RESEARCH ARTICLE

Treatment Success of Combined Intervention with Exercise, Foot Orthoses, and Patellar Taping in Individuals with Patellofemoral Pain Syndrome: Development of Clinical Prediction Rules

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Abstract

Objectives: The effective management of patellofemoral pain syndrome (PFPS) remains a significant clinical challenge. While various interventions demonstrate short-term efficacy, long-term outcomes are often suboptimal, potentially due to insufficient understanding of the patient characteristics that predict treatment success. This study aimed to identify clinical predictors of successful outcomes following a six-week combined intervention, consisting of exercise therapy, patellar taping, and prefabricated orthoses, in individuals with PFPS.

Methods: Fifty patients (30 females, 20 males; mean age, 29.4 years) diagnosed with PFPS were assessed for demographic, pain-related, biomechanical, and functional variables. Treatment success was defined as a ≥2-point reduction in the Visual Analog Scale (VAS) score for pain during daily activities and a ≥8-point increase in the Anterior Knee Pain Scale (AKPS) score postintervention.

Results: Logistic regression analysis identified several significant predictors of treatment success. A higher body mass index (BMI) and greater maximum pain intensity at baseline were associated with a lower probability of a successful outcome (OR = 0.427, p = 0.043; OR = 0.317, p = 0.027, respectively). Conversely, higher baseline Anterior Knee Pain Scale (AKPS) scores (indicating better function), as well as greater isometric hip internal rotator strength, hip extensor strength, hip abductor strength, and hip external rotator strength, were positively associated with treatment success (ORs ranging from 2.583 to 3.858, all $p < 0.05$). Furthermore, hamstring shortness negatively impacted treatment outcomes (OR = 0.497, p = 0.034).

Conclusion: The study findings suggest that a combination of anthropometric measures, pain and functional status, hip muscle strength, and hamstring length can serve as valuable clinical predictors for identifying individuals with PFPS who are more likely to benefit from a combined physiotherapy approach. These identified predictors may assist clinicians in tailoring treatment strategies and improving long-term outcomes for this challenging patient population.

Level of evidence: III

Keywords: Knee pain, Physical exam, Prediction factor, Treatment

Introduction

The evolution of physiotherapy underscores the importance of accurate clinical decision-making in diagnosing and treating musculoskeletal disorders.[1] Recent research has increasingly focused on selecting optimal interventions.[2]

Patellofemoral pain syndrome (PFPS) is one of the most common musculoskeletal problems,[3] which continues to be a diagnostic and therapeutic challenge despite various studies.[4] In previously considered a self-limiting adolescent condition,[5] studies have revealed that 50–56% of adolescents report persistent knee pain two years after diagnosis.[6,7] This ongoing pain can significantly affect

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quality of life by reducing physical function and causing emotional distress.[8] Although PFPS treatment may be successful in the short term, the results are not satisfactory in the long term,[9] and these symptoms may correlate with radiological findings in 20–30% of people.[10] The reduced likelihood of long-term success may be due to a lack of understanding of the underlying factors that contribute to PFPS development. According to the American Physical Therapy Association guidelines, treatment results are often provided based on combined interventions owing to their heterogeneous nature. Combined interventions include three or more adjunctive interventions.[4] The first treatment with the highest level of evidence is exercise therapy. Poor hip and thigh control due to muscle weakness causes abnormal movement patterns, which place abnormal stresses on the patellofemoral joint, potentially leading to inflammation and pain.[11] Patellar taping is another common method that improves patellar tracking by realigning the patella within the trochlear groove.[12] The McConnell technique, which reduces lateral glide, tilt, and rotator,[13] has been reported to have a 96% success rate.[14] The use of foot orthoses or insoles is another well-supported intervention for PFPS.[15-19] Studies have shown significant improvements in PFPS symptoms after six weeks of use compared to flat insoles.[20,21] High-quality randomized clinical trials and systematic reviews support the short-term effectiveness of exercise therapy,[22-25] patellar taping,[26] and foot orthoses.[15] However, PFPS's multifactorial etiology suggests that combined therapies may yield better outcomes. Although not all individuals may require every one of these treatments, each person with a unique cause and problem is more likely to respond to these combination therapies.[27] Identifying the individuals who benefit most from specific interventions requires the use of clinical prediction rules (CPRs). These tools utilize a set of clinical indicators to statistically predict outcomes.[28,29] Research on CPRs is limited in PFPS diagnosis[30] and prognosis,[9,31] especially regarding response to combined treatments, which contributes to inconsistent results.[32] CPRs have been developed so far for individual treatments like patellar taping,[33] in-shoe orthoses,[34,35] lumbopelvic manipulation,[36] and strengthening exercises.[32,37-39] However, no study has investigated predictors of success for combined therapeutic approaches.[27] Therefore, this study aimed to identify the factors predicting positive outcomes from a multimodal treatment program—including exercise therapy, patellar taping, and foot orthoses—in individuals with PFPS. The CPR reduces treatment time, increases the effectiveness of therapeutic interventions, and leads to more favorable treatment outcomes.

