation, along with dynamic knee valgus, which creates abnormal pressure on the

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patellofemoral joint and ultimately triggers an inflammatory response and knee pain.[9] Evidence suggests that decreased endurance of the trunk muscles increases an individual's susceptibility to musculoskeletal injuries, including knee injuries. Engaging in targeted therapeutic exercises for these muscles may reduce the risk of such injuries.[10] While numerous studies have reported positive outcomes from therapeutic exercise protocols targeting the thigh and trunk muscles in individuals recovering from PFPS,[11] to our knowledge, no study has specifically examined the association between hip muscle strength, trunk endurance, pain severity, and muscle function in these individuals. A study by Piva et al.[12] examined the relationship between lower extremity muscle strength and physical characteristics but did not assess trunk muscle endurance. Understanding the factors that influence pain severity and functional outcomes enables a more targeted treatment approach, allowing clinicians to focus on training and rehabilitating the muscles most relevant to PFPS. This could help alleviate pain and improve functionality in individuals affected by the condition. Therefore, the present study aims to investigate the association between PFPS and the strength and endurance of the trunk and thigh muscles.

Materials and Methods

Fifty patients (30 females and 20 males) diagnosed with PFPS, with an average age of 29.4 years, were recruited for this study. In cases of bilateral PFPS, the knee with more pronounced symptoms was designated as the target knee. After meeting the eligibility and exclusion criteria, participants received both a verbal and written explanation of the study's objectives and procedures. They provided written informed consent before entering the study. Subsequently, the History Questionnaire and Demographic Information were collected, including age, gender, height, body mass, and the duration of the current PFPS episode. An 11-point Visual Analogue Scale (VAS), a validated and reliable tool for assessing knee pain, was used to evaluate pain. On this scale, 0 indicated no pain, and 10 represented the worst imaginable pain.[13] Function was assessed using the 13-item Persian version of the Anterior Knee Pain Scale (AKPS).[14] This questionnaire has a maximum score of 100, with higher scores indicating better function. A score of 13 points represents the minimum clinically relevant level.[15]

The inclusion criteria were a lasting, gradual onset of pain above or below the kneecap for at least 6 weeks,[16] pain that appears or worsens during a minimum of two activities: running, jumping, squatting, sitting, walking, going up or down stairs, and kneeling, and pain present upon palpation or compression of the patella, or during isometric quadriceps contraction.[14]

The exclusion criteria included the history of knee surgery and trauma, patellofemoral joint instability or tendinopathy, pain and injury in the lower back and pelvis, neurological disease, history of dislocation, and knee effusion,[17] use of anti-inflammatory medications, intra-articular impingement, and damage to the knee ligaments.[16]

