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Is there a subgroup of females with patellofemoral pain syndrome likely to benefit from proximal control exercises?

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Khaled A. Shalash[1], Abd El Rahman Chabara[2], Ahmad Hamdi Azzam[3], Nabil A Mohamed[2], Ahmed M. ElMelhat[2,4]

[1] Department of Physical Therapy for Musculoskeletal Disorders and their Surgeries, Alhayah University, Cairo, Egypt
[2] Department of Physical Therapy for Musculoskeletal Disorders and their Surgeries, Faculty of Physical Therapy, Cairo University, Cairo, Egypt
[3] Department of Orthopaedic Surgery, Faculty of Medicine, Cairo University, Cairo, Egypt
[4] Department of Physical Therapy, Faculty of Health Sciences, Beirut Arab University, Beirut, Lebanon

Abstract

Introduction. Patellofemoral pain syndrome (PFPS) is one of the most popular complaints among young females. Proximal hip control exercises can improve hip strength and reduce the stresses and pain. However, there is a lack of studies that investigate predictors of the success of proximal hip control exercises in this disorder. This predictive validity diagnostic trial aimed to investigate the effect of body mass index, age, duration of symptoms, and knee angle valgus on proximal control exercise success to improve hip muscle abductors and external rotator isometric strength.

Methods. Fifty females with PFPS recruited from Ain shams University Hospital with a mean age of 25 years received proximal control exercises (transversus abdominis and multifidus activation, hip extensor, abductor and external rotator strengthening). Participants were assessed for hip strength using a handheld dynamometer, and dynamic knee valgus via video analysis using the Kinovea v.0.8.15 computer program.

Results. Age was found to be a predictor of success in hip abductor strength, and duration of symptoms a predictor of success in hip external rotator strength with proximal control exercises in patellofemoral pain syndrome female individuals, with no specific cut-off points.

Conclusions. Proximal control exercises can improve hip strength in females with PFPS with no specific cut-off points for the significant predictors found (age and duration of symptoms).

Key words: patellofemoral pain syndrome, hip strength, proximal control exercises, predictors

Introduction

Patellofemoral pain syndrome (PFPS) is one of the most common chronic conditions encountered in musculoskeletal clinical physical therapy practice and is challenging for sport medicine clinicians and general practitioners [1]. PFPS occurs among both sedentary and active individuals and accounts for around 11–17% of knee pain complaints [1, 2], affecting females more than males [3]. A review demonstrated high incidence and prevalence levels for patellofemoral pain and the annual prevalence for patellofemoral pain in the general population was reported as 22.7%, and adolescents as 28.9% [4].

Hip muscles have been claimed to play an important role in controlling transverse-plane and frontal-plane motions of the femur [5, 6]. Consequently, it has been shown that individuals with PFPS have poor or improper isometric / dynamic strength and power in the hip abductors and extensors [7, 8]. Hip muscle weakness and poor hip control have been highly correlated with PFPS, leading to abnormal patellofemoral displacements with increased femoral adduction and internal rotation [9, 10]. International research hotspots show the biomechanical characteristics of increased knee external rotation, increased hip adduction, and decreased hip internal rotation during patient exercise. Strengthening the hip abductors and external rotators can effectively improve the pain and function of patients [11].

Thus, achieving proper lumbopelvic control has been claimed to be an important element in rehabilitation to ensure a stable origin for the hip abductors and lateral rotator muscles during movements. The proposed stable attachment can eventually enhance the force production by these muscles during activities and reduce the frontal plane displacements during single-limb stance activities [12].

Clinical prediction rules (CPRs) are tools that help clinicians make better decisions in clinical practice by assisting them in making a specific diagnosis, determining a prognosis, or matching patients to the best interventions. This is usually based on a small number of predictor variables drawn from the history and physical examination [13].

To the authors' knowledge, no published study has identified specific clinical examination variables that are predictive of which individuals with the PFPS will respond successfully to proximal hip control exercises. Identifying these variables would provide clinicians and therapists with a useful clinical decision-making tool and may help increase the efficacy of treatment plans. Furthermore, development of a clinical prediction rule (CPR) to identify individuals likely to succeed with proximal hip control exercises would enhance clinical decision-making, reduce treatment time, and result in optimum outcomes. Therefore, the objective of this study was to investigate the effect of body mass index (BMI), age, duration of symptoms, and knee angle valgus on patients' individuals responses (hip strength) to proximal control exercises.