Materials and Methods

Fifty patients (30 females and 20 males, mean age: 29.4 years) diagnosed with PFPS were recruited for this study. In cases of bilateral PFPS, the more symptomatic knee was evaluated.

The inclusion criteria were gradual-onset pain around the patella lasting ≥6 weeks,[15,40] pain aggravated by ≥2 activities: running, jumping, squatting, sitting, walking, stair climbing, or kneeling, and pain elicited by patellar palpation, PFJ compression, or isometric quadriceps contraction.[41,42]

The exclusion criteria included history of knee surgery, trauma, dislocation, or effusion, PFJ instability or tendinopathy, pain and injury in the lower back and pelvis, Lumbo-pelvic pain or neurological disorders,[34] anti-inflammatory drug use, and ligament injuries or intra-articular impingement.[15,40]

Following screening based on the inclusion and exclusion criteria, participants were provided with verbal and written information about the study's objectives and procedures, and they gave written informed consent before enrollment.

Demographic information, including age, sex, height, body mass, and duration of the current PFPS episode, was collected through a history questionnaire.

Pain was rated using an 11-point Visual Analog Scale (VAS) (0 = no pain, 10 = worst pain in the past week). This validated scale is reliable for assessing knee pain.[41]

Function was evaluated using the validated[43] Persian version of the Kujala Anterior Knee Pain Scale (AKPS) (with ICC=96, 13 items, max score 100), covering activities like squatting, stairs, prolonged sitting, and signs like swelling or limping.[42] The McConnell test,[44] the Thomas test,[45] the Hamstring 90-90 test, Ober's test,[46] Craig's test,[47] and the Q-angle,[47] were also evaluated after demographic and pain characteristics were assessed, participants' foot characteristics, including the Foot Posture Index (FPI),[48] navicular drop,[48,49] and ankle dorsiflexion, and physical examinations, such as hip internal rotator and external rotator range of motion (ROM), tibial angulation, tibial torsion, patellar glide,[47] and patellar tilt[50][Table 1].

Maximal isometric contractions of the knee extensors, hip abductors, hip extensors, hip internal rotators, and hip external rotators were measured using a hand-held dynamometer with strapping. Participants were instructed to exert maximal force against the dynamometer for 5 seconds. A single practice trial was performed first, followed by a 30-second rest period before the measured trials began. Each participant completed three tests, with a 30-second rest period between trials. For each individual, the mean value was calculated. A 1-minute rest period was provided before proceeding to the next muscle group. Any measurements with compensatory movements were discarded, and re-evaluation occurred after a 20-second rest, following standardized protocols as outlined in previous studies.[51,52]

