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ORIGINAL ARTICLE

Posterolateral Hip Muscle Strengthening Versus Quadriceps Strengthening for Patellofemoral Pain: A Comparative Control Trial

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Abstract

Objective: To compare the efficacy of posterolateral hip muscle strengthening versus quadriceps strengthening in reducing pain and improving health status in persons with patellofemoral pain (PFP).

Design: Comparative control trial.

Setting: Rehabilitation facility.

Participants: Persons with a diagnosis of PFP (N=36; 18 men, 18 women).

Interventions: Patients were alternately assigned to a posterolateral hip muscle strengthening group (9 men and 9 women) or a quadriceps strengthening group (9 men and 9 women). The posterolateral hip muscle strengthening group performed hip abductor and external rotator strengthening exercises, whereas the quadriceps strengthening group performed quadriceps strengthening exercises (3 times a week for 8wk).

Main Outcome Measures: Pain (visual analog scale [VAS]) and health status (Western Ontario McMaster Universities Osteoarthritis Index [WOMAC]) were assessed at baseline, postintervention, and 6-month follow-up.

Results: Significant improvements in VAS and WOMAC scores were observed in both groups from baseline to postintervention and baseline to 6-month follow-up ($P<.001$). Improvements in VAS and WOMAC scores in the posterolateral hip exercise group were superior to those in the quadriceps exercise group postintervention and at 6-month follow-up ($P<.05$).

Conclusions: Although both intervention programs resulted in decreased pain and improved function in persons with PFP, outcomes in the posterolateral hip exercise group were superior to the quadriceps exercise group. The superior outcomes obtained in the posterolateral hip exercise group were maintained 6 months postintervention.

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Patellofemoral pain (PFP) is the most common lower extremity diagnosis among those who are physically active.[1-3] Historically, the etiology of PFP has been attributed to abnormal patella tracking secondary to impairments in quadriceps muscle performance (eg, weakness or insufficiency of the vastus medialis oblique relative to the vastus lateralis).[4-7] As such, conservative interventions (eg, patella taping, vastus medialis oblique strengthening) are commonly prescribed for persons with PFP.[8,9] Although the ability to selectively strengthen the vastus medialis oblique has been questioned,[10,11] several clinical trials have shown that quadriceps strengthening is beneficial for persons with PFP.[12-16]

The premise that a strength imbalance between the vastus medialis oblique and vastus lateralis contributes to abnormal patella tracking has been recently challenged. Dynamic imaging studies performed in weight-bearing suggest that lateral patella displacement and lateral tilt are a function of medial rotation of the femur as opposed to patella motion.[17,18] This suggests that impaired hip muscle performance may be a contributing factor

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with respect to abnormal patella tracking and PFP. Indeed, biomechanical studies have reported that persons with PFP demonstrate excessive hip internal rotation[19,20] and hip adduction[21] compared with pain-free individuals. Furthermore, persons with PFP have been reported to exhibit impaired muscle performance of the hip abductors,[19,21-23] hip extensors,[19,21,23] and external rotators.[21]

Because of recent focus on the contribution of abnormal hip mechanics to patellofemoral disorders, several randomized controlled trials have sought to evaluate the effects of hip muscle strengthening on PFP symptoms.[15,16,24-26] Khayambashi et al[25] reported that 8 weeks of hip abductor and external rotator strengthening resulted in reduced pain and improved health status in women with PFP compared with a control group that did not receive hip strengthening exercises. The improvements in the hip strengthening group were sustained at 6-month follow-up. Studies by Fukuda,[15,16] Nakagawa,[26] and colleagues found that the combination of hip and quadriceps strengthening resulted in a greater reduction in PFP compared with quadriceps strengthening performed in isolation.

To date, to our knowledge, only 1 study has compared hip strengthening with quadriceps strengthening in persons with PFP. Dolak et al[24] reported that 4 weeks of hip strengthening was superior to 4 weeks of quadriceps strengthening in reducing symptoms in women with PFP. However, the between-group difference was not maintained when followed by an additional 4 weeks of combined hip and knee functional training. Although the findings of Dolak[24] suggest that hip strengthening may be superior to quadriceps strengthening, at least in the short term, additional research is necessary to test this hypothesis.

