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Hip Strengthening Prior to Functional Exercises Reduces Pain Sooner Than Quadriceps Strengthening in Females With Patellofemoral Pain Syndrome: A Randomized Clinical Trial

STUDY DESIGN: Randomized clinical trial.

OBJECTIVES: To determine if females with patellofemoral pain syndrome (PFPS) who perform hip strengthening prior to functional exercises demonstrate greater improvements than females who perform quadriceps strengthening prior to the same functional exercises.

BACKGROUND: Although PFPS has previously been attributed to quadriceps dysfunction, more recent research has linked this condition to impairment of the hip musculature. Lower extremity strengthening has been deemed an effective intervention. However, research has often examined weight-bearing exercises, making it unclear if increased strength in the hip, quadriceps, or both is beneficial.

METHODS: Thirty-three females with PFPS performed either initial hip strengthening (hip group) or initial quadriceps strengthening (quad group) for 4 weeks, prior to 4 weeks of a similar program of functional weight-bearing exercises. Self-reported pain, function, and functional strength were measured. Isometric strength was assessed for hip abductors, external rotators, and knee extensors. A mixed-model analysis of variance was used to determine group differences over time.

RESULTS: After 4 weeks, there was less mean $\pm$ SD pain in the hip group (2.4 ± 2.0) than in the quad group (4.1 ± 2.5) ($P = .035$). From baseline to 8 weeks, the hip group demonstrated a 21% increase ($P<.001$) in hip abductor strength, while that remained unchanged in the quad group. All participants demonstrated improved subjective function ($P<.006$), objective function ($P<.001$), and hip external rotator strength ($P = .004$) from baseline to testing at 8 weeks.

CONCLUSION: Both rehabilitation approaches improved function and reduced pain. For patients with PFPS, initial hip strengthening may allow an earlier dissipation of pain than exercises focused on the quadriceps.

LEVEL OF EVIDENCE: Therapy, level 2b–.
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KEY WORDS: *anterior knee pain, clinical trial, kinetic chain, knee rehabilitation*

Patellofemoral pain syndrome (PFPS) is a common source of knee pain in the physically active population. Women have a higher prevalence of PFPS than their male counterparts (2:1), with an even higher incidence within the population for athletic women (4:1).[18] Despite being deemed a multifactorial condition with no single cure, PFPS is commonly attributed to muscular dysfunction, for which conservative rehabilitation is the treatment of choice.[19,23,35,45,46]

Historically, PFPS has been linked to impairments of the quadriceps muscle.[27,33,35,45] Countless studies have cited quadriceps strength deficits, imbalances, and timing errors as the source of PFPS. But more recent research regarding PFPS has focused on strength deficits of the proximal hip musculature as a contributor to this disorder. Several authors have reported that females with PFPS demonstrate weaknesses of the hip external rotators and hip abductors.[11,17,26,30,31,36,37] During functional activities, especially single-leg activities, the hip muscles prevent hip adduction and internal rotation, which may result in dysfunctional lower extremity joint alignment and can lead to the development of PFPS.[20]

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TABLE 1 PARTICIPANT CHARACTERISTICS

	Hip Group (n = 17)	Quad Group (n = 16)	*P* Value
Age, y	25 ± 5	26 ± 6	.57
Height, m	1.66 ± 0.08	1.66 ± 0.08	.95
BMI, kg/m²	24 ± 4	27 ± 6	.13
Duration of symptoms, mo	36 ± 34	27 ± 34	.48

**Values are mean ± SD, except where otherwise indicated.*

Quadriceps strengthening exercises have been repeatedly demonstrated to be an effective intervention for individuals with PFPS.[7,12-15,22,39,40,42] However, few of these studies evaluated the efficacy of isolated quadriceps strengthening. Many published rehabilitation protocols target functional exercises in a weight-bearing position, which requires a contribution of both hip and quadriceps musculature. Despite this, many review and concept articles continue to highlight quadriceps strengthening as an important intervention for patients with PFPS.[3,23,44] Limited research on the efficacy of isolated hip strengthening has provided evidence of improvements in pain, function, and strength in this population.[31,34]

The presence of multiple effective interventions creates a dilemma for clinicians treating patients with PFPS. It is unclear whether initial hip or quadriceps strengthening will better prepare patients for more functional lower extremity exercises, particularly if functional activities cannot be initiated immediately or are not initially tolerated in some patients. Despite the growing evidence suggesting the importance of hip strength in the rehabilitation of PFPS, few, if any, randomized clinical trials have attempted to compare the benefit of isolated hip to isolated quadriceps strengthening prior to weight bearing or functional exercises. Therefore, the purpose of this study was to compare the effects of hip strengthening to quadriceps strengthening prior to weight-bearing exercises in the treatment of females with PFPS. We hypothesized that a rehabilitation program initially focused on isolated hip strengthening would result in a greater reduction of symptoms and better preparation for functional exercises than would initial quadriceps strengthening.

METHODS

THE STUDY DESIGN WAS THAT OF A randomized clinical trial. Participants were randomly assigned to a hip strengthening program (hip group) or a quadriceps strengthening program (quad group) for 4 weeks. Both groups were then combined into a functional exercise strengthening group for the subsequent 4 weeks. No placebo treatments were used. Prior to initiation of the study, group allocation for each participant was made with a random-number generator in Microsoft Excel (Microsoft Corporation, Redwood, WA). This concealed assignment and minimized selection bias for investigators.