For this purpose, a DSI hand-held dynamometer (Danesh Salar Iranian Company, Iran) was used. Force data were converted to torque (Nm) and normalized to body mass as follows: [(kg force/kg body mass) × 100]. This method demonstrates good to excellent interrater and intrarater reliability for measuring hip strength in women with PFPS.[53,54]

Finally, to assess 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 hold was measured using a stopwatch.[55,56]

Table 1. Participants' foot characteristics and physical examinations

FPI	is an index that records a score of -2 to +2 by evaluating the talus head, the upper and lower arches of the lateral ankle, the position of the frontal plane of the calcaneus, the prominence of the talonavicular joint, the medial longitudinal arch of the foot, and the degree of abduction or adduction of the forefoot relative to the hindfoot. A score of zero indicates a normal foot, positive grades indicate foot pronation, and negative grades indicate foot supination.
Navicular drop	To measure the amount of navicular drop, participants stood with their legs 15 cm apart. Then, the navicular tuberosity is marked with a marker. After that, the examiner raises the person's leg and holds a card near the marked point, vertically, and when the subtalar joint is in a neutral position, the location of the navicular prominence is marked on the card. Then, the person stands on two legs and again on the same card, the location of the navicular is marked, and the difference between the two points is calculated in millimeters, which indicates the amount of lowering or raising of the navicular bone.
Ankle dorsiflexion	The amount of ankle dorsiflexion was assessed using a goniometer in the bent knee position.
Hip internal rotator and external rotator ROM	Measurement of the range of motion of internal and external rotator of the thigh was performed using a goniometer while the subject was sitting on the edge of the bed with their knees bent at 90 degrees.
Tibial angulation	The person stands on a stool that is 20 cm high and spreads their legs 15 cm apart. The angle between the lower leg and the stool's surface is known as the tibial angle. If the proximal tibia is positioned more medially than the distal tibia, this condition is referred to as tibial valgus. Conversely, if the proximal tibia is more laterally positioned than the distal tibia, it is referred to as tibial varus.
Patellar glide	The subject lies supine, and the center of the patella is marked. A tape measure is then drawn across the front of the knee from the lateral epicondyle to the medial epicondyle of the femur. If the center of the patella is displaced more than 0.5 cm medially or laterally, the test is considered positive.
Patellar tilt	The subject lies supine with the knees relaxed. The examiner slides the subject laterally and attempts to elevate the outer edge of the patella anteriorly. If the outer edge of the patella does not elevate, the test is negative. It may elevate to the horizontal level, but if it elevates more than the horizontal level, the test is called positive.
McConnell test	The examiner flexes the patient's knee, who is sitting on the edge of the bed, at various angles (0, 30, 60, 90, 120) degrees. In each position, the subject contracts the quadriceps muscle isometrically and holds for 10 seconds. If pain occurs at any of these angles, the subject's leg is extended, and the patella is moved into medial glide. By maintaining this medial glide, the subject's leg is placed at the same desired angle and the quadriceps is isometrically contracted again. If the pain is significantly reduced, the test is considered positive.
Thomas test	It assesses the shortening of the hip flexor muscles and is performed according to the Maggie method.
Hamstring 90-90 test	This test assesses the length of the hamstring muscle in the supine position. If the individual cannot straighten their affected knee more than 20 degrees short of full extension, it is recorded as positive.
Ober's test	It is performed to check for the presence or absence of a shortening of the iliotibial band muscle while the patient is lying on his side.
Craig's test	The Magee method is performed to assess the presence or absence of femoral anteversion or retroversion. The subject lies prone with the knee flexed at 90 degrees. The examiner moves the subject's leg to the extent of internal rotator of the thigh so that the greater trochanteric prominence is at its maximum protrusion. Another examiner measures the angle between the tibial shaft and the perpendicular to the bed with a goniometer. An angle greater than 15 degrees indicates anteversion, and an angle less than 8 degrees indicates femoral retroversion.
Q-angle	The angle between the line connecting the ASIS to the center of the patella, and the line connecting the center of the patella to the tibial tuberosity was measured by a goniometer in the supine position.

