Effects of Core Neuromuscular Training on Pain, Balance, and Functional Performance in Women With Patellofemoral Pain Syndrome: A Clinical Trial

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Abstract

Objective: The purpose of this study was to determine the effects of core neuromuscular training on pain, balance, and performance in women with patellofemoral pain syndrome (PFPS).

Methods: This randomized single-blind trial was based on a convenience sample of 28 women with unilateral PFPS. All participants were assigned randomly to the intervention or control group with a block randomization method. The control group received routine physical therapy exercise for PFPS. The intervention group received core neuromuscular training in addition to routine physical therapy exercise. The outcome measures evaluated were pain intensity (Visual Analog Scale), function (Kujala patellofemoral questionnaire and step-down performance test), and balance (Y balance test).

Results: In both groups the pain score was significantly lower after treatment ($P = .001$). The slope of this trend was greater in the intervention group. The Kujala and step-down scores improved significantly after treatment in both groups, although the improvements were greater in the intervention group. The Y balance score improved in all 3 directions after therapy in both groups ($P < .05$); improvement was significantly greater in the intervention group only in the posteromedial direction ($P = .016$).

Conclusion: For the group of participants studied, a 4-week core neuromuscular training plus routine physiotherapy exercise was more effective than routine physiotherapy exercise alone for improving pain, balance, and functional performance in individuals with PFPS. (J Chiropr Med 2019;18:9-18)

Key Indexing Terms: *Patellofemoral Pain Syndrome; Exercise; Postural Balance; Physical Therapy Modalities; Knee Joint*

Introduction

Patellofemoral pain syndrome (PFPS) is a common musculoskeletal disorder affecting a large proportion of clinical patients.[1] The prevalence of PFPS is twice as high in women as in men, and this high prevalence imposes health care and socioeconomic costs on communities.[2,3] Inflammation, stiffness, giving way, crepitation, and diffuse retropatellar pain during functional activities, such as stair climbing, are prevalent among these patients.[4,5] There is no consensus regarding the pathophysiology of this syndrome. Recent views support a multifactorial basis in which different contributing factors result in excessive stress on the patellofemoral joint.[6] Previous studies considered patellar maltracking to be the most likely cause of PFPS.[7] Maltracking may lead to inappropriate timing of quadriceps muscle activity.[8]

In addition to quadriceps muscle dysfunction, some studies showed that core (lumbo-pelvic-hip complex) muscle activation (onset and recruitment pattern) is impaired in patients with PFPS.[9-13] Because of impaired core muscle activation, these muscles should be a focus of rehabilitation protocols.

Moreover, recent studies have found that balance in individuals with PFPS and other musculoskeletal problems also is compromised.[14-17] Because of the importance of balance in daily activities, patellofemoral joint rehabilitation programs should be designed to include this factor.

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Currently the focus of treatment is on quadriceps muscle strengthening, gastrocnemius or hamstring stretching, and the use of nonsteroidal anti-inflammatory drugs.[2] Despite the importance of core training, the related exercises are rarely used in rehabilitation for PFPS to improve balance.

Fillipa et al showed that core training improves performance in the star excursion balance test in healthy people.[18] Moreover, core exercises are potentially effective in improving function, balance, and pain in patients with PFPS. Although previous studies have documented the importance of core muscle impairment in patients with PFPS,[19-21] the effectiveness of core muscle training has not been investigated in detail. Considering these gaps, the purpose of the present study was to evaluate the effectiveness of adding core neuromuscular training to routine physical therapy exercise in improving pain, balance, and performance in these patients. We hypothesized that adding core neuromuscular training to routine physical therapy exercise can improve pain, balance, and performance in patients with PFPS.

Methods

Study Design

This parallel, single-blind randomized clinical trial was designed to compare the effect of 2 different treatment protocols (routine physical therapy exercise vs routine physical therapy exercise plus core neuromuscular training) on balance, function, and pain in patients with PFPS. Ethics approval was granted by the research ethics committee of the Shiraz University of Medical Sciences (approval code: 92-01-06-5724). This study was registered in the Iranian Registry of Clinical Trials (IRCT2014021315932N2).