Participants

Fifty-eight women with knee pain were considered from a sample of convenience for this study. Thirty-three women with PFPS, between 16 and 35 years of age, agreed to participate and met the inclusion criteria for the study. Participants' characteristics are presented in **TABLE 1**. Seventeen women were assigned to the hip group, 9 with bilateral and 8 with unilateral symptoms, and 16 women were assigned to the quad group, 7 with bilateral and 9 with unilateral symptoms. A certified athletic trainer associated with the study evaluated all participants for the presence or absence of inclusion criteria. The inclusion criteria were that participants needed to exhibit or report (1) anterior or retropatellar knee pain during at least 2 of the activities of stair climbing, hopping, running, squatting, kneeling, and prolonged sitting, (2) an insidious onset of symptoms not related to trauma, (3) pain with compression of the patella, and (4) pain on palpation of patellar facets.[7] Participants were excluded if they had (1) symptoms present for less than 1 month, (2) self-reported other knee pathology, such as cartilage injury or ligamentous tear, (3) a history of knee surgery within the last year, (4) a self-reported history of patella dislocations or subluxations, and (5) any other concurrent significant injury affecting the lower-extremity.[7] All individuals who met these criteria and were willing to participate in the study read and signed a consent/assent form approved by the University of Kentucky Institutional Review Board. Participants were asked to refrain from taking any prescription or over-the-counter pain medication within 24 hours of all testing visits.

Instrumentation

Primary Outcome Measures Self-report questionnaires were completed using a visual analog scale (VAS) and the Lower Extremity Functional Scale (LEFS), both of which have previously been reported as reliable for assessing perceived pain and function, respectively, in patients diagnosed with PFPS.[2,16,43] On the VAS, participants were asked to indicate the worst pain experienced in the previous week. On a similarly worded VAS, a minimally clinically important change of 2 cm has been previously reported,[16] and on the LEFS a minimally clinically detectable change of 8 points has been reported.[43]

Secondary Outcome Measures Isometric strength measures were taken for the hip abductors (HABD), hip external rotators (HER), and knee extensors (KE) using a handheld dynamometer (HHD) (JTech Commander PowerTrack II Muscle Dynamometer; OPS Medical, LLC, Pasadena, MD). For HABD strength testing, participants were in sidelying, with the

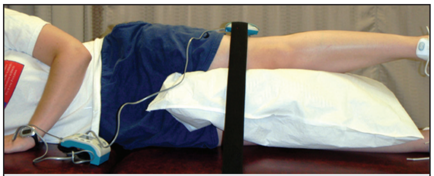
FIGURE 1. Hip abductors strength testing.


FIGURE 2. Hip external rotators strength testing.

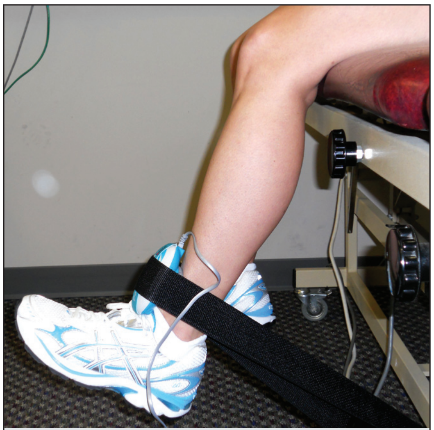
FIGURE 3. Knee extensors strength testing.

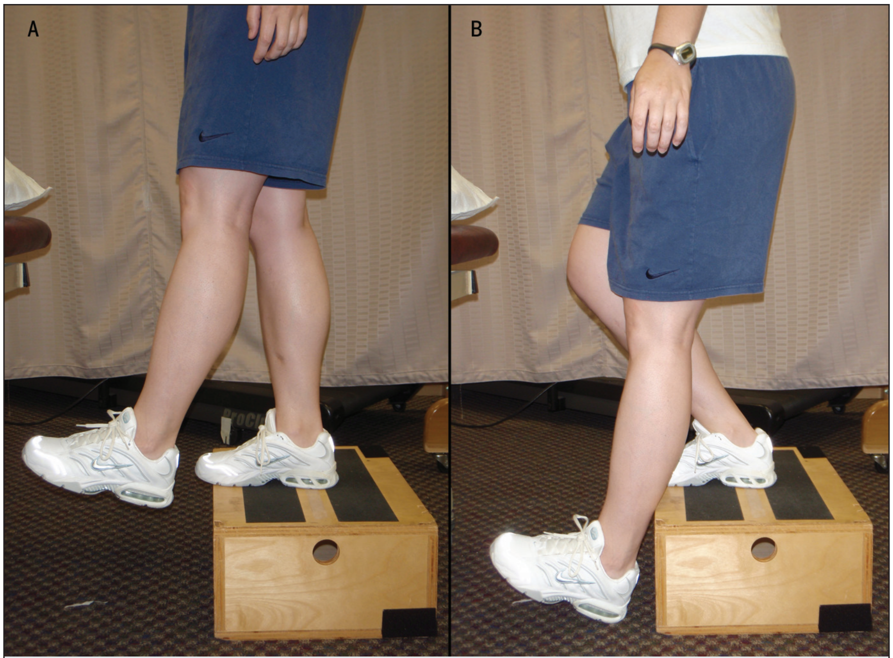

FIGURE 4. Step-down test. The right lower limb is involved. One repetition consists of starting in position (A), touching the heel to the floor with uninvolved limb (B), and returning to the starting position (A).

nontested limb in contact with the table. The test limb was supported by a pillow in 0° hip abduction and 0° hip and knee flexion. The HHD was placed over the lateral femoral condyle (**FIGURE 1**). For HER strength testing, participants were seated with the test limb in 0° hip rotation and 90° knee flexion. The HHD was placed 2.5 cm proximal to the medial malleolus (**FIGURE 2**). For KE strength testing, participants were seated with the test limb in 0° hip rotation and 60° knee flexion. The HHD was placed 2.5 cm proximal to the medial malleolus (**FIGURE 3**). For all strength testing, the participants' limb was secured to the test table with a nylon strap. Participants were instructed to produce a maximal voluntary isometric contraction. They completed 1 practice before beginning test trials, and each test trial lasted 7 seconds, with 1 minute of rest between trials. During test trials, participants were instructed to build strength gradually over the first 2 seconds to generate a maximum contraction for the last 5 seconds.[4] A metronome, set to 60 beats per minute, was used to standardize the second counts. The order of muscle testing was counterbalanced to minimize any potential fatigue bias.

