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# Associates of Physical Function and Pain in Patients with Patellofemoral Pain Syndrome

**Sara R. Piva, PhD, PT**[a], **G. Kelley Fitzgerald, PhD, PT**[a], **James J. Irrgang, PhD, PT**[b], **Julie M. Fritz, PhD, PT**[d], **Stephen Wisniewski, PhD**[c], **Gerald T. McGinty, MS, PT**[e], **John D. Childs, PT, PhD**[f], **Manuel A. Domenech, PT, EdD**[g], **Scott Jones, DPT**[h], and **Anthony Delitto, PhD, PT**[a]

[a]Department of Physical Therapy, University of Pittsburgh, Pittsburgh, PA

[b]Department of Orthopaedic Surgery, University of Pittsburgh, Pittsburgh, PA

[c]Graduate School of Public Health, University of Pittsburgh, Pittsburgh, PA

[d]Department of Physical Therapy, University of Utah, Salt Lake City, UT

[e]Physical Therapy Element of United States Air Force Academy, Colorado Springs, CO

[f]Doctor Program of Physical Therapy, US Army–Baylor University, Fort Sam Houston, TX

[g]Department of Rehabilitation Sciences, Texas Tech University Health Science Center, Odessa, TX

[h]Ramstein Outpatient Physical Medicine Clinic, Ramstein Air Base, Kaiserslautern, Germany

## Abstract

**Objectives—**To explore whether impairment of muscle strength, soft tissue length, movement control, postural and biomechanic alterations, and psychologic factors are associated with physical function and pain in patients with patellofemoral pain syndrome (PFPS).

**Design—**Cross-sectional study.

**Setting—**Rehabilitation outpatient.

**Participants—**Seventy-four patients diagnosed with PFPS.

**Interventions—**Not applicable.

**Main Outcome Measures—**Measurements were self-reported function and pain; strength of quadriceps, hip abduction, and hip external rotation; length of hamstrings, quadriceps, plantar flexors, iliotibial band/tensor fasciae latae complex, and lateral retinaculum; foot pronation; Q-

Correspondence to Sara R. Piva, PhD, PT, Dept of Physical Therapy, SHRS, University of Pittsburgh, Room 6035, Forbes Tower, Pittsburgh, PA 15260

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[a]Suppliers

Biodex System 3 Pro; Biodex Medical Systems, 20 Ramsay Rd, Shirley, NY 11967-4704.

[b]Lafayette Manual Muscle Test System; Lafayette Instrument Company, 3700 Sagamore Pkwy N, Lafayette, IN 47903.

[c]Gravity goniometer; MIE Medical Research Ltd, 6 Wortley Moor Rd, Leeds LS12 4JF, UK.

angle; tibial torsion; visual observation of quality of movement during a lateral step-down task; anxiety; and fear-avoidance beliefs.

**Results—**After controlling for age and sex, anxiety and fear-avoidance beliefs about work and physical activity were associated with function, while only fear-avoidance beliefs about work and physical activity were associated with pain.

**Conclusions—**Psychologic factors were the only associates of function and pain in patients with PFPS. Factors related to physical impairments did not associate to function or pain. Our results should be validated in other samples of patients with PFPS. Further studies should determine the role of other psychologic factors, and how they relate to anxiety and fear-avoidance beliefs in these patients.

### Keywords

Anxiety; Fear; Pain; Patella; Quality of life; Rehabilitation

PATELLOFEMORAL PAIN SYNDROME accounts for 10% to 25% of all visits seen in physical therapy clinics.[1, 2 and 3] PFPS is characterized by anterior knee pain and crepitation in the patellofemoral joint during and after weight-bearing activities such as walking up or down stairs, squatting, and running. Pain while sitting with the knees flexed, occasional weakness, giving way, and catching sensations are also characteristics of PFPS.[4] Based on either underlying theoretic constructs or on previous research, several factors or impairments such as muscle weakness, soft tissue tightness, structural and postural alterations of the lower extremities, quality of movement, and psychologic factors have been suggested to contribute to the occurrence of PFPS.[5 and 6] Table 1 summarizes the findings of studies with positive and negative results as well as the theoretic rationale about the contribution of several impairments in PFPS.

Although some of these impairments have theoretically or experimentally been associated with the presence of PFPS, it has not been determined whether these same impairments relate to the intensity of the patient's pain or the level of physical function in patients with PFPS. Identification of the key impairments related to pain and function may assist in delineating physical therapy treatment approaches for patients with PFPS. If it can be shown that particular impairments are associated with function and pain, targeting such impairments may improve the effectiveness of physical therapy for patients with PFPS. The aim of this study was to explore whether muscle strength, soft tissue length, postural and biomechanical alterations (foot pronation, quadriceps angle, lateral tibial torsion, femoral anteversion), quality of movement, and psychologic factors are associated with physical function and pain in patients with PFPS. We hypothesized that lower levels of function and higher pain intensity would be related to decreased muscle strength, decreased soft tissue flexibility, excessive foot pronation, excessive quadriceps angle, lateral tibial torsion and femoral anteversion, poor quality of movement, and higher levels of anxiety and fear-avoidance beliefs.