Correspondence address: Ahmed M. ElMelhat, Department of Physical Therapy for Musculoskeletal Disorders and their Surgeries, Faculty of Physical Therapy, Cairo University, 7 Ahmed El Zaiat Street, Bein El, Sarayat, Cairo, Egypt, e-mail: ahmed.elmelhat@cu.edu.eg; https://orcid.org/0000-0001-8429-2335

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Subjects and methods

Participants

This was a predictive validity and diagnostic study for determining predictors of success in hip strength with proximal control exercises in PFPS patients.

Individuals were recruited between May 2020 and October 2021. A convenient sample of 50 female participants, recruited from Ain Shams University Hospital, was enrolled and assessed for their eligibility to participate in this study. All were diagnosed as PFPS and were aged between 18 and 35 years. This age range was chosen for many reasons: prevalence of PFPS in this age range, not having wide variations in pathology, to improve generalisability, to address age as a predictor, to avoid cases of degenerative changes in the joints, and because it is supported with many studies [14, 15]. Individuals were considered eligible to participate if they were diagnosed by an orthopaedic surgeon as having PFPS. Then, each subject provided an informed consent after being informed of the nature, purpose, and value of the study. Each one was given the freedom to refuse or withdraw at any time and was assured of the confidentiality of any information obtained during the study.

Inclusion criteria included: females aged from 18 to 35 years who had anterior or retropatellar knee pain of non-traumatic origin of more than six weeks duration, and provoked by at least two predefined activities (prolonged sitting or kneeling, squatting, jogging or running, hopping, jumping, or stair walking) [16]; pain on palpation of the patellar facets; or with step down from a 15 cm step, or double leg squat with positive physical tests (Clarke's test, patellar crepitus). Only females only were included as sex is a risk factor for PFPS and females have high risk and prevalence of PFPS and have prevalent lower limb pathomechanics and strength deficits [17]. Participants were excluded if they had a concomitant injury or pathology of other knee structures (by history and physical examination), previous knee surgery (by history and observation), patellofemoral instability (by apprehension test), knee joint effusion (by observation), Osgood-Schlatter disease, hip or lumbar spine pain (by palpation, history and provocative tests), physiotherapy within the previous year; prior foot orthoses treatment or use of anti-inflammatory or corticosteroids (by history).

Outcome measures

A handheld dynamometer to assess hip abductor and hip external rotator strength, which is a valid and reliable tool for testing hip strength [9, 18].

Hip abduction strength testing

Subjects were tested for hip abductor isometric strength while laying sideways on a plinth. A pillow was put between the individuals' legs, with supplementary towelling if needed, to allow abduction of the hip of the tested leg by nearly 10° in relation to a line joining the anterior superior iliac spine. To support the individual's trunk, a belt was placed just proximal to the iliac crest and tightly attached underneath the table. The centre of the strength pad of a Nicholas handheld dynamometer (Lafayette Instruments, Lafayette, IN) was placed directly over a mark located 5.08 cm proximal to the lateral knee joint line. This dynamometer uses a load cell force-detecting system [9].

Hip external rotation strength testing

Participants were allowed to sit in a padded chair with 90 degrees of hip and knee flexion for the hip external rotation (ER) isometric strength assessment. A strap was used to support the thigh of the tested leg and a roll was positioned between the individual's knees to avoid hip adductor substitution. The dynamometer was then adjusted so that the centre of the force pad was directly above a mark 5.08 cm proximal to the medial malleolus. During contractions, a belt around the leg and around the base of a fixed object held the dynamometer in place. After turning the dynamometer to zero, the participant was asked to drive the leg inward with maximum effort for 5 seconds. The displayed force value on the dynamometer was registered, and the device was reset to zero. One rehearsal trial and three investigational trials were undertaken with a 15-second interval. The highest reading was adopted and recorded [15].

Dynamic knee valgus

Kinovea v.0.8.15 computer program video analysis is claimed to be a valid and reliable method of ROM assessment [19, 20].