The purpose of the current study was to compare the immediate and short-term efficacy of posterolateral hip strengthening versus quadriceps strengthening in reducing pain and improving health status in persons with PFP. Based on existing biomechanical and clinical studies, we hypothesized that patients assigned to the hip strengthening group would exhibit greater improvements in pain and health status than patients assigned to the quadriceps exercise group. Information obtained from this study will assist clinicians in better prescribing rehabilitation exercises for this population.

Methods

Screening for specific inclusion and exclusion criteria was performed by 2 physicians. Only subjects with a diagnosis of unilateral or bilateral PFP were included. The diagnosis of PFP was based on symptom location (peripatellar and/or retropatellar) and reproduction of pain with activities commonly associated with this condition (eg, stair decent, squatting, kneeling, prolonged sitting). Patients were screened by physical examination to rule out ligamentous laxity, meniscal injury, pes anserine bursitis, iliotibial band syndrome, and patella tendinitis. Patients who reported a history of patella dislocation, patella fracture, knee surgery, previous physical therapy, or symptoms that had been present for <6 months were excluded from participation.

Thirty-six patients (18 men, 18 women) met the study inclusion criteria. The men and women were sequentially assigned in an alternating fashion to the posterolateral hip exercise group (n=18; 10 with bilateral pain, 8 with unilateral symptoms) and the quadriceps exercise group (n=18; 12 with bilateral pain, 6 with unilateral symptoms) (fig 1). Demographic data for the 2 groups at baseline are included in table 1. In general, patients were not physically active and did not participate in recreational sport activities or exercise beyond that of activities of daily living. Prior to participation, all patients were informed of the purpose of the study and provided written informed consent.

List of abbreviations:

ANOVA	**analysis of variance**
PFP	**patellofemoral pain**
VAS	**visual analog scale**
WOMAC	**Western Ontario McMaster Universities Osteoarthritis Index**

Intervention

Study participants completed exercises supervised by a physical therapist 3 times per week for 8 weeks. Exercises were performed bilaterally in patients with bilateral pain and on the symptomatic side in patients with unilateral pain. Each session consisted of 5 minutes of warm-up (walking around the gym at a self-selected pace), 20 minutes of directed exercise, and 5 minutes of cooldown (walking around the gym at a self-selected pace). Patients participating in the study were asked to refrain from exercises beyond that of their assigned exercise sessions throughout the duration of the study. Patients were allowed to take over-the-counter pain and/or anti-inflammatory medication as needed; however, subjects were asking to refrain from taking medications for 24 hours before sessions in which outcome measurements were obtained.

Patients assigned to both groups performed standardized protocols. Resistance and repetitions were progressed at 2-week intervals (table 2). TheraBand elastic tubing[a] was used to provide resistance during each exercise. Subjects were required to complete at least 19 out of the 24 treatment sessions (~80%) to remain in the study. In addition, if a patient missed 3 consecutive treatment sessions, their participation in the study was terminated. All subjects completed the required number of treatment sessions over the 8-week intervention period.

Patients assigned to the posterolateral hip exercise group performed 2 exercises: one targeting the hip abductors and the other targeting the hip external rotators. Hip abductor strengthening was performed with patients positioned sidelying on a treatment table. Elastic tubing was tied just above the ankle at one end and attached to the bottom of the treatment table at the other (fig 2). The length of tubing was individualized across patients based on their lower limb length (distance from the anterior superior iliac spine to the medial malleolus). The distance between the exercise limb and the bottom of the treatment table was adjusted to remove slack from the tubing. Patients were allowed to hold on to the edge of the table for stabilization purposes. The exercise was performed against the resistance by abducting the hip from 0° to 30°.[24]

Hip external rotator strengthening was performed with patients seated at the edge of a treatment table and the knee flexed to 90° (fig 3). A strap was used to prevent sagittal and frontal plane motion of the thigh. Elastic tubing was tied around the ankle and was secured to a rigid pole. The length of tubing was individualized across patients based on thigh length (distance from the anterior superior iliac spine to the medial femoral epicondyle). The distance between the exercise limb and pole was adjusted