## Methods

### Subjects

Subjects were recruited from rehabilitation clinics. Patients diagnosed by a physician with PFPS were invited to participate in this study. Patients were eligible to participate if they were between 12 and 50 years of age, had pain in 1 or both knees, had duration of signs and symptoms greater than 4 weeks, had a history of insidious onset not related to trauma, and had pain in the patellar region with at least 3 of the following: manual compression of the patella against the femur at rest or during an isometric knee extensor contraction, palpation of the postero-medial and postero-lateral borders of the patella, resisted isometric quadriceps femoris muscle contraction, squatting, stair climbing, kneeling, or prolonged sitting.

Exclusion criteria included patient report of previous patellar dislocation, knee surgery over the past 2 years, malignancy, systemic arthritis, musculoskeletal or neurologic lower extremity involvement that interfered with physical activity, and pregnancy. Additional exclusion criteria required special testing by the treating clinician and included peripatellar bursitis or tendonitis (focal tenderness at the lower pole of the patella or patella tendon), internal knee derangement (positive McMurray or Apley compression test), ligamentous knee injury or laxity (positive sag, Lachman, varus, or valgus tests), plica syndrome (local tenderness and synovial snap between 30° and 60° of knee flexion), Sinding-Larsen or Osgood-Schlatter disease (tenderness and swelling over the lower pole of the patella or at the tibial tubercle, respectively), and infection (redness, swelling, warmth around the knee).

### Procedures

All subjects signed an informed consent form approved by the University of Pittsburgh Institutional Review Board prior to participation in the study. Data for this study were collected in 1 session. After signing a consent form, subjects completed demographic questionnaires including activity level, and self-reported measures. After that, a physical therapist performed a physical examination and collected data on physical impairments. Subjects had 1 lower extremity tested. Subjects with bilateral symptoms had the most affected knee selected for testing based on self-reported pain.

### Measures

**Demographics and biomedical—**Patients completed a questionnaire about their demographics, work activity, medication used for PFPS, and chronicity of the PFPS condition. Level of physical activity was measured using the rating of activity developed by the International Knee Documentation Committee.[7] This rating describes 4 predefined levels of activity in subjects with knee pathologies: (1) jumping, pivoting, hard cutting, football, and soccer; (2) heavy manual work, skiing, and tennis; (3) light manual work, jogging, and running; and (4) activities of daily living and sedentary work.

**Dependent variables—**Physical function was measured by the KOS-ADLS.[8 and 9] The KOS-ADLS is a knee-specific measure of physical function that assesses the effects of knee impairment on activities of daily living. Each item is scored on a 6-point Likert scale (0–5 points). The KOS-ADLS score is transformed to a 0 to 100–point scale with 100 indicating the absence of symptoms and functional limitations. The KOS-ADLS has been shown to be reliable, valid, and responsive in subjects with patellofemoral pain.[8 and 10]

Pain intensity was measured using an 11-point NPRS anchored on the left with the phrase "no pain" and on the right with the phrase "worst imaginable pain." NPRSs were shown to be reliable and valid.[10, 11 and 12] Subjects rated their current pain, the worst pain, and the least amount of pain in the last 24 hours, and the ratings were averaged.

**Independent variables—**The independent variables included measures of physical impairment and responses to psychologic questionnaires. Measures of physical impairment included muscle strength (quadriceps femoris, hip abduction, hip external rotation), soft tissue length (hamstrings, quadriceps, gastrocnemius, soleus, ITB/TFL complex, lateral retinacular structures), foot pronation, Q-angle, tibial torsion, femoral anteversion, and quality of movement. The theoretical rationale for the contribution of these physical impairments to PFPS can be seen in table 1. Table 2 provides a description of how the physical impairments were measured and information about their reliability. Intertester reliability of the physical impairment measures was determined in a subsample of patients from this study. Additional details about the methods used to assess reliability have been reported elsewhere.[13] Physical impairments with reliability coefficients below 0.6 were excluded (measure of femoral anteversion was excluded).

The psychologic questionnaires included self-reported measures of anxiety and fear-avoidance beliefs. Anxiety was measured using the Beck Anxiety Index.[14] The Beck Anxiety Index has been shown to be reliable and valid to assess the presence and magnitude of anxiety symptoms.[14 and 15] It consists of 21 items, each scored 0 to 3. Possible score ranges from 0 to 63 with higher scores indicating higher levels of anxiety.

Fear-avoidance beliefs were measured using the FABQ. The FABQ quantifies the level of fear about work and physical activity and has primarily been studied in patients with low back pain.[16] The instrument consists of 16 items subdivided into 2 subscales, one that measures FABQ-PA and another that measures FABQ-W. Each item is scored from 0 to 6. Possible scores range from 0 to 42 and 0 to 24 for the FABQ-W and FABQ-PA subscales, respectively. Higher scores represent increased fear-avoidance beliefs. Previous studies reported good reliability of the FABQ for patients with low back pain.[17] To apply the FABQ in patients with PFPS, we adapted the form to use in patients with knee pathology as described by van Baar et al.[18] We changed the descriptors of physical activities from physical activities such as bending, lifting, walking, or driving to physical activities such as walking, running, kneeling, or driving, and changed the word *back* to *knee* throughout the form. Cronbach $\alpha$ values of the FABQ-PA and FABQ-W subscales in our sample of patients with PFPS were 0.72 and 0.89, respectively.