A DSI handheld dynamometer (Danesh Salar Iranian Co., Iran) was used to quantify muscle strength, with results expressed as a percentage of body mass. In women with PFPS, this method demonstrates good to excellent interrater and intrarater reliability when assessing hip strength.[18] HHD has intraclass correlation coefficient (ICC_2) values between 0.80 and 0.95 in individuals suffering from PFPS, considered reliable and comparable to standard isometric strength testing.[8] A strap was used during all tests to minimize examiner influence. Participants were instructed to exert maximal force against the dynamometer for 5 seconds. A single practice trial was administered initially, followed by a 30-second rest period before the measured trials began. Each participant completed three trials, with a 30-second rest period between them. For each participant, a mean value was calculated. A 1-minute rest period was provided before testing a different muscle group. Any measurements with compensatory movements were discarded, and re-evaluation occurred after a 20-second rest. Torque (Nm) was derived from the force data and normalized to body mass [(kg force/kg body mass) × 100]. For the knee extension assessment, both the hip and knee were flexed to 90°, and the handheld dynamometer was placed 4 cm proximal to the anterior aspect of the ankle joint. A stabilization strap was used throughout testing. To measure isometric hip abductor strength, participants were positioned in lateral decubitus with the lower hip and knee flexed to 45 degrees. The test limb was abducted to 20 degrees, slightly extended to 10 degrees, maintained in neutral hip rotation, and had the knee extended. The dynamometer was placed 5 cm proximal to the midpoint of the lateral malleolus. The moment arm was defined as the distance from the greater trochanter to the center of the dynamometer. To quantify isometric hip extensor torque, participants were positioned in the prone position. The non-tested limb was fully extended, while the tested limb was positioned with 10 degrees of hip extension, slight hip external rotation, and 90 degrees of knee flexion. The dynamometer was placed over the posterior thigh, 5 cm proximal to the popliteal crease. The distance from the ischial tuberosity to the center of the dynamometer was used to define the moment arm. For isometric hip external rotator strength testing, participants were seated with both hips and knees flexed to 90 degrees. The dynamometer was positioned 5 cm proximal to the midpoint of the medial malleolus, over the distal-medial tibia. Straps were used to ensure accurate measurements by preventing unwanted hip adduction. The distance from the lateral femoral condyle to the center of the dynamometer was considered the moment arm. For isometric hip internal rotator torque assessment, participants were seated with hips and knees flexed to 90 degrees. The dynamometer was positioned over the distal-medial tibia, 5 cm proximal to the midpoint of the lateral malleolus. Straps were applied to prevent hip abduction. The moment arm was defined in the same way as for the isometric hip external rotator torque assessment. To measure trunk muscle endurance, participants were instructed to maintain the plank position in three directions—anterior, posterior, and lateral—for as long as possible. The duration of each plank exercise was measured using a stopwatch. For the anterior plank exercise, participants kept their forearms in contact with the ground, forming fists with their hands and maintaining a 30 cm distance between their elbows. They were instructed to protract their scapulae, keep their ankles at 90-degree angles, and contract their abdomens using the abdominal drawing-in maneuver. The shoulders and hips were held at a height of 25 cm from the ground, with the feet in contact with the floor. For the posterior plank exercise, participants were asked to engage their core and push down through it. They were instructed to hold their palms on the floor while lifting their hips, ensuring the trunk was separated from the floor and maintaining a straight line from the knees to the shoulders. For the lateral plank, participants lay on one side, bearing weight through the abducted shoulder and flexed elbow (at 90 degrees). The wrist of the supporting arm was pronated and slightly extended. The legs were split, with the supporting-side leg positioned forward and the non-supporting leg positioned backward, so that the rear toe touched the front heel. A straight line was maintained through the head, trunk, and feet. The non-weight-bearing hand was placed on the pelvis, with a relaxed, bent elbow.

The sample size for this study was determined using G*Power software, based on a Type I error rate ($\alpha = 0.05$), a Type II error rate ($\beta = 0.20$), and a desired statistical power of 80% for detecting a correlation. Statistical analysis was conducted using correlation analysis to examine the association between muscle characteristics, pain levels, and functional impairment, with a significance level set at 0.05. To assess the predictive influence of key variables on pain levels and functional performance, multiple linear regression analysis was applied.

Results

This study was conducted on 50 participants diagnosed with Patellofemoral Pain Syndrome (PFPS), consisting of 30 females (60%) and 20 males (40%). Table 1 presents the descriptive statistics of the studied variables, including their mean values and standard deviations [Table 1]. The table includes characteristics such as age, BMI, maximum pain, AKPS, as well as all measures of muscle strength and endurance.

Table 1. Descriptive Statistics of Variables

Variable	Mean	SD[1]
Age	29.4200	9.15421
BMI[2]	26.6520	6.16071
Max pain	6.68	1.659
AKPS[3]	71.46	14.476
Knee extensor strength[4]	138.57	34.639
Hip external rotator strength	91.75	26.594
Hip internal rotator strength	87.46	20.179
Hip extensor strength	99.18	27.994
Hip abductor strength	109.46	24.290
Anterior plank endurance[5]	34.64	26.226
Posterior plank endurance	31.56	29.583
Lateral plank endurance	16.34	15.072

1-Standard deviation
2-Body Mass Index
3-Anterior Knee Pain Scale
4-(Nm) and normalized to body mas: [(kg force/kg body mass) × 100]
5-Second

Table 2 presents the results of the Pearson correlation analysis between the main variables [Table 2]. The findings reveal a significant inverse relationship between pain intensity and functional performance, with a correlation coefficient of -0.504 and a significance level of $p < 0.001$. This indicates that as pain intensity increases, functional performance decreases. Additionally, functional performance was significantly correlated with Knee Extensor Strength ($p < 0.001$), Hip Abductor Strength ($p = 0.020$), and Lateral Plank Endurance ($p = 0.020$).