Recruitment and Participants

A convenience sample was recruited consisting of 28 women with unilateral PFPS diagnosed by an orthopedic specialist. In this study, the pain score was considered as primary outcome measure. Based on the data in a similar previous study,[22] a minimum of 28 participants, 14 per group, was considered necessary to detect a significant change of 3 points[23] in the pain score ($\alpha = 0.05$, $\beta = 0.2$).

The participants were selected among patients who were referred to the Motahari Clinic of Shiraz University of Medical Sciences. These participants were not athletes and did not exercise regularly. All women were referred to the physiotherapy clinic by an orthopedic specialist, and each participant completed a consent form before enrollment. The participants then were assigned randomly to the intervention or the control group with a block randomization method (14 blocks, 2 block sizes), using a random-number generator in randomization software. The results of group allocation were concealed via drawing from a sealed opaque envelope. The participants in each group were not aware of the treatment plan of the other group. The physiotherapist who measured the outcome measures was blinded to the patient's allocation group. Baseline information was collected after randomization, and post-intervention outcomes were collected immediately after the last session.

Women in the intervention group received core neuromuscular training in addition to routine physical therapy exercise for PFPS. Individuals in the control group received only routine physical therapy exercise. The demographic characteristics of participants are shown in Table 1.

Inclusion Criteria. Women between 18 and 40 years old with PFPS were included if they had anterior knee pain during at least 2 functional activities including step-up and step-down, squatting, kneeling, jumping, or running, of at least 2 months' duration.[7,24,25] The diagnosis of PFPS was confirmed by a positive patellar grind test and tenderness of the medial and lateral patellar facets.[24] The patellar grind test has acceptable sensitivity (29%-49%) and specificity (67%-95%).[26] Additional inclusion criteria were pain intensity of more than 3 on a Visual Analog Scale (VAS) and Kujala patellofemoral questionnaire score of 50 to 80 before the intervention.[23,27] We included participants who did not get analgesic drugs from 2 weeks before the study commencement.

Exclusion Criteria. Participants were excluded if they had knee meniscus, ligament, or tendon pathologies; subluxation or dislocation of the patella; Sinding-Larsen-Johansson syndrome; Osgood-Schlatter disease; or plica syndrome.[28,29] Patients also were excluded if they had low back pain, previous pathology, or surgery of the spine or lower limb with or without referred pain.[28] In addition, women with any neuromuscular, rheumatologic, or metabolic diseases (such as diabetic neuropathy) that might affect the outcome measures were excluded.

Procedure

Pain intensity, functional ability, functional performance, and balance were assessed before and after the intervention with the VAS, Kujala questionnaire, step-down test, and Y balance test, respectively.

Pain. We used a VAS to evaluate average level of usual pain in last month before assessment and immediately after the intervention. In this reliable tool,[30,31] patients determine their pain intensity along a 100-mm line (0 indicates no pain and 100 indicates maximum pain).

Functional Ability and Performance. The validated Persian version of the Kujala questionnaire was used for subjective functional assessments of the knee joint (Persian Kujala: intraclass correlation coefficient = 0.96, Cronbach's α = 0.81) This questionnaire is a specific, time-saving, and easily understandable tool for PFPS.[32] On this scale the highest obtainable score is 100, and lower scores indicate

Table 1. *Patient Demographics at Baseline, Mean (SD)*

Demographics	Control Group	Intervention Group
Age (y)	30.42 ± 6.13	28.35 ± 5.67
Height (m)	1.59 ± 0.05	1.61 ± 0.06
Weight (kg)	58.70 ± 7.90	58.52 ± 8.82
Body mass index (kg/m^2)	23.20 ± 3.32	22.55 ± 3.03

SD, standard deviation.