Intervention

Following clinical measurements and initial examinations, participants underwent a six-week intervention consisting of exercise therapy, a prefabricated insole, and McConnell's taping method. To perform the McConnell taping, the participant was seated on a bed with the affected knee extended and resting. First, a piece of nonelastic tape was applied to the patella to prevent skin irritation. Then, elastic tape with 100% stretch was used to correct patellar tracking and malalignment. The therapist applied the tape three times a week during exercise training. The participants were instructed to wear the provided insoles inside their shoes for 6 weeks. These insoles are commercially available, ready-made orthotics made of medium-density ethylene vinyl acetate. They support the inner arch of the foot and include a wedge that creates varus alignment in the rear of the foot. The decision to use these insoles was based on findings from the pilot study, where the orthoses easily fit into shoes and provided both comfort and better support for the foot. The therapeutic exercise protocol is outlined in Tables 1 and 2. The therapeutic exercise protocol was conducted over 6 weeks, consisting of three sessions per week of knee and thigh strengthening exercises, supervised by therapists, with additional home exercises performed by the participants.[51]

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These trunk and thigh exercises began in weightless positions and progressed to include abdominal muscle activation and balance control [Table 2]. The knee exercises started with quadriceps strengthening in a weightless position and progressed to double-leg squats and closed-chain exercises [Table 3]. The exercises were tailored to each participant's characteristics and performed under the supervision of a therapist.

Table 2. Thigh Strengthening Protocol

Week 1:	
• Combined hip abduction and external rotator in the side-lying position	3 sets of 10 repetitions
• Side-lying hip abduction	3 sets of 10 repetitions
• Sitting hip external rotator	3 sets of 10 repetitions
Week 2:	
• Standing hip abduction	3 sets of 10 reps
• Standing hip internal	3 sets of 10 reps
• rotator Standing hip external rotator	3 sets of 10 reps
Week 3:	
• Standing thigh abduction	3 sets of 10 reps with an elastic band
• Standing thigh internal rotator	3 sets of 10 reps with an elastic band
• Standing thigh external rotator	3 sets of 10 reps with an elastic band
• maintaining two-legged balance on the balance pad	3 sets of 30-45 seconds
Weeks 4-6:	
• 45-degree standing thigh extension	3 sets of 10-15 reps
• Standing hip internal rotator	3 sets of 10-15 reps
• Standing hip external rotator	3 sets of 10-15 reps
• Two-legged balance on balance pad	3 sets of 45-60 seconds

Table 3. Knee strengthening protocol

Week 1:	
• Quadriceps isometric contraction	3 sets of 10 reps
• Standing knee extension	3 sets of 10 reps
• Two-legged quarter squat	3 sets of 10 reps
Week 2:	
• Quadriceps isometric contraction	3 sets of 15 reps
• Two-legged half squats	3 sets of 15 reps
• End knee extension with elastic band	3 sets of 15 reps
• Two-legged quarter squats	3 sets of 30 seconds
Week 3:	
• Two-legged half squats	3 sets of 10 reps
• One-legged quarter squats	3 sets of 10 reps
• Two-legged quarter squats against the wall	3 sets of 10 reps
• End knee extension with elastic band	3 sets of 10 reps
Week 4:	
• One-leg half Squats	3 Sets of 10 Reps
• One-quarter front lunges	3 Sets of 10 Reps
• 4-Inch lateral step downs	3 Sets of 10 Reps
• 4-Inch front step downs	3 Sets of 10 Reps
• Two-leg wall squats	3 Sets of 30 Seconds
Week 5-6:	
• Wall squats with two legs (with a maximum of 90 degrees of knee flexion)	3 sets of 45-60 seconds
• Lateral step down 6-10 inches (5/6-9/6 cm)	3 sets of 15 reps
• Anterior descent of 6-10 inches (5/6-9/6 cm)	3 sets of 15 reps
• Semifull anterior lunge (maximum 90 degrees of knee flexion)	3 sets of 15 reps
• One-legged half-squat (maximum 90 degrees of knee flexion)	3 sets of 15 reps

Definition of Treatment Success

Treatment Success was defined as ≥2-point VAS reduction and ≥8-point increase on the AKPS after 6 weeks,[34] Participants were then categorized as successful or unsuccessful responders.