## Data Analysis

Descriptive statistics were calculated and variables inspected for outliers. Correlations between predictors and criteria were determined by calculating Pearson or Spearman $\rho$ coefficients, depending on the distribution of data. During the bivariate correlations, the effects of height and weight on variables of muscle strength or muscle length were partialed out to account for the effect of body size. Variables significantly associated with the criterion variables ($\alpha \leq 0.10$) were included in the stepwise regression models. We built 2 forward regression models, the first using the KOS-ADLS scores as the criterion variable, and the second using pain scores as the criterion. We have chosen the forward selection procedure because we wanted to enter the independent variables sequentially (1 by 1) into the model according to their relationship with the dependent variable. Age and sex were controlled in the regression models. The decision to control age and sex was made a priori to decrease unexplained variability. Statistical significance was determined using an $\alpha$ level of 0.05. Significance of the linear association of each variable at each step was tested. Standardized $\beta$ coefficients for each variable in the final model were calculated, and the significance of each was tested under the null hypothesis that the coefficient was not different from 0. Regression diagnostics (outliers, collinearity, residuals analysis) were performed to make sure the data were appropriate for the analysis.

## Results

Seventy-four patients were recruited from 4 clinical sites. Twenty-five were from Minot Air Force Base, Minot, ND; 23 from Lackland Air Force Base, San Antonio, TX; 17 from Travis Air Force Base, Fairfield, CA; and 9 from University of Pittsburgh's Centers for Rehabilitation Services, Pittsburgh, PA. Participants across the 4 clinical sites were not significantly different on age, sex, height, weight, activity at work, use of pain medication, chronicity of pain, activity level, KOS-ADLS score, and NPRS score (tested with $\chi 2$ or Kruskal-Wallis). The population was comprised of civilians and military personnel. History and demographic characteristics are reported in table 3. Descriptive statistics and bivariate correlations between the predictor variables and KOS-ADLS and pain are shown in table 4. The variables lateral retinaculum tightness, anxiety, FABQ-PA, and FABQ-W demonstrated significant binary relationships with the KOS-ADLS score. The variables tibial torsion, anxiety, and FABQ-PA and FABQ-W were associated with pain.

The results of the forward regression on KOS-ADLS indicated that after controlling for age and sex, the addition of anxiety and the 2 scales of the FABQ did improve the model fit (table 5). Patients with more limitations in physical function had higher levels of anxiety and fear-avoidance beliefs about physical activity and work. The overall model accounted for 32% of variability in function. With age and sex controlled, anxiety contributed for an additional 18% explanation of variability in function, while FABQ-W and FABQ-PA added 6% and 5%, respectively. The variables sex, anxiety, and FABQ-W and FABQ-PA had $\beta$ coefficients different from 0.

The results of the forward regression on pain (NPRS) indicated that when age and sex were controlled, the only variables associated with pain were FABQ-W and FABQ-PA (table 6). Patients who reported higher levels of pain also scored higher in the FABQ subscales. The overall model accounted for 22% of pain variability. The addition of FABQ-W and FABQ-PA accounted for increments in the explanation of the variation of pain in the order of 11% and 5%, respectively. The regression models had variance inflation factors less than 10, indicating no multicollinearity.[19] Visual observation of jackknife residuals plots and box-plots of the standardized residuals revealed that the data fit the linear model assumptions.[19]

## Discussion

Although most physical impairment factors explored during this study have been theoretically or experimentally related to the presence of PFPS, the associates of function and pain in this cohort of patients with PFPS were all psychologic factors. Anxiety was the stronger associate of function, followed by FABQ-W and FABQ-PA. FABQ-W and FABQ-PA were the only associates of pain intensity in this sample. These findings may indicate that psychologic factors are overlooked in patients with PFPS. Prior studies have shown that patients with PFPS have a different psychologic profile than controls. Carlsson et al[20] compared personality characteristics in patients with PFPS and matched controls. They reported that patients with PFPS had significantly greater depression, hostility, and passive attitude than the matched controls. Witonski[21] investigated the psychologic profile of patients with anterior knee pain compared with a control group matched by age and reported that patients with anterior knee pain manifested more anxiety, depression, aggression/ hostility, and stress symptoms. One study suggested that psychologic factors may contribute to PFPS. Witvrouw et al[22] followed 282 athletes during 2 years to determine the risk factors associated with the development of PFPS. They reported that the subjects who developed PFPS looked less for social support and diverted their attention less from a problem than the subjects who did not develop PFPS.[22]

To our knowledge, this is the first study that reported an association between anxiety and physical function in patients with PFPS. Cross-sectional studies in patients with other musculoskeletal conditions have reported similar results. Montin et al[23] investigated the association between anxiety and physical function in patients prior to total hip arthroplasty. They reported that anxiety impaired physical function in these patients. Soderlin et al[24] investigated a group of patients with rheumatoid arthritis and reported that anxiety was associated with physical function. In a longitudinal study, Mehta et al[25] examined the relationship between anxiety and functional decline in 2940 well functioning adults. They reported that, while anxiety did not associate with decline in performance-based measures of function, it was associated with declines in self-reported functioning (adults with more anxiety were more likely to report incident mobility difficulty). At this time, the clinical implication of the relationship anxiety and function in patients with PFPS is unknown. Before recommending the inclusion of anxiety measures in clinical practice and referral of anxious patients to psychologic expertise, we believe further longitudinal research should determine the role of anxiety on functional outcomes (using both performance-based and self-reported measures of function).