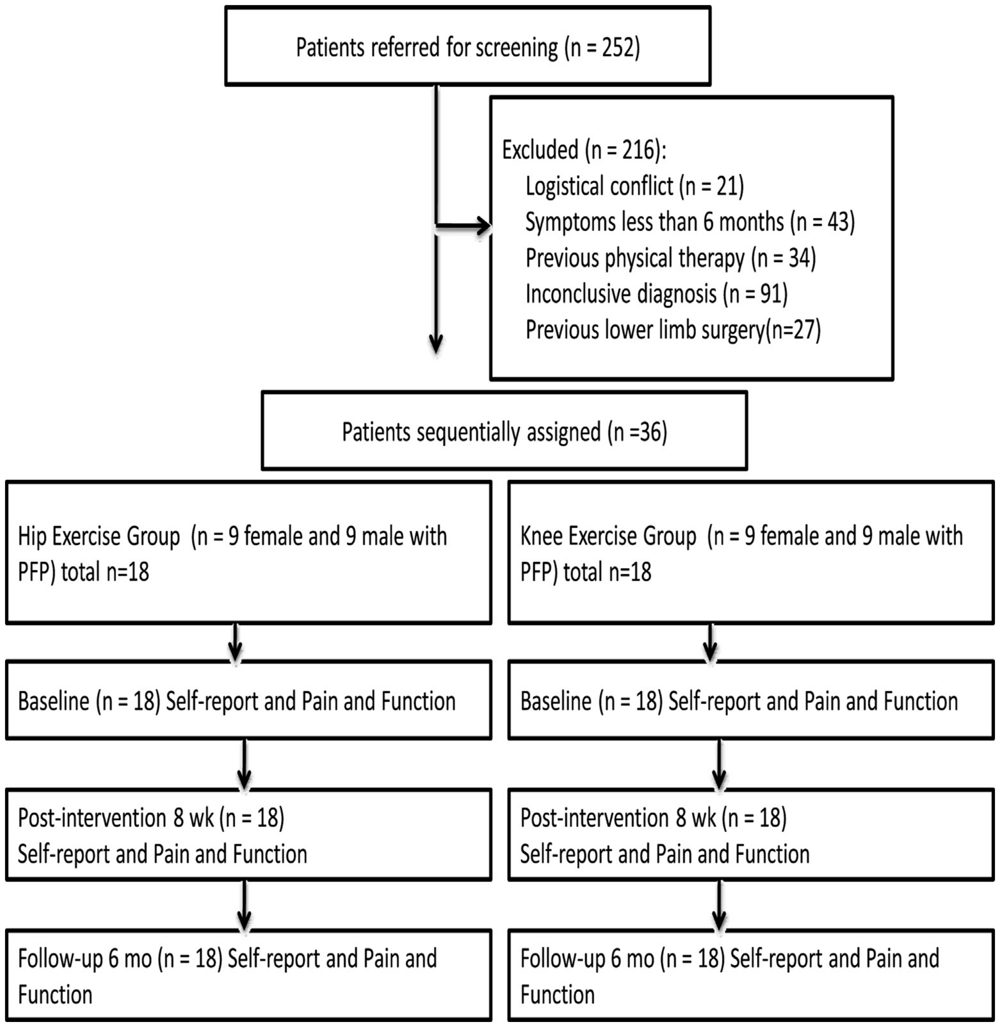

Fig 1 Flow diagram outlining patient recruitment, group assignment, and outcome assessment.

to remove slack from the tubing. The exercise was performed against the resistance by externally rotating the hip from 0° to 30°.[15,16,24,25]

Patients assigned to the quadriceps exercise group also performed 2 exercises. For the first exercise, the patient was seated at the edge of a treatment table, and the knee was flexed to 30° (fig 4). Elastic tubing was tied around the ankle and was secured to the bottom of the treatment table. The length of tubing was individualized across patients based on lower leg length (distance from the lateral femoral epicondyle to the medial malleolus). The distance between the exercise limb and the bottom of the treatment table was adjusted to remove the slack from the tubing. In accordance with previous studies, patients performed the exercise against resistance by extending the knee from 30° of knee flexion to full knee extension.[12,14,24]

For the second exercise, patients stood with elastic tubing passing beneath both feet while holding one end of the tube in each hand (fig 5). The tubing length was individualized across patients based on lower leg length (2 times the distance from the lateral femoral epicondyle to the medial malleolus). Patients flexed their knees to 30° and removed the slack from the tubing. As described in previous publications,[12,15,16,26] patients then performed a partial squat against resistance from the start position to full knee extension while squeezing a ball between both knees.