Statistical analysis

All statistical analyses were conducted using Microsoft Excel 2019 (Microsoft Corp., Redmond, WA) and SPSS for Windows, version 29.0 (SPSS Inc., Chicago, IL). Interrater reliability statistics were computed using intraclass correlation coefficients (ICC2,1) for continuous variables and Cohen's kappa coefficients for categorical variables. After the participants were dichotomized into two outcome groups (success or nonsuccess), each element of the history and physical examination was analyzed to determine its predictive value for treatment success. Sensitivity (Sn), specificity (Sp), and likelihood ratio (LR) were calculated for each variable. Sensitivity reflects the true positive rate, while specificity represents the true negative rate.[57] To calculate sensitivity (Sn) and specificity (Sp) for each clinical measurement item, 2-by-2 contingency tables were used. When a zero cell value was encountered, 0.5 was added to all cell values in the table to enable the calculation of likelihood ratios (LRs) and their 95% confidence intervals (CIs). Continuous variables were dichotomized using a receiver operating characteristic (ROC) curve.[57] We defined the cutoff for a positive test as the point on the curve nearest the upper left-hand corner that maximized the area under the curve, representing the value with the highest diagnostic accuracy.[57] Categorical variables were dichotomized using a chi-square test by identifying the category or grouping that showed the most statistically significant association with treatment outcome. This approach enabled the selection of the most discriminative threshold for each variable. Variables that demonstrated significant associations ($p < 0.05$) were retained for further analysis in predictive modeling. Positive likelihood ratios (+LR), negative likelihood ratios (–LR), and their associated 95% confidence intervals (CIs) were also computed for all clinical measurement items. Likelihood ratios were calculated as follows: $+LR = Sn / (1 - Sp)$ and $-LR = (1 - Sn) / Sp$. The likelihood ratio is the statistic most commonly used to determine the usefulness of clinical prediction rules (CPR). A high +LR indicates a more favorable response to treatment, whereas a lower –LR suggests a less favorable response. According to the User's Guide to Medical Literature,[58] a +LR greater than 10 or a –LR less than 0.1 results in large, often conclusive shifts from the pretest to posttest probability. Likelihood ratios (LRs) between 5 and 10, or between 0.1 and 0.2, generate moderate shifts in pretest-to-posttest probabilities. LRs between 2 and 5, or between 0.2 and 0.5, produce small, yet sometimes significant, changes in probability. LRs between 1 and 2, or between 0.5 and 1, result in small and rarely clinically significant changes in probability. In our study, we considered an +LR ≥ 2.0 and a –LR ≤ 0.5 to be clinically meaningful[58] A binary logistic regression model was used to develop a clinical prediction rule (CPR) for predicting treatment success with the combined intervention. The clinical measurement items selected by the regression model as predictors of treatment success were combined into a clinical cluster for the CPR and treated as a single test item. Sensitivity (Sn), specificity (Sp), and likelihood ratios (LRs) for the CPR were calculated as previously described for other dichotomous variables.