Dynamic knee valgus (DKV) was calculated using 2D frontal plane projection angle (FPPA) analysis. The axes of each of the hip, knee, and ankle joints were determined using a tape measure. For the axis of the ankle joint, markers were placed at the median of the ankle malleoli. For the axis of the knee joint, markers were positioned at the midline of the femoral condyles and on the proximal thigh at the midpoint of the line from the anterior superior iliac spine to the knee joint centre. Markers were used to highlight joint axes as this has been shown to increase the intra- and inter-rater reliability in comparison to manual digitisation of joint centres via video [21].

The video camera (ON EOS Rebel T3i / 600D), which records video at 1080p resolution at 30 fps, was fixed on a tripod at knee height, three metres away from the centre of the landing floor. Participants were asked to flex their knee from the floor with the untested leg and squat with the tested leg. A snapshot was taken at the moment of maximum knee valgus. Normative 2D FPPA values were found to be 5° to 12° for single-leg squat activities in women [22].

A knee valgus shift greater than 10.6° predicted PFPS with sensitivity of 0.75 and specificity of 0.85. The associated positive likelihood ratio was 5 [23].

Intervention procedure

Participants enrolled in the study attended two physical therapy sessions per week for one month, which consisted of proximal control exercises in the form of: controlling pelvic motion through execution of active lower-limb movement or alternative hip and knee flexion/extension motions (in which patients were in a supine lying position, stabilising their pelvis by activating the deep trunk muscles using a drawing-in manoeuvre, then they were asked to flex and extend one lower extremity while the other is flexed, then change the motion to raising and lowering the leg, which was then repeated on the other side, then to alternate the motion of both sides, 10 times each), strengthening of the hip abductors (patients were in a side-lying position with both legs flexed 90° at the knees and neutral at the hips, then they were to externally rotate the uppermost one against sandbag weights of 40% 1RM resistance for 10 repetitions and 3 sets, progressing through increasing the lever arm by extending the highest knee, and retaining the hip in less than 25° external rotation and mild extension), hip abductor and external rotator strengthening (by acquiring a quadruped starting position and performing an external rotation/abduction/extension action of the lower extremity against gravity) [10], and side and prone planks (patients were in a side-lying and prone-lying position and bridged on an elbow and lateral foot and elbow and toes, respectively) to strengthen the lateral core and posterior core muscles [24].

Sample size

This sample was chosen based on the rule that recommended that 10–15 subjects should be enrolled into the study for each prospective predictor variable in clinical prediction rule studies for accurate statistical results [25, 26]. However, we recruited 50 participants in anticipation of drop-out.

Statistical analysis

The SPSS Version 24 statistical software package (SPSS Inc., Chicago, IL, USA) was used to assess the ability to predict the outcome of proximal control exercises using the independent variables identified. Patients were grouped based on their outcome (success or failure) for each dependent variable, based on the minimally clinical important difference (MCID) (0.8 kg for abductor and 0.7 kg for external rotator strength). Due to the dichotomous nature of the outcome (success or failure), logistic regression was used for analysis. Differences in independent variables (DKV pre, age, duration of symptoms, and BMI) between the successful and failed groups for hip abductor strength and external rotator strength were calculated using univariate analysis with the independent *t*-test. Finally, all independent variables were analysed in a multivariate logistic regression model. Sensitivity and specificity were calculated for all statistically significant independent variables measured on a continuous scale. Receiver operating characteristic (ROC) curves were plotted to show the balance between sensitivity and specificity. Sensitivity was plotted on the y-axis and 1 minus specificity on the x-axis to determine the best cut-off points which would distinguish between success and failure.

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, followed the tenets of the Declaration of Helsinki, and was approved by the ethical Committee of Faculty of Physical Therapy, Cairo University (Project-ID: #P.T.REC/012/002712). The study was recorded at ClinicalTrials.gov, Identifier: NCT (NCT04481022), registered July, 2020.

Informed consent

Informed consent has been obtained from all individuals included in this study.

Results

This study included 50 female patients (50 knees) with unilateral PFPS and their baseline characteristics are summarised in Table 1.