The distances from the greater trochanter to the lateral femoral condyle and from the lateral knee joint line to the lateral malleolus were measured. These measurements were completed to establish the perpendicular distance from the HHD and the hip and knee joints, respectively. This information was used to convert all strength values into a measure of torque.

Functional strength was assessed using a step-down task that mimicked stepping down stairs, which has previously been established as reliable in the PFPS population.[29] Standing with the test extremity on a 20-cm (standard height) step, participants were instructed to lower their body enough to touch the heel of the opposite lower extremity on the floor in front of the step, then to return the knee to full extension. This sequence constituted 1 repetition. Participants were permitted to lightly contact the investigator's hand to prevent loss of balance. The number of repetitions correctly completed in 30 seconds was counted (**FIGURE 4**).[29]

Testing Procedures

The affected lower extremity of each participant was used for data collection. For participants with bilateral symptoms, the limb reported to be the most painful during initial testing was used throughout all testing sessions. Following administration of the questionnaires, participants warmed up on a stationary bicycle er-

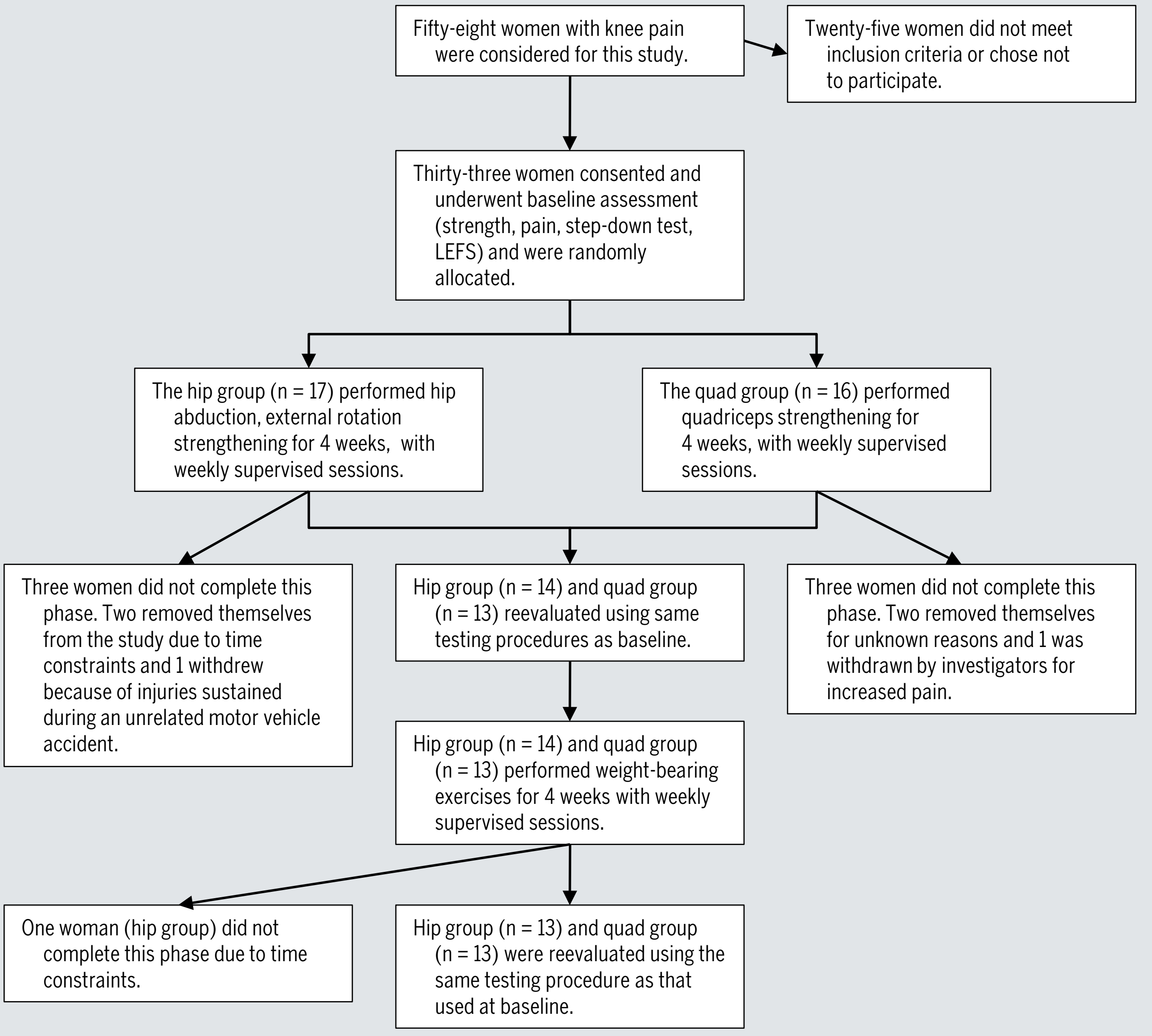

FIGURE 5. Flow chart for enrollment and testing procedures.

gometer at submaximal speed for at least 3 minutes in a pain-free range of motion. The order of testing was counterbalanced to prevent any bias associated with fatigue. Individuals were retested for all measures at the completion of the fourth and eighth weeks. The researcher responsible for setup and testing was blinded to participants' group assignment during the initial testing session.