Table 1 Baseline measurements

Variable	Hip Group	Knee Group	*P*
Age (y)	28.2±7.9	27.3±6.7	.70
Height (cm)	170.6±8.9	171.1±9.9	.86
Weight (kg)	70.6±11.5	66.7±14.7	.38
Body mass index (kg/m^2)	23.6±2.4	22.7±3.6	.25
VAS	7.6±1.8	6.91±1.9	.25
WOMAC	46.8±21.9	44.1±22.1	.71

NOTE. Data are presented as mean ± SD or as otherwise noted.

Outcome measures

Outcome measures were obtained on 3 separate occasions: at baseline, after 8 weeks of exercise (postintervention), and at 6 months (follow-up). A single tester who was not blinded to group assignment recorded all outcome measurements. For patients with

Table 2 Standardized exercise progression using elastic tubing

Week	Set 1	Set 2	Set 3	Frequency/wk
1–2	Red (20)	Green (20)	Blue (20)	3
3–4	Red (25)	Green (25)	Blue (25)	3
5–6	Green (20)	Blue (20)	Black (20)	3
7–8	Green (25)	Blue (25)	Black (25)	3

NOTE. Values are band color (number of repetitions) or as otherwise indicated. Band color indicates level of resistance; levels are as follows: red (medium), green (heavy), blue (extra heavy), and black (special heavy).

bilateral PFP, the limb reported to be the most painful during initial testing was evaluated for all testing sessions.

Self-reported pain intensity was quantified using a 10-cm visual analog scale (VAS), which ranged from 0 (no pain) to 10 (worst pain possible). Individuals were asked to rate their pain based on activities that aggravated symptoms during the previous week. The 10-cm VAS is a valid and responsive outcome measure for PFP with a minimal clinically important difference of 2.[27]

Self-reported health status was quantified using the Western Ontario McMaster Universities Osteoarthritis Index (WOMAC). The WOMAC is a 24-item questionnaire evaluating pain, stiffness, and physical function.[28] This tool is a valid outcome measure for knee osteoarthritis[29] and has been reported to be significantly correlated with an outcome measure specifically designed for PFP.[30] The total summed score for the Likert scale version used in the current study ranged from 0 to 96 (pain, 0–20; stiffness, 0–8; physical function, 0–68); higher scores indicated worse health status.

Statistical analysis

Independent t tests were used to evaluate group differences at baseline. A 2-factor, mixed-model analysis of variance (ANOVA) (2 groups $\times$ 3 time points) was used to compare outcome measures between groups over time. This analysis was repeated for the VAS and WOMAC scores. If a significant interaction was found, paired t tests (2-tailed) were used to assess changes in each group across the 3 time points. Additionally, independent t tests (1-tailed) were used to compare group differences at each time point. Because data were normally distributed and variance was equal between groups, parametric tests were justified. All statistical analyses were conducted with SPSS software[b] using a significance level of $P=.05$.

Results

At baseline, demographic characteristics, VAS scores, and WOMAC scores were comparable between groups (see table 1). Patients in both groups were moderately to severely impaired with respect to pain intensity and health status. All subjects completed the postintervention and 6-month follow-up assessments. On average, patients assigned to the posterolateral hip exercise group attended 22.4 supervised exercise sessions, whereas subjects assigned to the quadriceps exercise group attended 22.1 supervised exercise sessions.