greater disability.[33] The step-down performance test (Fig 1) was used to estimate the participants' functional level objectively. In this test, only the heel touches the floor after each knee extension. The patient was instructed to perform maximum forward step-down on the affected side for 30 seconds, and the number of step-downs was recorded. This test was repeated 3×, and the average of the 3 numbers was recorded as the final score. The height of the step was 20 cm.[34] This test simulates stair descent and is correlated with pain in patients with PFPS and has high intrarater reliability (0.94).[35]

Balance. The Y balance test was used to measure dynamic balance.[23] The patient was asked to place the heel of her affected limb at the center of the Y pattern and move her big toe on the unaffected side as far as possible in the anterior, posteromedial, and posterolateral directions. Each direction was repeated 3×, and the average score was recorded as the result. If the patient lost her balance, the test was repeated.[36,37] An appropriate Y balance test was performed by applying 3 strips of tape on the ground to make a Y with anterior, posteromedial, and posterolateral directions. The test results were normalized to the individual's leg length.[37] The Y balance test has high inter-rater (0.99-1.00) and intra-rater reliability (0.85-0.91).[38] This test is easy to use in the clinic. To measure true leg length, the patient was asked to bridge and the leg was straightened by the physiotherapist. We measured the distance between the anterior superior iliac spine and the medial malleolus.[39]

Fig 1. *The step-down test.*

Interventions

Control Group. The physical therapy exercise program focused mainly on strengthening the knee muscles (mainly quadriceps and hamstring) and flexibility exercises for the gastrocnemius, iliotibial band, and hamstring muscles (Table 2).

Intervention Group. The physical therapy exercise program was the same as in the control group, and core neuromuscular training also was used (Table 2). The participants were taught how to contract their deep abdominal muscles to obtain core muscle activation. The patient should contract the abdominal muscles, lifting her lower belly up away from pubic bone, while breathing slowly and normally. The patient should not hold her breath (Appendix A).

Both groups received physiotherapy exercise for 4 weeks. Each patient performed 3 exercise sessions per day. Patient attendance at the clinic for supervised exercise therapy was considered 1 of 3 exercise sessions per day. The quality and frequency of home exercise was the same as clinic program. To avoid fatigue, a 3-minute rest was allowed between exercises.[39] The exercise trainer and assessor were different therapists.

Data Analysis

All data were analyzed with SPSS software (version 16) (SPSS Inc, Chicago, Illinois), and the significance level was set as 0.05 (power = 0.8). The results of the Kolmogorov-Smirnov test revealed a non-normal distribution of the data. Accordingly, the Wilcoxon signed rank and Mann-Whitney U tests were used, respectively, for within-group and between-group analyses.

Table 2. *Exercise Protocol*

Sessions	Control Group	Intervention Group
First 3 sessions (approximately 19 min)	1. Hamstring, ITB and gastrocnemius stretching (30-s hold, 5 repetitions)[7,40,41] 2. Quadriceps setting (10 repetitions, 10-s hold)[40]	1. Hamstring, ITB, and gastrocnemius stretching (30-s hold, 5 repetitions)[7,40,41] 2. Quadriceps setting (10 repetitions, 10-s hold)[40] 3. Bridging while holding a small ball between knees (3 sets, 10-s hold)[42] 4. Side-lying hip abduction (clam exercise) (6 repetitions, 10-s hold)[41]
Second 3 sessions (approximately 21 min)	1. SLR (3 sets, 10 repetitions, 10-s hold)[40,41] 2. Forward step-up (3 sets, 10 repetitions)[40,41]	1. SLR (3 sets, 10 repetitions, 10-s hold)[40,41] 2. Forward step-up (3 sets, 10 repetitions)[40,41] 3. Lateral SLR (3 sets, 10 s hold)[42] 4. Curl-up while holding a small ball between bent knees (5 repetitions, 10-s hold)[42]
Last 4 sessions (approximately 25 min)	1. Squatting with 30° knee flexion (3 sets, 10-s hold)[7,41] 2. Lateral step-up (3 sets, 10-s hold)[7]	1. Squatting with 30° knee flexion (3 sets, 10-s hold)[7,41] 2. Lateral step-up (3 sets, 10-s hold)[7] 3. Isometric hip abduction in standing position (15 repetitions, 5-s hold)[42] 4. Intermittent shoulder flexion/extension while standing on affected limb (15 repetitions, 5-s hold)[42] 5. Trunk rotation toward healthy side while maintaining hip internal rotation in standing position on the afflicted leg (15 repetitions, 5-s hold)[42] 6. Curl-up while holding a small ball between straight knees (6 repetitions, 10-s hold)[42] 7. Lateral curl-up while holding a small ball between straight knees (6 repetitions, 10-s hold)[42]

ITB, iliotibial band; *SLR*, straight leg raise.