Rehabilitation Program

Following the initial testing session, all women were taught and supervised on the first phase of rehabilitation, based on their assignment to either the hip group or quad group. Both groups received the same flexibility exercises. A seated hamstring stretch, standing quadriceps stretch, and standing wall stretch for the triceps surae were performed throughout the 8-week program. Flexibility exercises were performed 3 times for 30 seconds each, prior to strengthening exercises. All women received an exercise DVD/CD, instruction booklet, and exercise log to document home exercise compliance and medication use. Participants performed rehabilitation exercises 1 day a week with an investigator and 2 days a week at home, for a total of 3 exercise sessions each week.

Individuals were progressed through rehabilitation exercises individually per exercise protocol. In addition, minor adjustments were made to individual protocols based on improvement, changes in pain and swelling, as well as the participants' ability to maintain postural control

TABLE 2 Reliability Data for Isometric Strength Testing

Testing Measure	ICC	ICC (95% CI)	SEM
HABD isometric strength, Nm	0.94	0.60, 0.99	5.4
HER isometric strength, Nm	0.79	–0.30, 0.97	2.3
KE isometric strength, Nm	0.95	0.67, 0.99	6.9

Abbreviations: CI, confidence interval; HABD, hip abductors; HER, hip external rotators; ICC, intraclass correlation coefficient; KE, knee extensors; SEM, standard error of measurement.

TABLE 3 Descriptive Statistics of All Dependent Variables Measured Through the Course of the Study*

	Hip Group (n = 17)	Quad Group (n = 16)
VAS (0-10)		
Baseline	4.6 ± 2.5	4.2 ± 2.3
4 wk	2.4 ± 2.0	4.1 ± 2.5
8 wk	2.4 ± 2.8	2.6 ± 2.0
3 mo†	2.1 ± 2.5	2.4 ± 2.3
LEFS (0-80)		
Baseline	59 ± 12	54 ± 12
4 wk	67 ± 11	59 ± 14
8 wk	70 ± 10	65 ± 13
3 mo†	70 ± 10	67 ± 11
Step-down test, n		
Baseline	15 ± 5	14 ± 8
4 wk	17 ± 5	17 ± 7
8 wk	19 ± 5	20 ± 6
HABD strength‡		
Baseline	5.2 ± 1.5	5.7 ± 2.2
4 wk	6.2 ± 1.1	5.5 ± 1.9
8 wk	6.6 ± 0.9	6.2 ± 1.8
HER strength‡		
Baseline	2.1 ± 0.7	2.1 ± 1.0
4 wk	2.5 ± 0.7	2.2 ± 0.8
8 wk	2.7 ± 0.7	2.2 ± 0.7
KE strength‡		
Baseline	6.1 ± 2.6	6.3 ± 2.1
4 wk	6.8 ± 1.9	6.1 ± 1.9
8 wk	7.0 ± 1.4	6.6 ± 1.9

Abbreviations: HABD, hip abductors; HER, hip external rotators; KE, knee extensors; LEFS, lower extremity functional scale; VAS, visual analog scale.
**Values are mean ± SD.*
†Change in number of participants, as all participants did not return a complete follow-up questionnaire at 3 months (for VAS: hip group, n = 14; quad group, n = 11; for LEFS: hip group, n = 12; quad group, n = 10).
‡Average torque normalized to participant height and weight: [(torque in Nm/body weight in N) × (participant height in m × 100)].

during the exercise.[41] All changes were kept within the guidelines of the outlined exercise program. Therapeutic exercises for the first 4 weeks were chosen from the therapeutic exercise literature for specifically targeting one of either the hip or quadriceps musculature while minimally activating the other.[8,25,28] Participants were progressed through the initial phase of rehabilitation with the goal of performing exercises against a resistance equal to 7% of their bodyweight (**APPENDIX**).

After completing the fourth week of rehabilitation and retesting, women from both groups were instructed on the second phase of rehabilitative exercises. This phase focused on functional weight-bearing resistance exercises and balance (**APPENDIX**). Participants continued to perform rehabilitation exercises, following the same routine for 4 additional weeks. After completing the eighth week of rehabilitation, participants were retested for the final time. **FIGURE 5** details participants' progression through the study.

Data Processing

We expressed hip abductor strength in units of torque by multiplying the force recorded on the HHD by the distance from the greater trochanter to the lateral femoral condyle. We expressed external rotator and knee extensor strength in units of torque by multiplying the force recorded on the HHD by the distance from the lateral femoral condyle to the lateral malleolus. The average torque from 3 trials having a coefficient of variation less than 10% was then normalized to participant height and weight: [(torque in Nm/body weight in N) × (participant height in m × 100)]. The normalization procedure resulted in strength being expressed without units, and allowed for comparison across all participants, without bias for height, weight, or limb length.[5,21] These values were used for statistical analysis.

Statistical Analysis

All data were analyzed based on intention to treat, with the last available measure moved forward.[1] One-way analyses of variance (ANOVAs) were used to determine if group differences were present at baseline for age, height, body mass index

(BMI), and symptom duration. Data to calculate intraclass correlation coefficients (ICCs) for between-day reliability of isometric strength testing were collected on 2 occasions, 1 week apart, during pilot testing. These data were collected on 6 asymptomatic women, 21 to 24 years of age. Standard error of measurement (SEM) was used to determine precision.

To determine group differences over time, separate 2-way ANOVAs were performed to analyze VAS scores, LEFS scores, number of repetitions for the step-down task, and isometric strength of HABD, HER, and KE. Each model included 1 between-subject factor (group, with 2 levels: hip and quad) and 1 within-subject factor (time, with 3 levels: baseline, 4 weeks, and 8 weeks). All data were analyzed at an alpha level of .05. Significant differences from the ANOVA were further examined using a Bonferroni post hoc analysis, with alpha level corrected for multiple comparisons of less than .05. All statistical analyses were run using SPSS Version 17 (Chicago, IL), and outcome data presented as mean ± SD.