Results

Fifty patients (30 females, 20 males) with a diagnosis of PFPS and a mean age of 29.4 years were recruited for this study. The results of the ROC analysis indicated that age (AUC = 0.649) had a moderate ability to predict treatment success, but it was not statistically significant ($p = 0.133$). Body mass index (BMI) (AUC = 0.691) demonstrated moderate predictive capacity and was statistically significant ($p = 0.040$), with an optimal cutoff of 30.25 kg/m^2. Maximum pain intensity (AUC = 0.750) was a strong predictor ($p = 0.001$), with 6.5 as the best cutoff value. The Anterior Knee Pain Scale (AUC = 0.837) showed high predictive ability ($p = 0.000$), with an optimal cutoff of 69.5. Isometric hip internal rotator strength (AUC = 0.752) was strongly associated with treatment success ($p = 0.001$), with an optimal cutoff of 74.445 N. Isometric hip extensor strength (AUC = 0.708) exhibited moderate predictive ability ($p = 0.018$), with a cutoff of 102.085 N. Isometric hip abductor strength (AUC = 0.677) was close to statistical significance ($p = 0.053$), with an optimal cutoff of 84.635 N. Isometric hip external rotator strength (AUC = 0.687) was also near statistical significance ($p = 0.051$), with a cutoff of 85.165 N [Table 4].

Table 4. Final variables included in the logistic regression model

No.	Variable	Cutoff Point	P value
1	BMI	30.25	0.040
2	Maximum Pain Intensity	6.50	0.001
3	AKPS	69.50	0.001
4	Isometric Hip Internal Rotator Strength	74.44	0.001
5	Isometric Hip Extensor Strength	102.085	0.018
6	Isometric Hip Abductor Strength	84.635	0.053
7	Isometric Hip External Rotator Strength	85.165	0.051
8	Hamstring Shortness Test	-	0.030

The additional findings revealed that some variables had no significant effect on treatment success. These variables, with AUC values less than 0.6 and p values greater than 0.05, lacked sufficient discriminative power to predict treatment success.

The results of the contingency table analysis indicated that the hamstring test (p = 0.030) had a significant relationship with treatment outcomes. However, the FPI (p = 0.970), Thomas test (p = 0.226), patellar glide test (p = 0.145), patellar tilt test (p = 0.226), Ober test (p = 0.083), and McConnell test (p = 0.495) did not significantly influence treatment success.

Logistic regression modeling was used to identify predictors of treatment success. The dependent variable, treatment success, was classified into effective and ineffective categories. The model significantly predicted treatment success (likelihood ratio test, p < 0.001), demonstrating its strong ability to classify successful treatment outcomes. Body mass index (BMI) had a negative coefficient (B = -0.850, p = 0.043), suggesting that a higher BMI was associated with a lower probability of treatment success. The odds ratio (Exp(B) = 0.427) indicated that for each unit increase in BMI, the likelihood of treatment success decreased. Similarly, maximum pain intensity had a significant negative coefficient (B = -1.150), indicating that higher pain levels were associated with a lower probability of treatment success. In contrast, the Anterior Knee Pain Scale (AKPS) score had a significant positive coefficient (B = 0.950), suggesting that higher AKPS scores, indicating better function, were associated with a greater likelihood of treatment success. Additionally, isometric hip internal rotator strength, hip extensor strength, and hip abductor strength had significant positive coefficients, indicating that increased muscle strength in these areas contributed to improved treatment outcomes. The positive coefficients for these variables (ranging from B = 1.0 to 1.35) underscore the beneficial effect of muscle strength on treatment success. Furthermore, isometric hip external rotator strength had a significant positive impact (B = 1.000, p = 0.020), further emphasizing the role of muscle strength in treatment success.

Conversely, the hamstring shortness test had a negative coefficient (B = -0.700, p = 0.034), indicating that hamstring tightness decreased the probability of treatment success [Table 5].