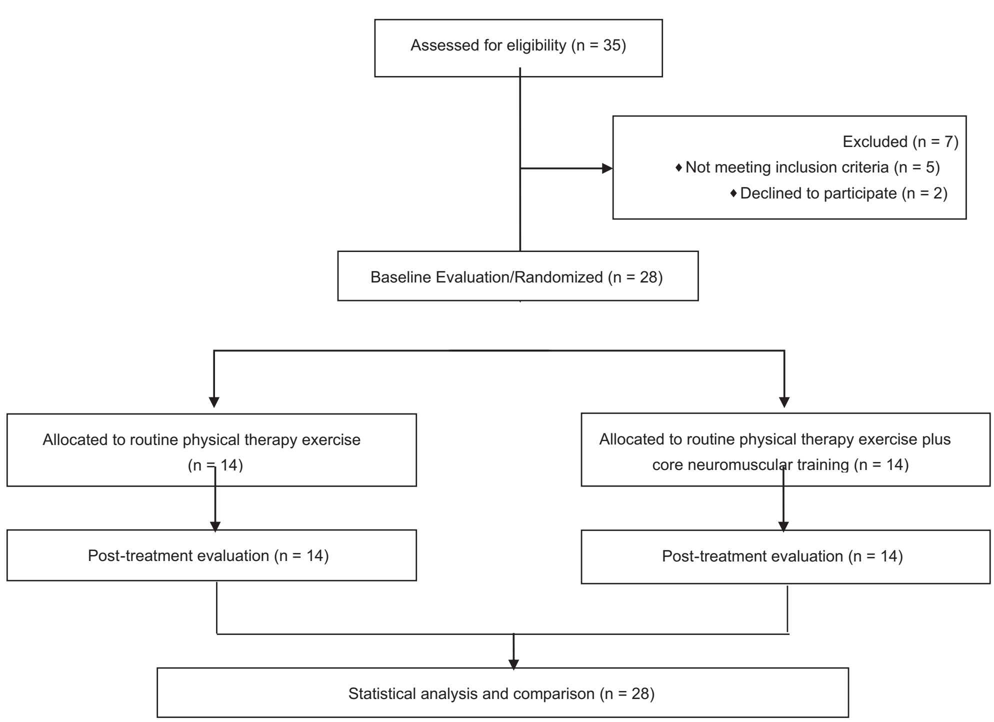

Fig 2. *Flowchart for eligibility, enrollment, and testing procedures.*

Table 3. *Comparison of Baseline Information Between the Control and Intervention Groups*

Outcome Measure		Control Group Median (IQR)	Intervention Group Median (IQR)	*P* Value [a]
Pain (VAS) (mm)		60.00 (40.00-72.5)	65.00 (47.5-70.00)	.999
Kujala score		71.50 (66.00-77.25)	69.50 (67.00-72.25)	.394
Step-down performance grade (steps/30 s)		9.50 (7.66-11.33)	9.16 (7.25-10.66)	.696
Y balance test score (normalized)	Anterior	0.67 (0.53-0.73)	0.60 (0.54-0.70)	.679
	Posteromedial	0.71 (0.63-0.85)	0.71 (0.58-0.81)	.550
	Posterolateral	0.69 (0.49-0.79)	0.72 (0.57-0.77)	.679

IQR, interquartile range; *VAS*, visual analog scale.
[a] $P < .05$ is significant.