Self-reported outcomes

The ANOVA evaluating self-reported pain intensity between groups across the 3 time points revealed a significant group by time interaction ($F=13.15$, $P<.001$, partial $\eta^2=.28$). Within-group post hoc testing revealed that the posterolateral hip exercise group exhibited a significant decrease in pain from baseline to postintervention ($t=14.62$, $P<.001$) and from baseline to 6-month follow-up ($t=12.02$, $P<.001$). The quadriceps exercise group also demonstrated a significant decrease in pain from baseline to postintervention ($t=11.10$, $P<.001$) and from baseline to 6-month follow-up ($t=7.21$, $P<.001$). Between-group post hoc testing revealed that the VAS scores were lower in the posterolateral hip exercise group than the quadriceps exercise group postintervention ($t=1.823$, $P=.039$) and at 6-month follow-up ($t=2.80$, $P>.004$) (table 3).

The ANOVA evaluating the WOMAC scores between groups across the 3 time points also revealed a significant group by time interaction ($F=9.76$, $P<.001$, partial $\eta^2=.22$). Within-group post hoc testing revealed that the posterolateral hip exercise group exhibited a significant improvement in health status from baseline to postintervention ($t=8.33$, $P<.001$) and from baseline to 6-month follow-up ($t=7.93$, $P<.001$). The quadriceps exercise group also demonstrated a significant improvement in health status from baseline to postintervention ($t=8.91$, $P<.001$) and from baseline to 6-month follow-up ($t=6.21$, $P<.001$). Between-group post hoc testing revealed that the WOMAC scores were lower in the posterolateral hip exercise group than the quadriceps exercise

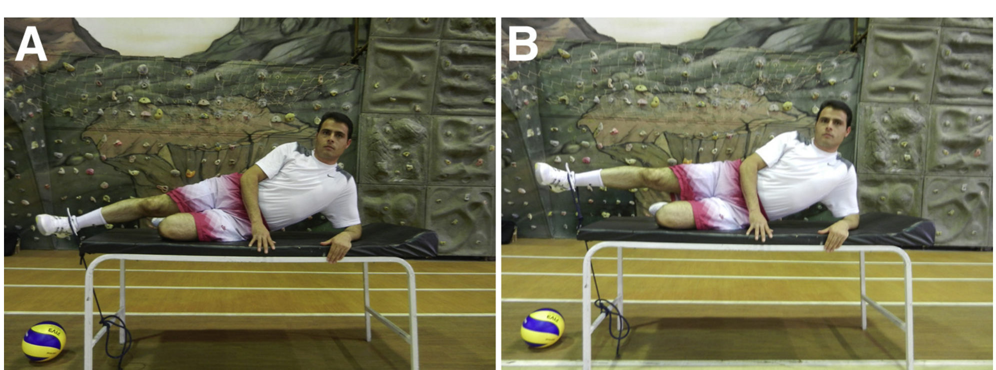

Fig 2 Patient starting (A) and ending (B) position for the hip abduction exercise.

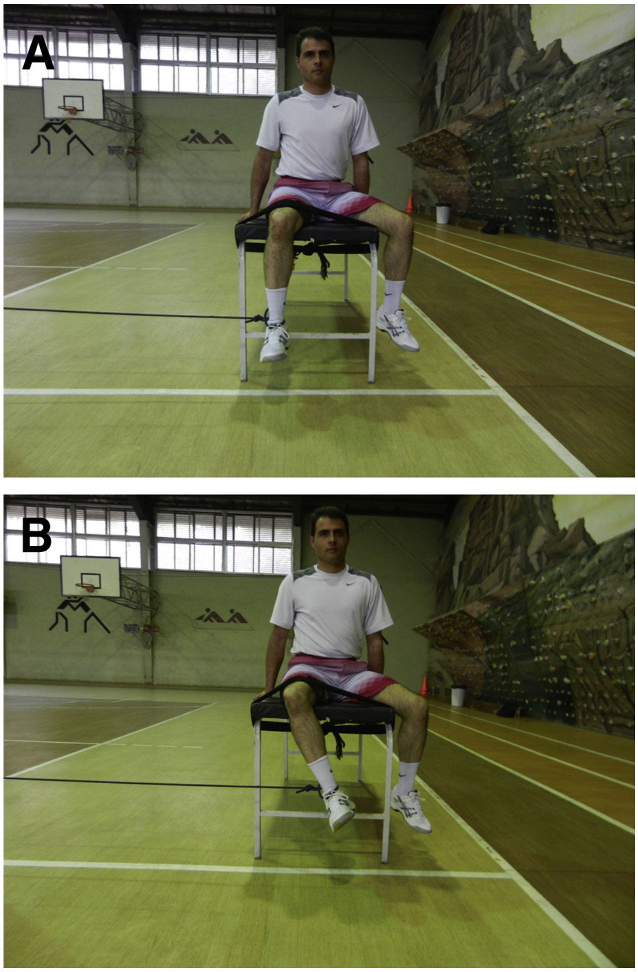

Fig 3 Patient starting (A) and ending (B) position for the hip external rotation exercise.