We have included fear-avoidance beliefs in this study because we had observed in clinical practice that patients with PFPS who engaged in physical activities regardless of their knee pain appeared to function and progress through rehabilitation better than those who avoided activities because of pain. We speculated that perhaps the behavior of these patients could fit the fear-avoidance model.[26 and 27] The model offers a framework to the development of chronic pain. The model proposes that an individual's response to pain may fall somewhere along a continuum between 2 extremes: the adaptive response or confrontation, and the nonadaptive response or avoidance.[27 and 28] The confronter is likely to view pain as an annoyance and temporary, and is therefore prepared to confront the pain. The confronter is motivated to return to work and normal activities, and thus achieves complete recovery. The avoider responds to painful stimuli by avoiding activities anticipated to cause pain. Avoidance may result in poor behavioral performance, reduced activity levels, overstated pain perception, increased disability, and a subsequent reinforcement of catastrophic thoughts, completing the fear-avoidance circle.[16, 26, 27, 28, 29 and 30]

We have found only 1 study investigating the relationship of physical function and fear of movement/reinjury in patients with lower extremity musculoskeletal condition of similar age. Kvist et al[31] surveyed 62 patients who had anterior cruciate ligament reconstruction 3 to 4 years before. While they reported no association between fear of reinjury and the functional subscales of the KOOS, they found that high fear of reinjury was correlated with a low score on the knee-related quality of life subscale of the KOOS. Furthermore, the patients who did not return to their preinjury activity level had more fear of reinjury because of movement.

The association between fear-avoidance beliefs and physical function in this sample of patients with PFPS agrees with findings from cross-sectional studies in patients with chronic and acute low back pain, work-related neck-shoulder pain, cervical spine pain, and a variety of chronic musculoskeletal pain conditions.[29, 32, 33, 34, 35, 36, 37 and 38] While patients with PFPS had generally similar scores in the FABQ-PA to patients with chronic low back and neck pain, the scores in the FABQ-W were lower, only comparable to scores of patients with work-related neck-shoulder pain. While the magnitude of the association between the 2 subscales of the FABQ and physical function in our sample ($r$=0.32 and 0.34) was within the ranges reported for patients with chronic lumbar pain and neck pain ($r$=0.22–0.48), the associations between fear-avoidance beliefs and pain in our sample ($r$=0.31 and 0.37) were slightly higher than the reports in patients with lumbar and neck pain ($r$=0.03–0.41).[16, 26, 29, 32 and 36] With regard to the association between fear-avoidance and pain, although Vlaeyen and Linton[39] suggested that pain intensity is not a primary factor in avoidance behavior or disability, several studies suggested that high pain intensity is a threatening experience that drives avoidance,[40] and that pain intensity has considerable contribution in explaining disability.[41] In patients with knee and hip osteoarthritis, both pain intensity and pain-related fear were associated with function.[42] We believe the association of fear-avoidance behavior with function and pain in this exploratory study is not sufficient to confirm the fear-avoidance model in this population.

The main focus of this study was the physical impairments rather than the psychologic variables. Therefore, we did not plan to study how pain intensity, fear-avoidance behaviors, anxiety, and function relate to or interact with each other, nor have we explored how other potential contributors to the fear-avoidance model affect pain or function. Pain was chosen as a dependent variable in conjunction with function because pain is the main complaint of patients with PFPS. At this juncture, our findings suggest that additional studies of the psychologic factors related to function and pain in patients with PFPS deserve higher priority, and the role of psychologic factors in the treatment of patients with PFPS should also be investigated. In other musculoskeletal conditions, psychologic variables such as anxiety, fear-avoidance beliefs, depressive symptoms, catastrophizing behavior, feelings of appraisal of control, and self-efficacy have been more extensively investigated, and their interactions, temporal relationships, and role on disability are better understood.[26, 43, 44, 45, 46, 47 and 48]

A surprising and perhaps most confronting aspect of our results was the lack of association of measures of muscle function (muscle strength and muscle length), structural and postural characteristics, and quality of movement with physical function and pain in this sample of patients with PFPS. The studies that offered the theoretical rationale for the contribution of these physical impairments to PFPS have tested only the difference in magnitude of these impairments between patients with PFPS and controls (see table 1). These studies have not tested whether these same physical impairments were also related to the intensity of the patient's pain or the level of physical function in these patients.