Table 2. Correlation Coefficients between Variables

Variables	Pain Intensity	Functional Performance
Pain Intensity	1.000	-0.504 (p<0.001)
Functional Performance	-0.504 (p<0.001)	1.000
Knee Extensor Strength	-0.050 (p = 0.712)	0.658 (p<0.001)
Hip Abductor Strength	-0.012 (p = 0.936)	0.328 (p = 0.020)
Hip Extension Strength	-0.095 (p=0.512)	0.179 (p=0.480)
Hip Int[1] Rotation Strength	-0.107 (p=0.460)	0.054 (p=0.841)
Hip Ext[2] Rotation Strength	0.008 (p=0.956)	0.013 (p=0.927)
Anterior Plank Endurance	0.026 (p=0.858)	0.251 (p=0.079)
Posterior Plank Endurance	0.077 (p=0.594)	0.228 (p=0.111)
Lateral Plank Endurance	-0.225 (p = 0.117)	0.328 (p=0.020)

The regression analysis involved conducting multiple linear regressions to determine the impact of key variables on functional performance, as presented in Table 3 [Table 3]. This analysis explained 85.8% of the variance in performance (R^2 = 0.858, $p < 0.001$). The findings indicated that three variables significantly contributed to functional performance. BMI was negatively associated with performance, with a coefficient of B = -7.459 and a p-value of 0.021. Knee extensor strength showed a positive association with performance, with a coefficient of B = 0.156 and a high level of significance ($p < 0.0001$). Similarly, lateral plank endurance was positively linked to performance, with a coefficient of B = 1.457 and p = 0.002. These results suggest that higher BMI is associated with lower performance, while greater knee extensor strength and increased lateral plank endurance are positively related to improved functional outcomes.

Table 3. Regression Analysis of Factors Affecting Functional Performance

Variable	Coefficient (B)	P-Value
BMI[1]	-7.459	0.021
Knee Extensor Strength	0.156	< 0.001
Lateral Plank Endurance	1.457	0.002
Model Summary	R^2 = 0.858	p < 0.001