Fig 4 Patient starting (A) and ending (B) position for the knee extensor exercise.

group postintervention (t=3.91, P<.001) and at 6-month follow-up (t=4.51, P<.001) (see table 3).

Discussion

Historically, the etiology of PFP has been attributed to impairments in quadriceps muscle performance.[4-7] As such, strengthening the quadriceps muscles has been widely advocated as the treatment of choice for PFP.[8] Over the last decade, there has been an emergence of research suggesting that PFP may have proximal origins. In particular, excessive hip adduction and internal rotation has been reported to contribute to abnormal patellofemoral joint loading.[17,18] Furthermore, recent publications have shown that hip strengthening is a viable treatment option in this population.[15,16,24-26,31] Given the multifactorial nature of PFP, optimal treatments for this condition remain unclear. The current study sought to compare the effects of posterolateral hip muscle strengthening versus quadriceps strengthening on pain intensity and health status in patients with PFP.

Both the posterolateral hip muscle strengthening program and the quadriceps strengthening program decreased pain and improved the health status in patients with PFP. Improvements in both groups were maintained at 6-month follow-up. The mean postintervention changes in VAS and WOMAC scores for the hip exercise group were 5.5 and 40.6, respectively, whereas the changes for the quadriceps exercise group were 3.6 and 22.2, respectively. The changes in VAS and WOMAC scores in both groups exceeded the minimal clinically important differences for both of these measures (2cm and 15 for VAS and WOMAC, respectively).[27,32] Despite the improvements obtained in both groups, the decreases in pain and improvements in health status were greater in patients who received the posterolateral hip exercises than in patients who received the quadriceps exercises. The superior improvements obtained in the posterolateral hip exercise group were still present at 6-month follow-up.

Consistent with previous studies, we found that hip muscle strengthening resulted in decreased pain[25,31] and improved health status[25] in persons with PFP. In the current study, pain decreased by 70% in our patients after 8 weeks of hip strengthening, which was similar to the 82% decrease in pain reported by Khayambashi[25] and the 88% decrease reported by Earl and Hoch[31] after their respective 8-week hip strengthening programs in persons with PFP. Additionally, health status in our hip strengthening group improved by 87%, which was similar to the 80% improvement reported by Khayambashi.[25]

Also consistent with previous studies, we found that a quadriceps strengthening program resulted in decreased pain[12-16] and

Fig 5 Patient starting (A) and ending (B) position for the knee extensor exercise.

improved health status[13-16] in persons with PFP. Pain decreased by 53% in our quadriceps strengthening group, which was similar to the 59% decrease in pain reported by Chiu et al[12] after their 8-week quadriceps strengthening program in persons with PFP. Our finding of a 59% reduction in pain in the quadriceps strengthening group was superior to that reported by Fukuda et al,[15] who reported smaller reductions in pain (22%−31%) with 8 weeks of quadriceps strengthening. The lower reduction in pain reported by Fukuda[15] may have been the result of lower initial mean VAS scores compared with the current study (4.9 vs 6.9).

Our finding of decreased pain and improved health status in the posterolateral hip exercise group compared with the quadriceps exercise group is consistent with the results of previous studies that evaluated both hip and quadriceps strengthening protocols.[15,16,26] For example, Nakagawa et al[26] demonstrated that the addition of hip extensor and hip abductor exercises to a knee strengthening protocol resulted in decreased pain compared with when quadriceps exercises were performed in isolation. Similarly, Fukuda et al[15,16] reported decreased pain and improved function at 4 weeks and 1 year follow-up in persons receiving hip and knee strengthening compared with quadriceps strengthening alone. Furthermore, our findings are consistent with the 4-week follow-up outcome of Dolak,[24] who found decreased pain with hip strengthening when compared with quadriceps strengthening.