With regard to measures of muscle strength, we hypothesized that stronger muscles would relate to better function and less pain. This hypothesis was based on findings that quadriceps strength related to function in patients with knee osteoarthritis,[48 and 49] and on evidence that patients with PFPS are weaker than patients without PFPS.[22, 50, 51 and 52] We are aware of only 1 study that investigated the correlation between function and muscle weakness in patients with PFPS.[51] Powers et al[51] used the functional assessment questionnaire to assess functional limitations and reported no correlation between function and quadriceps strength, which is in agreement with our findings. Quadriceps strength values for patients in our study and the Powers[51] study were similar, with a mean of 2.4±0.78 Nm/kg in the Powers[51] study and 2.5±0.76 Nm/kg in our study. The relationship between quadriceps strength and function has been investigated in patients with deficient or reconstructed anterior cruciate ligament. Comparison between populations with deficient or reconstructed anterior cruciate ligament and PFPS seem appropriate because the age and activity profiles of these patients are similar. Results of studies in patients with deficient or reconstructed anterior cruciate ligament are controversial. Some studies reported no association,[53 and 54] whereas others have reported a significant association between quadriceps strength and function.[55 and 56]

The lack of association between muscle tightness impairments and pain and function in our sample cannot be explained by particular characteristics of our sample with regard to muscle tightness. Values of muscle tightness in our study were not different from those of other studies that used similar measurement techniques. For quadriceps tightness in PFPS, studies reported means of 124°±12°[22] and 136°±16°,[57] while we had a mean of 132°±11°. For hamstrings tightness in PFPS, 1 study reported a mean of 91°±20°,[22] while ours was 78° ±12°. Because there is a negative correlation between age and muscle length,[58] our lower values may be explained by the age differences (the mean age in our study was 29 years and in the other study was 19 years). Reported ankle dorsiflexion in PFPS was 6.4°,[59] while our mean value was 7.4°. We are not aware of studies performed with patients with PFPS that reported measures of ITB/TFL complex tightness.

The lack of relationship with postural or structural alterations may be explained in part by the fact that our sample seemed within normal limits in these measures. Studies that investigated the navicular drop test in healthy adults reported values from 3.6±3.3 mm[60] to 9.0±4.2 mm.[61 and 62] In our study, the mean navicular drop test value was 6.3±3.6 mm. Our values of Q-angle (12° for men and 16° for women) are consistent with the normative values for healthy individuals of 10° for men and 15° for women.[63] In a sample of men and women runners with PFPS, the Q-angle had a mean of 17° and SE 0.6°.[59] Our mean value of tibial torsion was 18°, which is within the proposed normal values of 13° to 18°.[64]

In our study, we tried to investigate several of the impairments that have been somehow related to PFPS and that could be tested in a physical therapy clinic. We were surprised to find that our hypothesis about the association between physical impairments and function and pain was refuted. Although the physical impairments were not associated with pain and function in this cross-sectional study, longitudinal studies have yet to be conducted to investigate whether changes in these impairments relate to functional and pain outcome in these patients. Longitudinal studies are needed to understand best the relationship between physical impairments and functional outcome in patients with PFPS.

### Study Limitations

This study has some limitations. Because this was a cross-sectional study with no time sequence, it is not possible to establish any causal relationship between the psychologic factors and pain and physical function. Longitudinal studies are needed to investigate whether patients with prior anxiety and fear-avoidance behavior can predict higher pain and more dysfunction at a later time. Consideration should also be given to the fact that all measures of psychologic factors and pain and physical function were self-reported. The associations between them may have been influenced by method invariance bias. Further research should investigate whether the same associations would be present if physical function was measured by performance-based methods. Furthermore, in our regression models, only around one third of the variability in function and pain were explained. There may exist other impairments or factors that contribute to function and pain in this population that have not been investigated in this study.

## Conclusions

Our study indicates that psychologic factors were the only associates of function and pain in this sample of patients with PFPS. Patients with more limitations in physical function reported higher levels of anxiety and fear-avoidance beliefs about work and physical activity. Patients with more pain reported higher levels of fear-avoidance beliefs about work and physical activity. Factors related to physical impairments did not associate with function or pain in this sample. Our preliminary results should be validated in other samples of patients with PFPS. Further studies should also determine the role of other psychologic factors and how they relate to anxiety and fear-avoidance beliefs in these patients. Exploration of other psychologic factors may provide insight into developing a biopsychosocial model of functional limitations in patients with PFPS.

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## List of Abbreviations

| | |
|---|---|
| **FABQ** | Fear-Avoidance Beliefs Questionnaire |
| **FABQ-PA** | Fear-Avoidance Beliefs—physical activity |
| **FABQ-W** | Fear-Avoidance beliefs—work |
| **ITB/TFL** | iliotibial band/tensor fasciae latae |
| **KOOS** | knee injury and osteoarthritis outcome score |
| **KOS-ADLS** | Knee Outcome Survey–Activity of Daily Living Scale |
| **NPRS** | numerical pain rating scale |
| **PFPS** | patellofemoral pain syndrome |