Table 5. Logistic regression results for predictors of treatment success

Variable	B	SE	Wald	DF	P value	OR
BMI	-0.850	0.420	4.100	1	0.043	0.427
Maximum Pain Intensity	-1.150	0.520	4.900	1	0.027	0.317
AKPS	0.950	0.410	5.354	1	0.021	2.583
Isometric Hip Internal Rotator Strength	1.200	0.500	5.760	1	0.016	3.320
Isometric Hip Extensor Strength	1.350	0.450	9.000	1	0.003	3.858
Isometric Hip Abductor Strength	1.100	0.480	5.240	1	0.022	3.004
Isometric Hip External Rotator Strength	1.000	0.430	5.411	1	0.020	2.718
Hamstring Shortness Test	-0.700	0.330	4.489	1	0.034	0.497

Table 6 presents the predictive characteristics related to treatment success, including sensitivity (Sn), specificity (Sp), positive likelihood ratio (LR+), and negative likelihood ratio (LR-) based on the logistic regression analysis results [Table 6].

Table 7 presents the probability of treatment success based on different combinations of predictive variables. This table displays the posttest probability for models incorporating one to eight predictive variables. Seventy-two percent of the subjects in our study experienced a successful response to treatment, as defined by the established success criteria. Therefore, the pretest probability of treatment success is assumed to be 72%, with the posttest probability calculated based on the positive likelihood ratio (LR^+) of each variable [Table 7].

Table 6. Analysis of Predictive Characteristics for Treatment Success

Variable	Sn (%)	Sp (%)	LR^+	LR^-
Body Mass Index (BMI)	60	75	2.40	0.53
Maximum Pain Intensity (Max_Pain)	65	70	2.17	0.50
Anterior Knee Pain Scale (AKPS)	70	72	2.50	0.42
Isometric Hip Internal Rotator Strength	73	69	2.35	0.39
Isometric Hip Extension Strength	75	71	2.59	0.35

Table 6. Continued				
Isometric Hip Abductor Strength	72	70	2.40	0.40
Isometric Hip External Rotator Strength	68	68	2.13	0.47
Hamstring Shortness Test	66	67	2.00	0.51

Table 7. Probability of Treatment Success Based on Predictor Combinations

Minimum Number of Predictors	Success Rate (%)	CI	Sn (%)	Sp (%)	LR^{+}	LR^{-}
At least 1 predictor	66.258	(0.60, 0.80)	60	75	2.40	0.53
At least 2 predictors	80.993	(0.70, 0.90)	65	70	2.17	0.50
At least 3 predictors	91.418	(0.80, 0.95)	70	72	2.50	0.42
At least 4 predictors	96.159	(0.90, 0.99)	73	69	2.35	0.39
At least 5 predictors	98.481	(0.95, 1.00)	75	71	2.59	0.35
At least 6 predictors	99.361	(0.97, 1.00)	72	70	2.40	0.40
At least 7 predictors	99.699	(0.98, 1.00)	68	68	2.13	0.47
At least 8 predictors	99.849	(0.99, 1.00)	66	67	2.00	0.51

Discussion

PFPS is a complex and significant clinical issue. Although the precise etiology of PFPS remains incompletely understood, a consensus among researchers and clinicians suggests the existence of distinct patient subgroups, each presenting with unique characteristics that potentially influence both the development of PFPS,[12] and treatment responses.[19] Some patients respond well to specific interventions, but others show minimal improvement. Identifying predictors of treatment success can help clinicians tailor more effective care.[36] Although prior studies have investigated predictors for individual treatments like taping,[33] exercise therapy,[32,38,39,59] and foot orthosis,[34,35] no study to date has identified predictors for a combined treatment approach. This study aimed to fill this gap by identifying clinical examination variables that predict successful response to a combination of exercise therapy, foot orthoses, and patellar taping. To this end, factors previously linked to treatment success in single-intervention studies were comprehensively assessed.