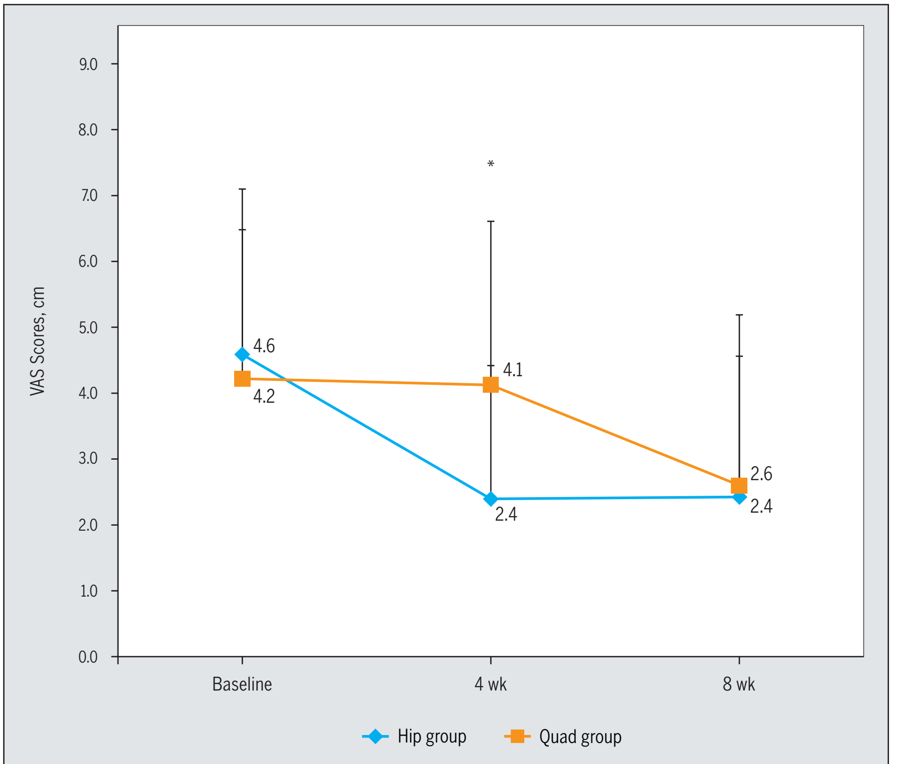

FIGURE 6. Mean pain on visual analog scale (VAS) scores for women in the hip and quad strengthening groups. Error bars are standard deviations. *Significant time-by-group interaction (P = .035), indicating a significant difference between groups at 4 weeks. In addition, pain scores at 4 and 8 weeks were significantly lower than baseline scores in the hip group (P = .001 and P = .003); in the quad group, pain scores were significantly lower than at baseline at 8 weeks (P = .028) but not at 4 weeks (P = .88).

RESULTS

Twenty-six of the 33 women completed the study (hip group, n = 13; quad group, n = 13). Four participants from the hip group and 3 from the quad group did not complete the study (**FIGURE 5**). No significant between-group differences for age, height, body mass index, or symptom duration were found at baseline (**TABLE 1**). ICCs with 95% confidence intervals and SEMs for isometric strength testing were found to be acceptable (**TABLE 2**). **TABLE 3** presents descriptive statistics for all dependent variables.

Primary Outcome Measures

A significant time-by-group interaction was present for knee pain (P = .04). A Bonferonni post hoc analysis comparing the 2 protocols at each time point revealed that the hip group (2.4 ± 2.0) had significantly less pain than the quad group (4.1 ± 2.5) at week 4 (P = .035) (**FIGURE 6**). In addition, pain scores at 4 and 8 weeks were significantly lower than baseline scores in the hip group (P = .001 and P = .003, respectively), and pain scores for the quad group significantly lower from baseline at 8 weeks (P = .028) but not at 4 weeks (P = .88).

There was no significant time-by-group interaction (P = .65) for the LEFS scores. However, LEFS scores significantly improved over time, regardless of the protocol performed by the participant (P<.001). A Bonferroni post hoc analysis demonstrated a significant improvement from baseline (56.5 ± 12.2) to 4 weeks (63 ± 12.7) (P = .006). At 8 weeks, the LEFS scores of all participants combined (67.6 ± 11.5), again, significantly improved (P = .006).

Secondary Outcome Measures

The step-down data were found to violate the assumption of homogeneity by Maulchy's sphericity test; therefore, a Greenhouse-Geisser correction was used. There was no significant difference between groups at baseline. Step-down scores significantly improved over the course of rehabilitation, regardless of group membership (P<.001). Mean step-down scores for all participants were 15 ± 6 at baseline, which significantly improved to 17 ± 6 at 4 weeks (P = .006), and again to 19 ± 5 at 8 weeks (P<.001).

HABD strength demonstrated a significant time-by-group interaction (P = .041). A Bonferroni post hoc analysis revealed that the hip group demonstrated a significant increase in strength from baseline (5.2 ± 1.5) to 8 weeks (6.6 ± 0.9) (P = .001), while the quad group did not (baseline, 5.7 ± 2.2; 8 weeks, 6.2 ± 1.8; P = .9) (**FIGURE 7**). There was no significant group-by-time interaction for HER strength (P = .06); however, there was a main effect for time, indicating that HER strength had increased over the 8-week program for both groups (P = .004). A Bonferroni post hoc analysis revealed only a significant increase from baseline (2.1 ± 0.8) to the 8-week assessment (2.5 ± 0.7) (P = .012). KE strength did not demonstrate a significant time-by-group interaction (P = .39), and no main effect was found between groups (P = .6) or across time (P = .12).