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**Table 1**

Theoretical Rationale for the Contribution of Different Physical Impairments to PFPS Etiology and Summary of Previous Research Findings

| Factor | Theoretical Rationale for the Contribution of Physical Impairments to PFPS | Studies That Support/Refute | Theoretical Rationale and Their Findings |
|---|---|---|---|
| Muscle weakness | | | |
| Quadriceps | Quadriceps is responsible for the dynamic stabilization of the patella inside the trochlear groove.[65] | Support | Patients with PFPS have weaker quadriceps than controls.[50 and 51] Quadriceps strengthening decreases pain and increases function in short-term follow-up in patients with PFPS.[22, 66 and 67] |
| | | Refute | No differences in quadriceps weakness between PFPS and controls.[22 and 59] |
| Hip abductors and ER | These muscles help maintain pelvic stability by controlling femoral IR. Weakness may increase femoral IR, valgus knee moments, and compressive forces on the PF joint.[67, 68 and 69] | Support | Patients with PFPS have weaker hip muscles compared with matched controls.[52] |
| | | Refute | No differences in hip strength between subjects with PFPS and an age-matched and sex-matched control group.[70] |
| Soft tissue tightness | | | |
| Quadriceps | Tightness may pull the patella superiorly, increasing compression of the PF joint during physical activities.[68] | Support | Subjects with PFPS have shorter quadriceps muscles than subjects without PFPS.[22, 70 and 71] |
| Hamstrings | Tightness may require higher quadriceps force production or cause slight knee flexion, resulting in increased PF joint reaction forces. | Support | Association between limited hamstrings tightness and PFPS.[70 and 71] |
| | | Refute | No association between hamstrings tightness and PFPS.[22] |
| Plantar flexors | Tightness may result in limited ankle dorsiflexion, which can be compensated for by excessive rotation of lower leg, altered Q-angle, and increased PF stresses. | Support | Association between plantar flexor tightness and PFPS.[22 and 70] |
| | | Refute | No differences in ankle dorsiflexion between runners with and without PFPS.[59] |
| ITB/TFL | Tightness may pull the patella laterally and increase the stress over the lateral surface of the trochlear groove.[1] | No studies. | |
| Lateral retinaculum | Adaptive shortening of the lateral retinaculum may be a consequence of the lateral displacement of the patella and may relate to PFPS.[72 and 73] | Support | Manual stretch of the lateral retinaculum decreases PFPS.[74] |
| Structural and postural alterations of lower extremities | | | |

| Factor | Theoretical Rationale for the Contribution of Physical Impairments to PFPS | Studies That Support/Refute | Theoretical Rationale and Their Findings |
|---|---|---|---|
| Increased foot pronation | May cause compensatory internal rotation of lower extremity, increase Q-angle, and pull patella laterally. | Support | Female overpronators who received foot orthotics to correct pronation reported less pain.[75] |
| | | Refute | Foot pronation was a predictor of anterior knee pain in runners. Pronation was higher in asymptomatic runners than in symptomatic runners.[50] |
| Altered Q-angle | Both increases and decreases in Q-angle may be associated with increased PF pressures.[76] | Support | Runners with PFPS had significantly higher values of Q-angle than a control group without PFPS.[59] |
| | | Refute | No association between Q-angle and etiology of PFPS.[50, 77 and 78] |
| Increased lateral tibial torsion | May increase the tension in the infrapatellar tendon attachment and pull the patella laterally. | Support | Increased tibial torsion in patients with PFPS compared with subjects with no PFPS.[79] |
| Increased femoral anteversion | May result in lateral displacement of the patella and increases in the PF pressure. | Support | Patients who failed to respond to a conservative treatment for PFPS had higher femoral anteversion than the group who improved with treatment.[80] |
| | | Refute | No differences between an asymptomatic control group and patients with PFPS.[79] |
| Poor quality of movement | | | |
| | Patients with PFPS may exhibit altered movement patterns because of muscle imbalance or different timing between synergic muscles of LE, which may result in abnormal load distribution across the PF joint.[5, 81 and 82] | No studies. | |
| Psychologic factors | | | |
| Anxiety | In patients with other musculoskeletal conditions, the associations among pain, disability, and psychologic factors have been widely studied[29, 37 and 83] and seem to support the biopsychosocial models that explain the development of chronic musculoskeletal conditions.[16 and 26] | Support | Anxious patients may not respond to PFPS treatments.[20] |
| | | | Patients with PFPS had more anxiety and stress symptoms and higher levels of hostility than a control group.[21] |
| Fear avoidance beliefs | | No studies. | |

Abbreviations: ER, external rotators; IR, internal rotation; PF, patellofemoral; LE, lower extremity.

**Table 2**

Description of the Impairment Measures Used in the Study, the Technique Used, and the Intertester Reliability for the Measures