Results

A total of 28 women participated in this study. The eligibility criteria are summarized in Fig 2.

No patients dropped out of the study. There were no statistically significant differences in demographic characteristics (height, weight, age, and body mass index) between the 2 groups ($P > .05$). There were no statistically significant differences in outcome measures (pain, Kujala scores, function performance grade, and balance score) between the 2 groups at baseline before the intervention ($P > .05$; Table 3). These findings show similarity between the 2 groups in baseline information.

VAS Score

In both groups, the pain score was significantly lower after treatment ($P = .001$; Table 4). Post-treatment median ± interquartile range of VAS in the control and intervention groups was 20 ± 20 and 20 ± 30, respectively.

Function and Performance

The Kujala and step-down scores improved significantly after treatment in both groups. As seen in Table 4, the improvements were greater in the intervention group. After treatment, the post-treatment median ± interquartile range

Table 4. *Effects of Treatment on Pain, Kujala Score, Step-Down Performance, and Y Balance Test Performance in the Control and Intervention Groups (Mann-Whitney Test)*

Variable		Control Group Median (IQR)	Intervention Group Median (IQR)	*P* Value
Pain score reduction (mm)		30.00 (20.00-40.00) [b]	40.00 (30.00-50.00) [b]	.035 [a]
Kujala score improvement		12.00 (7.75-19.25) [b]	18.50 (12-23.75) [b]	.039 [a]
Step-down improvement (steps/30 s)		2.83 (2.00-4.16) [b]	5.33 (3.33-7.08) [b]	.027 [a]
Balance difference	Anterior	0.08 (0.00-0.10) [b]	0.07 (0.00-0.12) [b]	.946
	Posteromedial	0.04 (0.01-0.13) [b]	0.13 (0.09-0.20) [b]	.016 [a]
	Posterolateral	0.11 (0.07-0.14) [b]	0.10 (0.07-0.14) [b]	.946

IQR, interquartile range.
[a] Indicates significance at $P < .05$ (between-group comparisons).
[b] Indicates significance at $P < .05$ (within-group comparisons).

of the Kujala score in the control and intervention groups was 88 ± 14 and 88 ± 7, respectively.

Y Balance Test

The balance score improved in all 3 directions after treatment in both groups. The improvement was significantly greater in the intervention group only in the posteromedial direction (Table 4). The post-treatment median of the normalized Y balance test (± interquartile range) in the control group was 0.71 ± 0.20, 0.78 ± 0.26, and 0.77 ± 0.23 in anterolateral, posteromedial, and posterolateral directions, respectively. The post-treatment median of the normalized Y balance test (± interquartile range) in the intervention group was 0.70 ± 0.13, 0.85 ± 0.15, and 0.81 ± 0.16 in anterolateral, posteromedial, and posterolateral directions, respectively.

Discussion

The results of this study showed that adding core neuromuscular training to routine physical therapy exercises was beneficial in decreasing pain and improving function and balance in patients with PFPS.

The greater improvements in pain, function, and posteromedial balance in our experimental group can be attributed to the program of core neuromuscular training. No one in either group had any difficulty for doing exercises.

Pain

Pain reduction can be attributed to different factors. One strategy to reduce pain is the use of exercise therapy. Balci et al showed that physical therapy exercise focusing on closed kinematic chain exercises can be effective in alleviating pain and improving function.[27] Better timing and neuromuscular control of the quadriceps muscle, which can be achieved with exercises, also may improve patellar alignment. Better alignment, in turn, leads to pain reduction by decreasing the pressure on the joint space.[7]

Poor core stability causes excessive pressure on lower-extremity joints, including the knee joint.[43] From a kinesiopathology perspective, uncontrolled trunk displacement may lead to increased hip internal rotation and adduction and result in knee valgus posture. This posture can indirectly affect hip and knee joint movement in different planes during activities,[24] and alterations in movements can in turn exert excess pressure on the patellofemoral joint. Core exercises may diminish this pressure and thus contribute to pain reduction.