Table 1. Baseline characteristics of all patients with unilateral PFPS

Demographic and clinical data (*n* = 50)	Mean	*SD*
DKV (degree)	21.62	1.244
Age (years)	25	3.75
BMI (kg/m^2)	25.3	4.5
Symptom duration (years)	0.56	0.32
Sex; count (%)	50 (100)	

DKV – dynamic knee valgus, BMI – body mass index

Effect of proximal control exercises on hip muscle strength

The paired *t*-test for the difference between the post-test and pre-test scores on hip strength revealed a significant difference with significant improvement ($p < 0.001$) post-treatment with proximal control exercises, as shown in Table 2.

Predictors of success in hip strength with proximal control exercises

Forty-three (86%) females with PFPS were successful in improving hip abductor strength with proximal control exercises, while 36 (72%) were successful in improving external rotator strength. Independent *t*-tests revealed a significant difference only in age ($p < 0.001$) and symptom duration ($p = 0.02$) between the groups, in hip abductor and external rotator strength, respectively, as shown in Table 3.

Univariate regression analysis

Each of the four independent variables identified was examined in a univariate logistic regression model. This analysis revealed that age and symptom duration were the only statistically significant variables (at $p < 0.25$) in predicting hip abductor and external rotator strength success, respectively, as shown in Table 4. This large *p*-value was chosen as recommended by researchers so as not to miss variables that may be more significant when added together in the next multivariate analysis than univariate.

Receiver Operating Characteristic curves

Receiver Operating Characteristic curves (ROC curves) were generated for age and symptom duration to determine

Table 2. Descriptive statistics and paired t-test for within-group differences in hip strength (kg)

Pre-post	PRE mean ± *SD*	POST mean ± *SD*	Paired differences					*t*	*df*	*p*- value
			mean	*SD*	*SEM*	95% CI				
						upper	lower			
HABS	34 ± 23.7	36.8 ± 23.7	–2.64	1.4	0.2	–3.03	–2.24	–13.5	49	0.000
HERS	11.4 ± 6	12.7 ± 6.3	–1.3	1.2	0.16	–1.64	–1	–8	49	0.000

HABS – hip abductor strength, HERS – hip external rotator strength *SEM* – standard error of the mean, CI – confidence interval of difference

Table 3. Descriptive statistics and differences between groups (successful and failed) in predictors for hip abductor strength

	Age mean ± *SD*	BMI mean ± *SD*	Symptom duration mean ± *SD*	DKV Pre mean ± *SD*
HABS				
Success (*n* = 43)	25.5 ± 3.8	25.2 ± 4.5	0.57 ± 0.33	21.6 ± 1.3
Failure (*n* = 7)	28 ± 1.35	25.7 ± 4.6	0.5 ± 0.25	21.6 ± 0.8
p-value	0.000*	0.8	0.57	0.9
HERS				
Success (*n* = 36)	25 ± 3.7	25.1 ± 5.2	0.5 ± 0.24	21.65 ± 1.3
Failure (*n* = 14)	25 ± 4	25.7 ± 1.4	0.73 ± 0.44	21.9 ± 1.03
p-value	0.87	0.64	0.02*	0.4

HABS – hip abductor strength, HERS – hip external rotator strength, DKV – dynamic knee valgus, BMI – body mass index,
failure – number of patients with a posttest score below minimal clinical important difference or MCID (0.8 kg) for abductor and (0.7 kg) for external rotator strength calculated using equation MCID = 0.2 * standard deviation [27]
significant at $p < 0.05$

Table 4. Univariate regression analysis for each independent variable in predicting hip abductor and external rotator strength

	B	*SE*	Wald	*df*	Sig.	Odds ratio
HABS						
Age	–0.356	0.169	4.431	1	0.035*	0.701
Constant	11.258	4.715	5.702	1	0.017	77532
BMI	–0.028	0.099	0.078	1	0.781	0.973
Constant	2.517	2.571	0.959	1	0.328	12.39
Symptom duration	0.907	1.563	0.337	1	0.562	2.476
Constant	1.332	0.891	2.236	1	0.135	3.788
DKV Pre	0.037	0.329	0.013	1	0.910	1.038
Constant	1.016	7.103	0.020	1	0.886	2.763
HERS						
Age	–0.014	0.085	0.029	1	0.865	0.986
Constant	1.305	2.154	0.367	1	0.545	3.688
BMI	–0.036	0.077	0.222	1	0.638	0.964
Constant	1.871	2.005	0.871	1	0.351	6.498
Symptom duration	–2.369	1.199	3.904	1	0.048*	0.094
Constant	2.346	0.796	8.690	1	0.003	10.449
DKV Pre	–0.228	0.270	0.710	1	0.399	0.796
Constant	5.882	5.887	0.998	1	0.318	358.49