DISCUSSION

The purpose of this study was to compare initial hip strengthening to initial quadriceps strengthening in the treatment of females with PFPS. It was hypothesized that rehabilitation initially focusing on isolated hip strengthening would result in less pain, more strength and function, and better preparation for functional exercises than initial quadriceps strengthening. While both groups experienced similar overall increased strength and function, the hip group reported less pain than the quad group after the first 4 weeks of rehabilitation.

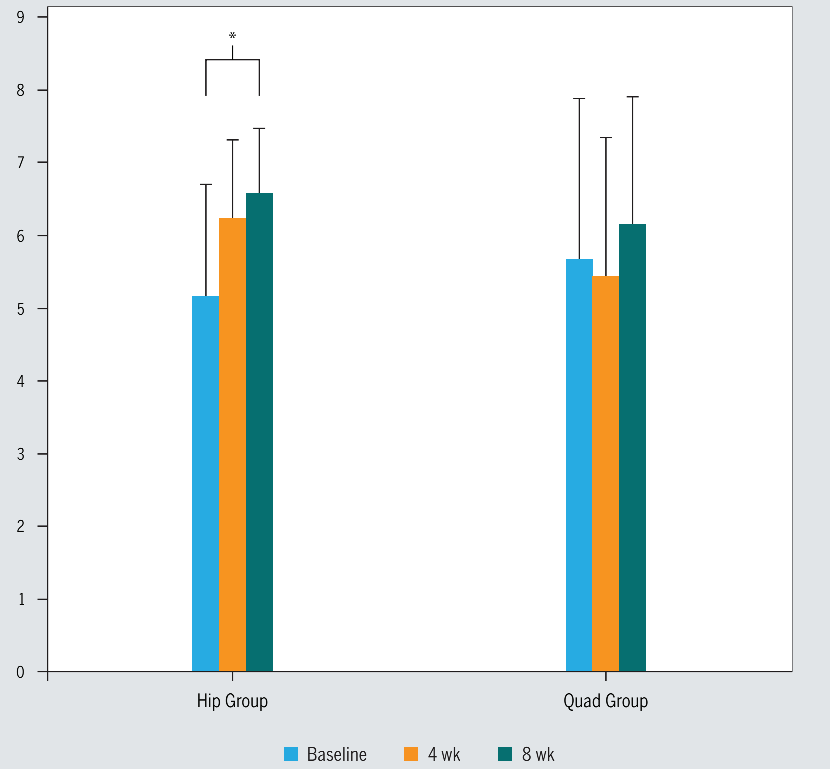

FIGURE 7. Mean percent strength values for hip abductors. Error bars are standard deviations. *Significant difference between baseline and 8 weeks for the hip group (P<.001).

Primary Outcome Measures

Although both groups reported reduced pain by the end of the intervention, we believe that the decrease of pain at 4 weeks in the hip group, contrasted by lack of change in the quad group, was most significant. Performing isolated hip exercises allowed participants in the hip group to strengthen the affected hip musculature, while simultaneously decreasing pain at the patellofemoral joint, in preparation for functional exercises. After 4 weeks of rehabilitation, VAS scores in the hip group lowered by approximately 43%, while the quad group scores differed by less than 3%. We believe that initiating PFPS rehabilitation with isolated quadriceps exercise might have either promoted existing poor knee extensor muscle function or further irritated patellofemoral joint structures through excessive force and pressure during exercises.[33]

This theory is further supported by the decreased pain experienced by the quad group between weeks 4 and 8, when isolated quad exercises were replaced by a comprehensive lower extremity exercise program. Pain in the quad group decreased by approximately 37% between weeks 4 and 8. While the initial exercises isolated the quadriceps muscles, the secondary group of exercises tended to emphasize cocontraction of the musculature around the knee. Research has found the vastus medialis to be more active during an isometric quadriceps contraction with a straight leg raise than during a bilateral squat or single-leg stance.[6]

The mean decrease in VAS scores for both groups at 8 weeks, although statistically significant, did not exceed 2 cm, which is commonly considered clinically important.[16] Previous research has found a wide range in VAS scores following rehabilitation intervention. Positive decreases following rehabilitative interventions have ranged between 1 and 8 cm on the VAS.[7,15,31] Additionally, a previous study on the reliability and responsiveness of VAS scores in individuals with PFPS identified a minimal clinically important difference of 1.5 to 2.0 cm, which would indicate that the change seen in the current study is clinically relevant.[16]

Coupled with the previous research on VAS scores following rehabilitative intervention, it is important to note that pain is a purely subjective measure. Participants were asked to rate their worst pain in the previous week, forcing them to compare their pain to an abstract maximum, not to a previous pain experience. Although the VAS has been deemed a reliable measure of pain symptoms and is widely used in PFPS literature, its use in linear studies of patients with chronic pain may be less reliable.[9] We did see a decrement in pain overall. However, the wording of our VAS question, which asked participants

TABLE 4 Comparison of Hip Abductor (HABD) and External Rotator (HER) Strength in Similar Studies*

	Baseline	PFPS	8 wk	Healthy Controls
HABD				
Current Study	23.5 ± 8.1	...	28.4 ± 6.5	...
Ireland et al[26]	...	23.3 ± 6.9	...	31.4 ± 6.2
Robinson and Nee[38]	...	16.0 ± 8.0	...	22.0 ± 3.0
HER				
Current Study	8.7 ± 3.4	...	10.4 ± 3.2	...
Ireland et al[26]	...	10.8 ± 4.0	...	16.8 ± 5.5
Robinson and Nee[38]	...	16.0 ± 6.0	...	23.0 ± 4.0

Abbreviations: HABD, hip abductors; HER, hip external rotators; PFPS, patellofemoral pain syndrome.
**Values are mean ± SD percentage of body weight.*

to rate their pain at its worst, could have revealed episodic pain changes rather than overall improvement.