Previous studies reported minimal clinically important difference for the VAS between 1.1 and 3.[31,44,45] In our study, mean difference of the VAS in the control and intervention groups was 18.6 ± 11.7 and 40.7 ± 14.4, respectively. These values are greater the than minimal clinically important difference, which was reported in previous studies and is clinically significant.

Function and Performance

Pain can influence function in many ways, and function often improves when pain is lessened. Quadriceps weakness and the resultant tibial external rotation can be improved by exercises to strengthen the quadriceps. Improved posture helps to reduce pain and pressure on the patellofemoral joint.[46] Pain and quadriceps inhibition were found to be correlated in patients with PFPS,[8] and pain reduction therefore may improve the function of this muscle. Muscular tightness is another symptom in patients with PFPS.[47,48] Improved iliotibial band flexibility may decrease the pressure of the band on the lateral border of the patella and thus result in functional improvement.[25,49] Adequate postural control and balance also contribute to functional movements.[39] Because balance improved in both groups in the present study, functional status also would be expected to improve.

The greater functional improvement in our intervention group was probably the result of greater pain reduction, and core exercises may have played a significant role in this improvement. The stability needed for lower-extremity movement in all 3 planes is provided by improved core muscle strength, especially from the cocontraction of the back extensor and abdominal muscles.[50] Control and coordination of the trunk and hip muscles is important for functional activity in patients with PFPS.[51] Therefore, improved coordination as a result of the core exercises is the most likely explanation for the better results in our intervention group. However, additional studies will be needed to identify the precise mechanism through which these exercises can lead to improvements.

Previous studies determined a minimal important change for the Kujala questionnaire (mean ± standard deviation) of 10 ± 19.[30,52] In our study, mean differences of Kujala score in the control and intervention groups were 13.21 ± 6.53 and 19.42 ± 7.96, respectively. These values are clinically significant and greater than the minimal important change noted in previous studies.

Balance

Balance outcomes may reflect the patients' functional status, and improvements in performance may be secondary to functional gains.[39] Emerging evidence suggests a direct relationship between pain and postural sway. Hence, reducing pain and improving muscle strength may improve balance.[53,54] In light of the relationship between pain and postural sway, the improvements in balance efficiency in both our groups are probably another reflection of the effects of pain reduction.

Core muscle control may help prevent balance disturbance.[18] In other words, appropriate activation of these muscles may reduce perturbation and favor dynamic stability.[18,55] The Y balance test is a complicated dynamic task that requires a stable base for limb movements,[56] and core muscle activation is important in the performance of this test. In the present study, we found a significant difference between groups only in posteromedial balance. Core exercises in this study required gluteus medius involvement, so our findings may be related to gluteus medius strengthening in the intervention group.

In summary, the core muscle activation pattern may have contributed to our results, and future studies should investigate the effects of this type of exercise in patients with PFPS. Based on the results of this study, we suggest that core neuromuscular training should be considered for inclusion as a part of PFPS rehabilitation protocols.

Previous studies reported a minimal detectable change for the Y balance test (posteromedial direction) of 7.5.[57] In our study, the mean difference of the Y balance test (posteromedial direction) in the control and intervention groups was 6.4 ± 7.6 and 13.6 ± 7.4, respectively. These values are greater than minimal detectable change that was reported in previous studies and is clinically significant.

Limitations

This study is one of the few studies specifically designed to investigate the effect of core training on pain, function, and balance in patients with PFPS. All our participants were women because PFPS is more prevalent in women. We did not measure core and lower-extremity muscle strength or knee and trunk proprioception, both of which may have limited the interpretation of results. So we cannot determine whether our findings are related to the improvement of proprioceptive inputs, muscle strength, or both. In addition, we used routine physical therapy exercise in our control group, hence we did not have a true control group. Because of our small sample size, further studies with a larger sample size and the same design are needed to confirm our results. Based on our inclusion criteria, minimum pain chronicity among patients was considered 2 months, and we did not determine any upper limits for chronicity. That is one of our study limitations. Although the statistical comparison of baseline information for the VAS and Kujala questionnaire did not demonstrate a significant difference between 2 groups, it may indicate that chronicity does not have much of an impact on pain and performance. Moreover, we did not ask any questions about confounders, such as level of physical activity, job, smoking, marital status, education level, and comorbidities.