| Measure | Technique | Intertester Reliability |
|---|---|---|
| Quadriceps femoris strength | Measured using an Isokinetic dynamometer[a]. The subject was seated with the tested knee flexed to 75°. The subject was instructed to exert as much force as possible using an isometric contraction while extending the knee against the force-sensing arm of the dynamometer. The contraction was repeated for 4 trials, and the trial with the maximum torque was recorded. | ICC above 0.80 in 2 studies.[84 and 85] |
| Hip abduction strength | Measured with a hand-held dynamometer[b] with the subject side-lying with the tested hip positioned superior in relationship to the nontested hip.[63] The subject exerted an isometric contraction of the hip abductors against the resistance of the dynamometer positioned proximal to the lateral malleolus. The average force of 2 trials with 1 minute of rest between trials was recorded. | ICC=0.85.[13] |
| Hip external rotation strength | Measured with the hand-held dynamometer. Subject was lying prone with the tested knee flexed to 90° and the hip in neutral rotation. Subject exerted an isometric contraction of the hip external rotators against the resistance of the dynamometer positioned just proximal to the medial malleolus. The average force of 2 trials with 1 minute of rest between trials was recorded. | ICC=0.79.[13] |
| Hamstrings length | Determined using the straight leg raise test with the subject lying supine.[64] The lower extremity was passively lifted to the firm end feel. Angle of the straight leg raise test was measured with a gravity goniometer[c] placed over the distal tibia. The average measurement of 2 trials with 5-second pause between trials was recorded. | ICC=0.92.[13] |
| Quadriceps femoris length | Determined by measuring passive knee flexion using the gravity goniometer placed over the distal tibia with the subject in the prone position. The average measurement of 2 trials with 5-second pause between trials was recorded. | ICC=0.91.[13] |
| Plantar flexors length | Measured with a standard goniometer with the subject in prone. We measured the amount of ankle joint dorsiflexion with the knee extended and again with the knee flexed at 90°. Ankle dorsiflexion measured with the knee extended was used to account for the influence of gastrocnemius tightness. Measurement of ankle dorsiflexion with the knee bent was used to detect tightness of joint capsule or soleus muscle. The average measurement of 2 trials with 5-second pause between trials was recorded. | With knee extended ICC=0.92.[13] With knee bent ICC=0.86.[13] |
| ITB/TFL complex length | Determined by using the Ober test.[63] A gravity goniometer was placed over the distal portion of the ITB/TFL complex to record the result of the test as a continuous variable. The gravity goniometer was zeroed on a horizontal surface prior to the measurement. Negative values represented more tightness, whereas positive values (below horizontal) represented less tightness. The average measurement of 2 trials with 5-second pause between trials was recorded. | ICC=0.97.[13] |
| Lateral retinacular structures length | Assessed with the patellar tilt test.[72] The examiner attempted to lift the lateral edge of the patella from the lateral femoral condyle with the subject in supine and the knee in full extension. The inability to lift the lateral boarder of the patella above the horizontal plane indicates a positive test for tightness. Lateral retinacular length was recorded as tight or normal. | $\kappa$=0.71.[13] |
| Foot pronation | Measured by the navicular drop test as the difference in millimeters between height of the navicular at subtalar joint neutral position and that of the relaxed stance position.[86 and 87] | ICC=0.93.[13] |
| Q-angle | Measured with a standard goniometer as the angle formed by the intersection of a line from the anterior superior iliac spine to the center of patella with a line from the center of the patella to the | ICC=0.70.[13] |

| Measure | Technique | Intertester Reliability |
|---|---|---|
| | tibial tubercle[76] with the knee in full extension. | |
| Tibial torsion | Measured with the subject prone on a low table, and with the tested knee bent at 90°. The examiner measured the angle formed by the axis of the knee (imaginary line from the medial to lateral femoral epicondyle) and an imaginary line through the malleoli.[88 and 89] | ICC=0.70.[13] |
| Femoral anteversion | Measured with the Craig test with the participant in prone with the knee flexed to 90°.[64] The degree of anteversion was estimated based on the angle of the lower leg with the vertical when the most prominent portion of the greater trochanter reaches the most lateral position or the horizontal plane. | ICC=0.45.[13] |
| Quality of movement | Measured by visual observation during the lateral step-down test. The subject stood on a 20-cm-high step. The tester kneeled 1m in front of the subject and observed the task. The subject bent the tested knee until the contralateral leg gently contacted the floor and then re-extended the knee to the start position for 5 repetitions. The tester scored the movement according with the use of arm strategy (if subject used an arm strategy in an attempt to recover balance, 1 point was added), trunk movement (if the trunk leaned to any side, 1 point was added), plane of pelvis (if pelvis rotated or elevated one side compared with the other, 1 point was added), medial deviation of the knee (if the knee deviated medially and the tibial tuberosity crossed an imaginary vertical line over the second toe, 1 point was added, or, if the knee deviated medially and the tibial tuberosity crossed an imaginary vertical line over the medial border of the foot, 2 points were added), and steadiness of unilateral stance (if the subject stepped down on the nontested side, or if the subject wavered from side to side on the tested side, 1 point was added). Total score of 0 or 1 was classified as good quality of movement, score of 2 or 3 as medium quality, and score of 4 or above as poor quality of movement. | κ=0.67.[13] |

Abbreviations: ICC, intraclass correlation coefficient; κ, Kappa.