1-Body Mass Index

Discussion

The relationship between muscle weakness and PFPS is well established.[19] However, the rehabilitation for PFPS patients primarily targets the quadriceps,[20,21,] hip muscles,[22] and trunk muscle endurance or core stability,[23,24] for symptom improvement. Thus, the relationship between the strength of these muscles and symptom severity remains unclear.[12,25] The stability of the lumbopelvic complex is derived from both deep stabilizing (local) and superficial muscles (global), collectively referred to as the core.[26] Core stability refers to the ability of the trunk to maintain control when faced with both expected and unexpected internal and external challenges. It is essential for producing, transferring, and controlling forces and motion within the distal segment of the kinetic chain.[27] A well-controlled and stable lumbopelvic-hip complex plays a key role in reducing the risk of knee injuries, with this benefit being particularly pronounced in women.[28] Physical therapists, athletic trainers, and musculoskeletal researchers are keenly interested in understanding how core stability is acquired and maintained. While core stability benefits from static components such as bones and soft tissues, its crucial foundation lies in the dynamic function of muscles. The movement of the lower extremities is well-documented to be related to trunk muscle activity. Current evidence suggests that a decline in core stability may increase the risk of injury, while appropriate training can help mitigate this risk.[10] However, the role of trunk muscle endurance in Patellofemoral Pain Syndrome (PFPS) has not been extensively studied. For this reason, we aimed to investigate the relationships between various muscle strengths (knee extensors, hip abductors, hip lateral rotators, and hip internal rotators), core endurance (measured by anterior, posterior, and lateral plank tests), and symptom severity and functional capacity in individuals with PFPS. Our study found that lateral plank endurance, a measure of lateral core stability, predicted functional outcomes in individuals with PFPS. This supports the findings of Almeida et al., who reported that in women with PFPS, the isometric peak torque of lateral core stability was the best predictor of function.[25] Given that core stability derives from the overall muscular capacity of the lumbopelvic-hip complex, with hip strength being only one contributing factor,[29] these results are particularly noteworthy. Prior research has reported a 24% to 29% deficit in lateral core stability in individuals with PFPS compared to controls.[30] The findings also demonstrate a direct correlation between quadriceps muscle strength and functional performance in individuals with PFPS. This contrasts with the findings of Piva and colleagues, who reported no relationship between hip and knee muscle strength and functional performance in individuals with PFPS.[12] The AKPS questionnaire was used to assess functional levels, whereas the KOS-ADLS was used in the study by Piva and colleagues. However, previous studies have reported significant weakness in the quadriceps, particularly in eccentric strength, in the affected limb of individuals with patellofemoral pain, compared to the unaffected limb.[23,24,31] The exact cause of quadriceps weakness in patellofemoral pain (PFP) remains unclear.[23] However, the most widely accepted theory suggests that knee pain leads to reflex inhibition of the quadriceps, which may result in reduced muscle fiber count and decreased muscle fiber size.[32] Ferreira et al.[33] found that individuals with patellofemoral pain exhibited reduced maximal torque in isometric, concentric, and eccentric knee extensors compared to controls. Previous research has suggested that muscle reflex inhibition predominantly affects Type II muscle fibers, which are responsible for maintaining eccentric muscle force.[8] The findings of the current study align with this, showing decreased eccentric and concentric quadriceps muscle strength on the affected side compared to the unaffected side. Recent literature emphasizes that short-term functional outcomes are significantly influenced by quadriceps cross-sectional area, as well as both eccentric and concentric quadriceps strength.[34] According to Natri et al., better functional outcomes are associated with a reduced strength disparity between the quadriceps on the involved and uninvolved sides.[35] The results also indicated that, contrary to the hypothesis, muscle strength and trunk muscle resistance are not related to pain severity. Similar studies have conducted analyses and found no correlation between isometric knee extensor and hip lateral rotator torque and VAS pain.[12] Contrary to the hypothesis, no relationship was found between hip abductor strength and functional status or knee pain. Despite reports of lower eccentric hip abductor torque and greater femoral adduction excursion during functional activities in patients with PFPS compared to healthy individuals,[33] other studies have indicated that women with PFPS exhibit greater femoral medial rotation excursion,[36] rather than excessive femoral adduction, when compared to a control group.[37] Patients with patellofemoral pain syndrome may experience different impairments in hip motion. The study found no correlation between eccentric hip abductor torque, functional capacity, and pain levels in the evaluated females, suggesting that while their coronal plane lower limb alignment may appear normal, impairments could exist in the transverse plane.[38] It is essential to interpret this finding with caution, as previous research has not consistently established a direct link between hip muscle strength and lower limb kinematics.[39] Thus, neuromuscular factors, rather than strength alone, might play a more significant role in predicting lower limb alignment. Future studies are needed to clarify the relationship between various altered hip motion patterns, functional performance, and pain levels in individuals with PFPS. Furthermore, future research should evaluate additional factors that may contribute to the development of PFPS. Evidence indicated that psychological factors, such as anxiety and fear-avoidant beliefs, influence the severity of symptoms experienced by PFPS patients.[12] The research highlighted the crucial role of both muscular strength and endurance in pain reduction and functional improvement in these patients. Clinicians can develop more comprehensive and effective rehabilitation programs by addressing both aspects of muscle performance. Specifically, incorporating exercises such as knee extensor strengthening and lateral planks can significantly enhance function in patients with PFPS by improving trunk endurance.

Conclusion

The findings indicate that individuals with PFPS exhibit poorer functional performance when experiencing higher pain levels or having a higher BMI. Conversely, those with stronger quadriceps muscles and better lateral core endurance demonstrate improved functional capacity. This highlights the importance of targeting both strength training, especially of the knee and core muscles, and weight management in rehabilitation programs for individuals suffering from PFPS. These insights can help clinicians develop more targeted and effective interventions for PFPS, aiming to enhance patients' quality of life through strength and endurance training while managing BMI.

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