Future Studies

Participant follow-up may disclose the long-term effects and durability of core training in patients with PFPS, and further studies should investigate this. The use of electromyography to record muscle activity during functional tasks may provide more precise data on muscle performance. Future studies with follow-up assessments are necessary to evaluate long-term effects of core neuromuscular training on patients with PFPS.

Conclusion

A 4-week core neuromuscular training plus routine physiotherapy exercise was more effective than routine physiotherapy exercise alone for improving pain, balance, and functional performance in individuals with PFPS.

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Contributorship Information

Concept development (provided idea for the research): A.M., M.B.M., N.N., N.A.
Design (planned the methods to generate the results): A.M., M.B.M., N.N., N.A.
Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): A.M.
Data collection/processing (responsible for experiments, patient management, organization, or reporting data): M.B.M., N.N., N.A.
Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): A.M., M.M., M.B.M., N.N., N.A., N.E.
Literature search (performed the literature search): M.M., M.B.M., N.N., N.A., N.E.
Writing (responsible for writing a substantive part of the manuscript): A.M., M.M., N.E.
Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): A.M., M.M., N.E.

Appendix A

Deep abdominal muscle contraction: The patient should contract abdominal muscles, lifting her lower belly up away

from pubic bone, while breathing slowly and normally. The patient should imagine drawing her stomach away from her pubic bone. The patient should not hold her breath.

- ✔ Self-static passive hamstring stretching: Supine, lies in a doorway, foot on the door frame, knee extended, close the body to the frame
- ✔ Self-static passive iliotibial band stretching: standing beside a wall, leg that is more near to the wall is crossed behind the other leg, hands overhead, side bend to opposite side
- ✔ Self-static passive gastrocnemius stretching: sitting, knee extended, ankle dorsiflexion with a strap
- ✔ Quadriceps setting: supine, a pillow under the knees, press back of knees to pillow
- ✔ Bridging while holding a small ball between knees: supine, knees bent, feet on the floor, a small ball between knees, elevate the pelvis, extend the hip
- ✔ Active side-lying hip abduction: side-lying, knees extended, abduct upper leg as high as possible
- ✔ Active straight leg raise: supine, one leg flex, the other leg fully extended and raise it approximately 60°
- ✔ Active forward step-up: low step, standing in front of step, step up forward, entire foot completely planted on step
- ✔ Lateral straight leg raise: side-lying, upper knee fully extended, lower knee bent, abducted upper leg
- ✔ Squatting with 30° knee flexion: standing, back lean to the wall, slide back on the wall till knees flexed 30°
- ✔ Curl-up while holding a small ball between bent knees: supine; knees bent; feet on the floor; a small ball between knees; curl the head, neck, and shoulders
- ✔ Lateral step-up: low step, standing, affected side closest to the step, step up laterally, entire foot completely planted on step, bring other foot up to join affected leg, then lower this foot back down
- ✔ Isometric hip abduction in standing position: standing, affected leg closest to a wall, knee extended, move this leg out to the side, press it into the wall
- ✔ Intermittent shoulder flexion/extension while standing on affected limb: standing on affected leg limb, flex and extend shoulder intermittently
- ✔ Trunk rotation toward healthy side while maintaining hip internal rotation in standing position on the affected leg: standing, affected hip internally rotated, trunk rotation toward healthy side
- ✔ Curl-up while holding a small ball between straight knees: supine; knees fully extended; a small ball between knees; curl the head, neck, and shoulders
- ✔ Lateral curl-up while holding a small ball between straight knees: supine; knees fully extended; a small ball between knees; curl the head, neck, and shoulders toward one side

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Practical Applications

- This study showed in the participants studied that core neuromuscular training can be beneficial in improving pain in women with PFPS.
- This study also showed that core neuromuscular training can improve balance and function in women with PFPS.

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