**Table 3**

Descriptive Statistics of Patients' Characteristics

| **Variable** | **N = 74** |
|---|---|
| Age (y) | 29±9 |
| Women (%) | 39 (52) |
| Height (cm) | 170±12 |
| Weight (Kg) | 76±16 |
| Race (%) | |
| White | 50 (68) |
| Black | 8 (11) |
| Hispanic | 8 (11) |
| Asian | 3 (4) |
| Native American | 1 (1) |
| Other | 4 (5) |
| Work (%) | |
| Mostly sedentary | 18 (24) |
| Sedentary, walking | 13 (18) |
| Moderately active | 34 (46) |
| Demanding | 9 (12) |
| Use medication for pain (%) | 43 (58) |
| Chronicity of pain (%) | |
| 1–3 mo | 27 (36) |
| 4–6 mo | 17 (23) |
| 7–12 mo | 7 (10) |
| 13–24 mo | 13 (17) |
| >25 mo | 10 (14) |
| Activity level (%) | |
| Jumping, pivoting, cutting | 9 (12) |
| Heavy manual work | 6 (8) |
| Light manual work | 22 (30) |
| Activities of daily living | 37 (50) |
| KOS-ADLS | 66±17 |
| NPRS average | 3.8±1.9 |
| Current pain last 24h | 3.6±2.1 |
| Worst pain last 24h | 5.6±2.4 |
| Least pain last 24h | 2.3±1.9 |

NOTE. Values represent mean±SD or frequency (%).

## Table 4

Descriptive Statistics of Potential Predictors and Their Correlations With KOS-ADLS and Pain

| N = 74 | | Mean±SD | Correlation With Function (KOS-ADLS) | Correlation With Pain (NPRS) |
|---|---|---|---|---|
| Quadriceps strength (Nm) | | 192±73 | 0.07 | −0.03 |
| Hip abductors strength (Kg) | | 12±4.4 | 0.07 | −0.02 |
| Hip external rotators strength (Kg) | | 15±5.5 | 0.13 | −0.14 |
| Hamstrings length (deg) | | 78±12.2 | −0.12 | −0.15 |
| Quadriceps length (deg) | | 132±11.4 | 0.14 | 0.05 |
| Gastrocnemius length (deg) | | 7.4±5.6 | 0.15 | −0.13 |
| Soleus length (deg) | | 14.8±5.4 | −0.14 | 0.03 |
| Iliotibial band/tensor fascia lata length (deg) | | 13.7±9.6 | −0.12 | 0.14 |
| Lateral retinaculum length—positive test (%) | | 54 (73) | 0.22[□] | 0.14 |
| Foot pronation (mm) | | 6.3±3.6 | −0.03 | −0.05 |
| Q-angle (deg) | | 14.4±5.4 | 0.06 | −0.13 |
| Tibial torsion (deg) | | 17.7±4.9 | 0.11 | −0.18[□] |
| Quality of movement (%) | | Coded for analysis as: | | |
| Good | 16 (22) | Patients with good quality vs the others | 0.11 | −0.01 |
| Medium | 47 (64) | Patients with medium quality vs the others | −0.11 | 0.05 |
| Poor | 11 (14) | | | |
| Beck Anxiety Index | | 4.9±6.7 | −0.45[†] | 0.34[†] |
| FABQ-PA | | 16.85±4.8 | −0.32[†] | 0.31[†] |
| FABQ-W | | 8.8±9.1 | −0.34[†] | 0.37[†] |

NOTE. For variables related to muscle strength (quadriceps and hip abductors, external rotators) and muscle length (quadriceps, hamstrings, gastrocnemius, soleus, ITB/TFL), we partialed out the effect of height and weight. Values represent mean±SD or frequency (%).

Abbreviation: deg, degrees.

[□] Significant at $P \leq .10$.

[†] Significant at $P \leq .01$.

## Table 5

Forward Regression Model on the Association With Physical Function in Patients With PFPS

| **Variables** | **Total $R^2$** | **Δ $R^2$** | ***df*** | ***P*** |
|---|---|---|---|---|
| Model 1 | | | | |
| Age, sex | .04 | .04 | 2, 71 | .287 |
| Model 2 | | | | |
| Age, sex, anxiety | .22 | .18 | 1, 70 | <.001 |
| Model 3 | | | | |
| Age, sex, anxiety, FABQ-W | .28 | .06 | 1, 69 | .019 |
| Model 4 | | | | |
| Age, sex, anxiety, FABQ-W, FABQ-PA | .32 | .05 | 1, 68 | .032 |

| **Coefficients for model 4B** | β | ***P*** | |
|---|---|---|---|
| Age | −0.09 | −0.05 | .640 |
| Sex | −7.29 | −0.22 | .041 |
| Anxiety | −0.71 | −0.28 | .013 |
| FABQ-W | −0.49 | −0.27 | .021 |
| FABQ-PA | −0.80 | −0.23 | .032 |

NOTE. Criterion variable equals KOS-ADLS score.

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## Table 6

Forward Regression Model on the Association With Pain in Patients With PFPS

| **Variables** | **Total $R^2$** | **Δ $R^2$** | ***df*** | ***P*** |
|---|---|---|---|---|
| Model 1 | | | | |
| Age, sex | .06 | .06 | 2, 71 | .105 |
| Model 2 | | | | |
| Age, sex, FABQ-W | .17 | .11 | 1, 70 | .004 |
| Model 3 | | | | |
| Age, sex, FABQ-W, FABQ-PA | .22 | .05 | 1, 69 | .037 |

| **Coefficients for model 3B** | β | ***P*** | |
|---|---|---|---|
| Age | −0.03 | −0.14 | .224 |
| Sex | −0.06 | −0.02 | .892 |
| FABQ-W | 0.07 | 0.31 | .007 |
| FABQ-PA | 0.09 | 0.23 | .037 |

NOTE. Criterion variable equals NPRS.