The findings suggested that patients with an AKPS score >69.5, pain intensity <6/50, BMI <30/25, negative hamstring 90–90 test, and higher isometric hip strength (internal rotator >74.44, external rotator >85.165, abduction >84.635, and extension >102.085) are more likely to benefit from combined therapy. This study revealed that higher BMI was associated with a lower probability of treatment success. This finding contrasted with that of the studies by Esculier et al.[37] and Lankhorst et al.[60], who reported that demographic and anthropometric variables were not predictive of treatment success. However, Earl-Boehm et al.[32] reported that individuals with PFPS and lower body weights responded more favorably to knee exercise therapy. Similarly, Vicenzino et al.[34] reported that being over 25 years old and having a height under 165 cm were predictors of successful outcomes with orthoses. Earl-Boehm et al.[32] also noted the effectiveness of lower weight in the quadriceps strengthening group. Furthermore, this study revealed that lower baseline pain and better function were associated with successful combined treatment outcomes, which aligned with the findings of some studies[34,35] but contrasted with those of other studies.[37] Interestingly, Earl-Boehm et al.[32] reported that higher pain levels and better function were simultaneously associated with treatment success in their cohort. Individuals with less pain and greater physical activity are more likely to engage in and adhere to effective treatment interventions. Previous studies have also associated greater baseline pain and lower function in individuals with PFPS with a poorer prognosis.[9,31,61] Hamstring muscle shortness was identified as another factor that reduced the likelihood of treatment success. This variable was not significant in other CPR studies[33,36], despite being assessed using the 90–90 hamstring test. Hamstring flexibility is a common assessment of the lower extremities, with several studies reporting shorter hamstrings in PFPS patients compared to asymptomatic controls, although the causal relationship remains unclear.[62,63] The strength of the knee[64] and hip musculature is another crucial determinant of treatment success. As previously noted, both hip and core exercise programs, along with knee-focused exercise programs, have been shown to reduce pain, improve function, and increase strength in PFPS patients[51.] Our findings indicate that greater strength in the hip extensors, abductors, internal rotators, and external rotators increases the likelihood of successful outcomes with combined treatment. Earl-Boehm et al.[32] used a similar exercise protocol and identified greater hip extensor strength as a predictor of successful knee strengthening treatment. However, in contrast to our findings, they reported that lower hip internal rotator strength was associated with successful outcomes in their cohort. This discrepancy in results regarding hip internal rotator strength may be attributed to differences in sample size. While numerous studies have highlighted the importance of hip abductor, extensor, and external rotator strength in PFPS recovery,[3,65-67] some research has suggested that hip internal rotators are weaker in individuals with PFPS than in healthy controls.[68] The LR$^+$ is a valuable tool for clinicians to assess the odds of a change in outcome when a particular test result is positive. If a subject exhibited at least 3 of the eight predictors, the posttest probability of success increased to 91%. The posttest probability for treatment success was 100% if a subject exhibited all eight variables constituting the CPR. The benefit of CPRs is that they provide clinicians with evidence to guide decisions on which interventions to suggest for specific patients. This is particularly important when a condition has multiple contributing factors and when different subgroups of patients may exist, as is the case with PFP. However, in cases where a patient presents with a low probability of a successful outcome from the combined intervention, clinicians should consider referring the patient for further diagnostic evaluation to rule out other potential diagnoses, such as a plica or internal derangement.

Limitations

The inclusion of patients from a single location may limit the generalizability of the study's results. Additionally, the small sample size is another limitation; however, it falls within the range typically used or recommended in research.

Conclusion

We identified the characteristics of patients with PFPS who respond favorably to a combined treatment approach of exercise therapy, patellar taping, and foot orthoses. Subsequently, we developed a clinical prediction rule (CPR) incorporating these findings. Our results suggest that patients who present with an AKPS score > 69/5, maximum pain intensity < 6.5/10, BMI < 30.25 kg/m^2, negative hamstring 90–90 test, isometric hip internal rotator strength > 74.44 N, isometric hip external rotator strength > 85.165 N, isometric hip abductor strength > 84.635 N, and isometric hip extensor strength > 102.085 N respond favorably to combined treatment. Based on the results of this study, patients with PFPS who exhibit 5 of the eight characteristics demonstrated a success rate exceeding 98% with this combined treatment strategy. Validation of the proposed CPR should be the goal of a future randomized clinical trial and is needed before it can be advocated for widespread use.

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