We found significant improvements in LEFS scores as a measure of participants' self-reported function. After 8 weeks of rehabilitation, the mean LEFS scores of all participants improved 12 points, surpassing the 8-point minimal detectable change suggested in previous research.[36]

The LEFS has been used to determine self-reported improvements in function following therapeutic intervention for patients with PFPS. In one study,[22] participants completed 1 of 2 four-week interventions for PFPS focused on either just quadriceps exercises or a combination of hip and quadriceps exercises. The authors reported improvement of between 9 and 16 points on the LEFS, which is similar to the changes we found.

Secondary Outcome Measures

Both initial hip and quad strengthening led to increased function over the entire intervention, as measured by repetitions in a 30-second step-down task. Previous research assessed reliability of this measure and reported an average of 18 repetitions in a healthy population and 14 in a PFPS population.[25] Our numbers were very similar, with participants performing an average of 15 ± 7 repetitions at baseline and 21 ± 5 repetitions after rehabilitation, indicating that our participants had returned to normal functional strength levels.

We attribute these gains in function to the strengthening protocols performed by participants. During the initial 4 weeks of rehabilitation, exercises were designed to strengthen only the target muscle group of either the hip or quadriceps. These initial strength protocols were integral to improvements in function because they targeted the musculature most active during the step-down task.

Both groups continued to make improvements during the functional exercises performed between weeks 4 and 8. This is attributed to the introduction of a lateral step-down into the participants' exercise routines. The lateral step-down was intentionally chosen over its anterior counterpart for rehabilitation due to a decrease in forces placed on the patellofemoral joint.[10] Additionally, the lateral step-down requires less knee flexion and balance, while still challenging the gluteal musculature.[32] We also believed that the lateral step-down task would not create as large a potential learning effect as if the anterior-step down test had been utilized as a rehabilitative tool and also a testing method.

HABD and HER strength values approached normal strength values with the exercise protocols utilized in this study. Women in the hip group demonstrated increased HABD strength at the 8-week testing, while both groups demonstrated increased HER strength at the same testing point. KE strength showed no improvements across the course of the intervention. When both hip and quad groups were combined, baseline values for hip torque during HABD and HER were 5.4 ± 1.9 and 2.1 ± 0.8, respectively. These values are very similar to previously reported strength in patients with PFPS (4.6 and 2.2, respectively).[5] Our postintervention strength values at 8 weeks for HABD and HER (6.4 ± 1.4 and 2.5 ± 0.8, respectively) were again similar to values reported for a healthy cohort (6.5 and 3.2, respectively).[5] Because we used a relatively unique means of reporting torque that controlled for individual variance due to height and weight, we additionally converted our strength measures for isometric HABD and HER into a percentage of bodyweight for further comparison to studies that did not use these corrections (**TABLE 4**).[26,38] At the conclusion of this intervention, hip strength values for women in this study were approaching those reported for healthy women.

The lack of KE strength gains is interesting, especially when contrasted with the observed gains in HABD and HER strength. One possible cause of the steady knee extensor strength could be due to pain preventing adequate muscular activation. Patients with patellofemoral pain have been shown to demonstrate decreased quadriceps muscular activation.[24]

Limitations

One limitation of the present study was the varying amounts of patellofemoral pain observed in the study sample. Participants in this study represented a wide spectrum of limitation, with some experiencing symptoms only after intense activity and some experiencing severe symptoms with activities of daily living. However, this factor could also be regarded as increasing the external validity of the study, because clinicians regularly work with patients who experience varying degrees of impairment.

Despite this, we believe that these differences between participants might have contributed to high data variation and decreased our ability to detect differences between groups. Another limitation was that we chose to tailor our participants' strengthening progression to a specific percentage of body weight, rather than a percentage of the maximal force generated at baseline testing. This was a delimitation of this study, however, as we attempted to simulate a clinical scenario in which baseline isometric strength data might not be available. Blinding of the investigators after initial testing was a further limitation of the study. Testers were not blinded to participants' group assignment after baseline testing, mostly due to the large number of patient exercise sessions supervised. Additionally, the exercises performed during the first 4 weeks of rehabilitation by the quad group might be regarded as antiquated and, therefore, also a limitation. However, the investigators felt that these exercises best isolated the quadriceps muscle group, while minimizing activation of the hip musculature. We would recommend further research in this area that would directly compare weight-bearing exercises to isolated hip exercises in an effort to determine their efficacy in treating the same patient population.

CONCLUSION

In the treatment of PFPS, targeting hip strengthening initially may be more efficient, allowing for muscle training while reducing exacerbation of patellofemoral symptoms. The patients who started with hip strengthening reported an earlier and more significant drop in knee pain after only 4 weeks of rehabilitation, while the patients who initially performed quadriceps strengthening required 8 weeks of rehabilitation to achieve a similar decrease in pain. Both rehabilitation approaches led to improvements in self-reported function, objective function, and hip strength. This study further supports the importance of proximal musculature as a key element in the rehabilitation of females with PFPS. ◉

KEY POINTS

FINDINGS: Females with PFPS who performed initial hip strengthening prior to starting a functional weight-bearing exercise program demonstrated more decreased pain after 4 weeks and increased hip strength after 8 weeks of rehabilitation than those who performed initial quadriceps strengthening.
IMPLICATION: The use of isolated hip strengthening in the first weeks of rehabilitation for patients with PFPS may be a more clinically efficient approach to reducing pain and improving function in the early stages of rehabilitation.
CAUTION: Only women were included in the study, and follow-up was limited to 8 weeks, which represented the end of the intervention.