Based on the findings of the present study and other recent investigations,[15,16,24-26,31,33-35] posterolateral hip strengthening appears to be a viable treatment approach for persons with PFP. Although the reason for the superior outcomes in the hip strengthening group is difficult to explain and beyond the scope of this study, decreased hip muscle performance has been suggested to be an underlying cause of abnormal hip kinematics in persons with PFP.[18,19,21-23] It is plausible that significant improvements in pain intensity and health status after the 8-week hip strengthening intervention could have been the result of changes in hip and knee biomechanics during functional activities.[31,33-37] Consistent with this hypothesis, Earl,[31] Mascal,[33] and colleagues have previously demonstrated changes in hip and knee biomechanics after hip strengthening programs.

Previous studies have suggested that persons with PFP limit the use of the quadriceps in an attempt to decrease patellofemoral joint loading.[38,39] This suggests that quadriceps atrophy in this population may be the result of pain as opposed to the cause of PFP. Given that quadriceps function is important for normative patellofemoral joint mechanics, restoration of quadriceps strength would appear to be important in this population. However, an

Table 3 Results of self-report measures in response to intervention

Group	Baseline	Postintervention (8wk)	Follow-Up (6mo)	Difference (8wk−baseline)	Difference (6mo−baseline)
Hip group					
VAS*	7.63±1.79	2.11±1.6†‡	2.00±1.97†‡	−5.53±1.60; 95% CI, −6.32 to −4.73	−5.64±1.99; 95% CI, −6.63 to −4.65
WOMAC§	46.83±21.86	6.22±3.87†‡	6.94±5.70†‡	−40.61±20.68; 95% CI, −50.89 to −30.32	−39.89±21.35; 95% CI, −50.50 to −28.27
Quadriceps group					
VAS*	6.91±1.94	3.27±2.19†‡	4.00±2.44†‡	−3.64±1.39; 95% CI, −4.33 to −2.95	−2.92±1.72; 95% CI, −3.77 to −2.06
WOMAC§	44.11±22.05	21.89±16.55†‡	23.16±14.15†‡	−22.22±10.59; 95% CI, −27.49 to −16.96	−20.94±14.30; 95% CI, −28.06 to 13.83

NOTE. Data are mean ± SD or as otherwise indicated.
Abbreviation: CI, confidence interval.
* Score of 0 to 10cm; larger numbers indicate more pain.
† Paired t test significantly different from baseline at $P<.001$.
‡ Independent t test significantly different between groups at $P\leq.05$.
§ Score of 0 to 96; larger numbers indicate worse health status.

argument could be made that hip strengthening may address the underlying cause of abnormal patellofemoral joint loading, whereas quadriceps strengthening may be addressing the symptom of pain. Further research is necessary to test this hypothesis.

Study limitations

Our study sample consisted of a relatively small, homogeneous group of patients with moderate to severe impairments. This may limit the generalizability of our findings to other PFP populations. Additionally, the exercises chosen may have influenced the results obtained. For example, the use of non−weight-bearing terminal knee extension (30°−0°) has been reported to increase patellofemoral joint reaction force and stress.[40] It is possible that superior results may have been obtained if patients performed this exercise at lesser knee flexion angles (ie, 90°−45°). However, all exercises were performed using a resistance that did not elicit pain. Finally, the partial squat exercise used in the quadriceps group was performed in weight-bearing. As such, it is possible that hip strength gains occurred in this group.

Conclusions

An 8-week program of posterolateral hip muscle strengthening was more effective in improving pain and health status in persons with PFP than a quadriceps strengthening program. The observed improvements were maintained at 6-month follow-up. Our results support the use of hip strengthening as a viable rehabilitation approach for persons with PFP.

Suppliers

a. Hygenic Corp, 1245 Home Ave, Akron, OH 44310.
b. IBM Corp, 1 New Orchard Rd, Armonk, NY 10504.

Keywords

Clinical trial [publication type]; Patella; Patellofemoral pain syndrome; Rehabilitation

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