HABS – hip abductor strength, HERS – hip external rotator strength, DKV – dynamic knee valgus, BMI – body mass index,
Wald test statistic = square (*B*/*SE*); * only significant at $p < 0.25$

cut-off scores which distinguish between success and failure in improving hip strength with proximal control exercises. It revealed no cut-off point with a high discriminative value as a predictor of success in improving hip abductor and external rotator strength with proximal control exercises in patellofemoral pain syndrome female patients, due to the small specificity, sensitivity, and area under the curve, as shown in Table 5 and Figure 1. The ROC curves and their coordinates may explain why age and symptom duration were not categorised

Table 5. Area under the ROC curve

Predictor	Predicts	Area	*SE*(a)	*p*-value	95% CI	
					upper	lower
Age	HABS	0.229	0.065	0.023	0.101	0.357
Symptom duration	HERS	0.318	0.09	0.048	0.142	0.495

HABS – hip abductor strength, HERS – hip external rotator strength

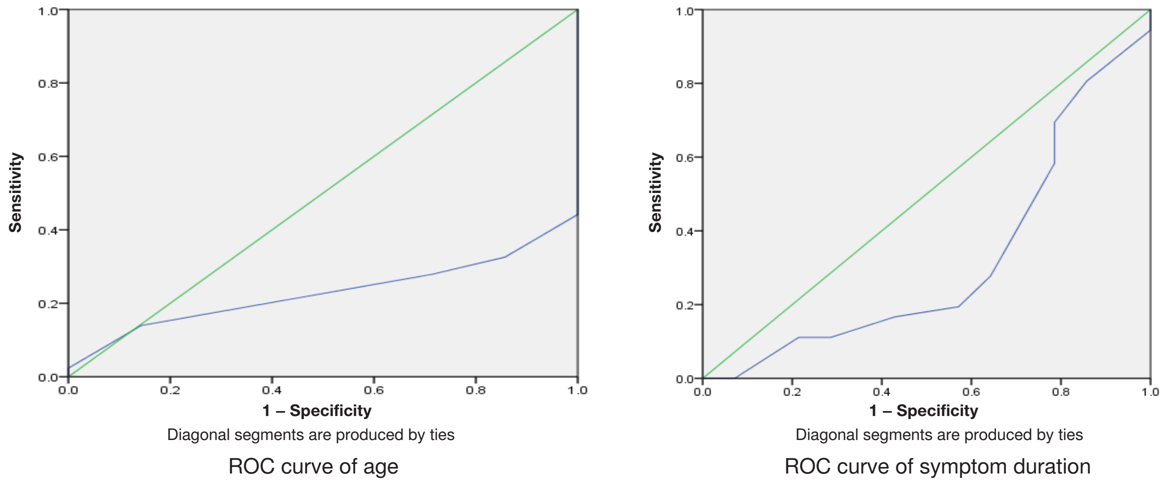

Figure 1. ROC curves for age and symptom duration

into subgroups, as there were no specific ranges in age or symptom duration or specific cutoff points that were related to success. In addition, this study design (predicting success, categorising outcome into success and failure, and the appropriate use of logistic regression) does not help in converting age and symptom duration from continuous to categorical variables. Finally, continuous variables provide a more inclusive meaning and prevent the loss of some information that occurs with categorical ones.

Discussion

PFPS is a complicated and common clinical issue. Although the origin of this syndrome is unknown, most researchers and clinicians agree that there are groupings of people with distinct characteristics which might contribute to the development of the disorder [28]. Similarly, there are likely to be subgroups of patients that respond well to specific interventions due to specific and unique traits [29].

The aim of the current study was to classify the features of individuals with PFPS that were prognostic of an effective response to proximal control strengthening exercises.