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APPENDIX

REHABILITATION PROTOCOLS

Week	Hip Group Exercises	Quad Group Exercises	Duration
Week 1	Sidelying combination hip abduction and external rotation	Quad sets	3 sets of 10 repetitions
	Standing hip abduction	Short-arc quads	3 sets of 10 repetitions
	Seated hip external rotation	Straight leg raises	3 sets of 10 repetitions

APPENDIX

Week	Hip Group Exercises	Quad Group Exercises	Duration
Week 2	Standing hip abduction with 3% body weight	Short arc quads with 3% body weight	3 sets of 10 repetitions
	Sidelying hip abduction with 3% body weight	Straight leg raises with 3% body weight	3 sets of 10 repetitions
	Seated hip external rotation with 3% body weight	Terminal knee extensions with 3% body weight	3 sets of 10 repetitions
Week 3	Sidelying hip abduction with 5% body weight	Short-arc quads with 5% body weight	3 sets of 10 repetitions
	Seated hip external rotation with 5% body weight	Straight leg raises with 5% body weight	3 sets of 10 repetitions
	Quadruped hydrant (combined hip abduction and external rotation)	Terminal knee extensions with 5% body weight	3 sets of 10 repetitions
Week 4	Sidelying hip abduction with 7% body weight	Short-arc quads with 7% body weight	3 sets of 10 repetitions
	Seated hip external rotation with 7% body weight	Straight leg raises with 7% body weight	3 sets of 10 repetitions
	Quadruped hydrant with 3% body weight	Terminal knee extensions with 7% body weight	3 sets of 10 repetitions
	Both Groups		
Week 5	Single-leg balance with front pull		3 sets of 30 seconds
	Wall slides with resistance		3 sets of 10 repetitions
	Lateral step-downs off a 10-cm step		3 sets of 10 repetitions
	2-leg calf raises		3 sets of 10 repetitions
Week 6	Single-leg balance with diagonal pull		3 sets of 30 seconds
	Single-leg mini-squats		3 sets of 10 repetitions
	Lateral step-downs off a 15.25-cm step		3 sets of 10 repetitions
	Single-leg calf raises		3 sets of 10 repetitions
Week 7	Single-leg standing on Airex pad		3 sets of 30 seconds
	Lunges to a 20.3-cm step		3 sets of 10 repetitions
	Lateral step-downs off a 15.25-cm step with resistance		3 sets of 10 repetitions
	Single-leg calf raises off a step		3 sets of 10 repetitions
Week 8	Single-leg standing on Airex pad with diagonal pull		3 sets of 30 seconds
	Lunges to a 10-cm step		3 sets of 10 repetitions
	Lateral step-downs off a 20.3-cm step		3 sets of 10 repetitions
	Single-leg calf raises on Airex pad		3 sets of 10 repetitions

ERRATUM

In the August 2011 issue of the *JOSPT*, the article "Hip Strengthening Prior to Functional Exercises Reduces Pain Sooner Than Quadriceps Strengthening in Females With Patellofemoral Pain Syndrome: A Randomized Clinical Trial" by Dolak et al (*J Orthop Sports Phys Ther 2011;41[8]:560-570. doi:10.2519/jospt.2011.3499*), **FIGURE 7**, page 566, the bars representing percent strength values for the quadriceps strengthening group (Quad Group) were incorrectly represented. We apologize for this error. The corrected graph is printed below. These changes are reflected in the electronic version of the article available at www.jospt.org (http://dx.doi.org/10.2519/jospt.2011.3499). ◉

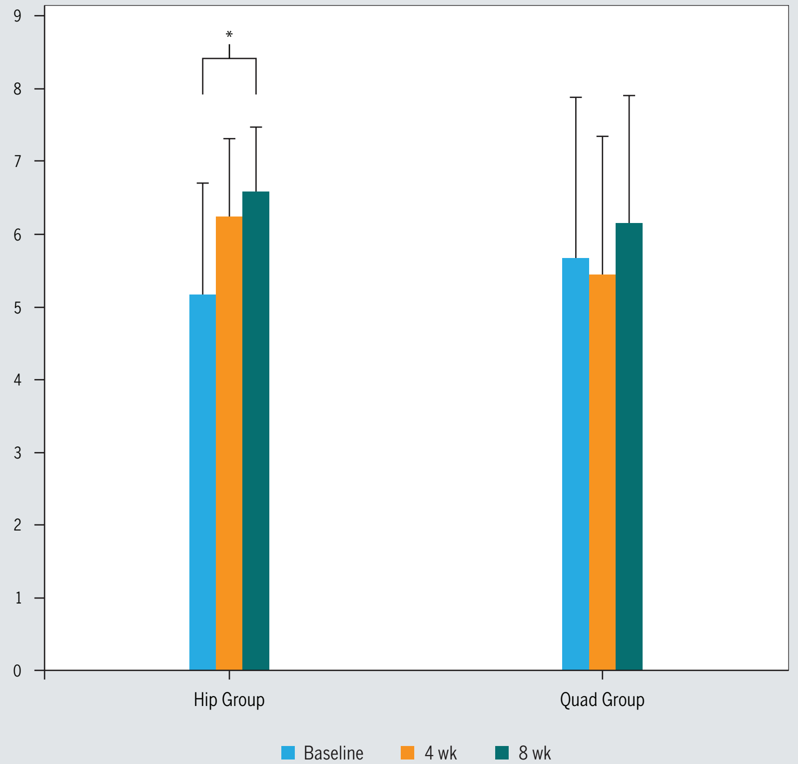

FIGURE 7. Mean percent strength values for hip abductors. Error bars are standard deviations. *Significant difference between baseline and 8 weeks for the hip group (*P*<.001).