The best-available evidence suggests that overall, isolated hip strengthening and knee strengthening were equivalent for the treatment of PFPS [30], suggesting that hip strengthening exercises had a significant role in PFPS.

By definition, a clinical prediction rule is the optimal amount of clinical examination items used to predict a diagnosis or prognosis. A rehabilitation regimen that emphasises strengthening and improving neuromuscular control of the hip and core musculature improves patient outcomes, increases hip and core muscle strength, and decreases knee abduction moment, all of which are thought to be linked to the development of PFPS. This information can help physicians, athletic trainers, and physical therapists make evidence-based judgements on which activities to include in a PFPS rehabilitation program [24].

This study included 50 females with PFPS and applied proximal control exercise. Thirty-six participants out of 50 (72%) were considered successful in improving their hip external rotator strength and 43 participants out of 50 (86%) were considered successful in improving their hip abductor strength following proximal control exercise.

Of the four predictors that had been selected for investigation, two predictors were statistically significant (age and symptom duration) for hip abductor and external rotator strength in the univariate comparisons, respectively.

Further, the ROC curve showed no best cut-off points for age and symptom duration in predicting success in hip strength after proximal control exercises.

The finding of the current study, regarding no specific cut-off points in age for success with proximal control exercises, agrees with previous literature in that some studies found that hip muscle strength improved after hip and core strengthening exercises in PFPS female patients with age 22–23 years [17, 24, 31] and others found that patients with PFPS with mean age 16 years demonstrated significant weakness in hip abduction and external rotation strength that responded to resistance or strengthening exercises well [32, 33]. This means that younger patients had more weakness and were more likely to be strengthened. On the other hand, it was found that hip/core training program responders demonstrated improved hip abductor and extensor strength in PFPS participants [34]. Exercises targeting the hip, pelvis, and trunk muscles also improved gluteus medius and maximus force production more in PFPS patients aged 37 years more than in younger patients [10].

Furthermore, some authors found hip strength success with hip muscle stretching and strengthening in PFPS patients with a mean age of 33 years [35]. However, the success rate in our study was greater than the latter [35] (86% vs. 66%). In addition to that, these authors questioned the clinical importance of hip abductor strength [35]. Those findings contradict our findings. One possible explanation for this is the differences in treatment duration and exercise program.

Increased dynamic knee valgus has been linked with PFPS [36, 37]. The hip abductors have been claimed to be an important factor for dynamic knee valgus [38]. In addition, proximal muscle strengthening exercise has been related to DKV in PFPS patients [39]. This may explain how patients with increased DKV benefitted from proximal control exercise, which does not correlate with our study results and may be because the DKV angles in the included sample were not wide enough to affect the results.

The present study finding regarding no specific cut-off point in symptom duration for predicting success in improving hip strength with proximal control exercises supports the finding that hip, knee, and trunk muscle strengthening and movement control exercises were more beneficial in improving hip muscle strength in women with PFPS with symptom duration of 60 months [31] and that shorter symptom duration significantly predicted exercise intervention success in patellofemoral pain management [40,41].

No specific criteria were identified here as there were no specific ranges in age or symptom duration or specific cut-off points that were related to success. In addition, logistic regression requires that age and symptom duration be continuous to categorise an outcome. Finally, continuous variables provide more inclusive meaning and prevent the loss of some information that occurs with categorical ones. One explanation of that is the strong possibility of the presence of other predictors (e.g. hip strength pre-test) that may guide and induce the effects that were created by the studied predictors (in particular, age and symptom duration). Finding and studying these predictors may help the categorisations and developing the criteria.

Limitations

Including patients from only one setting may limit the generalisability, while improvement after proximal control exercise may be affected by the interaction of many factors, not just the ones included in this study. Validation of the proposed CPR should be the goal of a future randomised clinical trial and is required before it can be advocated for widespread use. These findings need to be validated in a separate sample before the CPR can be used confidently in clinical settings.

Conclusions

Proximal control exercises can improve hip strength in females with PFPS with no specific cut-off points for the significant predictors found (age and duration of symptoms).

Disclosure statement

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Conflict of interest

The authors state no conflict of interest.

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