



Original Article

Carryover effect of hip and knee exercises program on functional performance in individuals with patellofemoral pain syndrome

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Abstract. [Purpose] This study was carried out to investigate the carryover effect of hip and knee exercises program on functional performance (single legged hop test as functional performance test and Kujala score for functional activities). [Subjects and Methods] Thirty patients with patellofemoral pain syndrome were randomly assigned into two equal groups. Group (A) consisted of 15 patients undergoing hip strengthening exercises for four weeks then measuring all variables followed by additional four weeks of knee exercises program then measuring all variables again. Group (B): consisted of 15 patients undergoing knee exercises program for four weeks then measuring all variables followed by additional four weeks of hip strengthening exercises then measuring all variables. Functional abilities and knee muscles performance were assessed using Kujala questionnaire and single legged hop test respectively pre and after the completion of the first 4 weeks then after 8 weeks for both groups. [Results] Significantly increase in Kujala questionnaire in group A compared with group B was observed. While, there were significant increase in single legged hop performance test in group B compared with group A. [Conclusion] Starting with hip exercises improve the performance of subjects more than functional activities while starting with knee exercises improve the functional activities of subjects more than performance.

Key words: Patellofemoral pain syndrome, Single legged hop test, Hip and knee exercises

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INTRODUCTION

Patellofemoral Pain Syndrome (PFPS) is a term for different pathologies or anatomical variations from the normal resulting into a kind of anterior knee pain². It is additionally a typical complaint in athletes and overall communities particularly in which repetitive lower limb loading is experienced. It is more predominant in female than in male with higher incidence rates in physically dynamic young adult more prominent than 25%². PFPS was referred to by such term as anterior knee pain, patellofemoral dysfunction, patellar subluxation or patellar compression syndrome¹.

Despite the fact that the etiology of PFPS was clearly uncovered, repetitive loading of patellofemoral joint can bring on damage to the retropatellar cartilage and subchondral bone³. Strength imbalance in extensor mechanism can result in patellofemoral pain by stimulating nociceptive fibers in synovium and retinaculum⁴. It has been accused that, patellofemoral joint reaction forces increased in conditions like running, stair-climbing and diving, slant climbing and plummeting, or sitting at flexion points at least 90°, and force a lot of weight on patellofemoral joint, subsequently bringing on an increase in pain complaints in patients^{5, 6}. One of the most commonly accepted causes of PFPS was abnormal tracking of the patella within the femoral trochlea. Potential contributing factors that have been studied included vastus medialis obliquus insufficiency,

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and decreased flexibility of soft tissues around the knee⁷). A few speculations for the inception of nontraumatic progressive onset of PFPS were (1) neuromuscular imbalance of both; vastus medialis obliquus and the vastus lateralis muscles; (2) shortening of the lateral knee retinaculum, hamstrings, iliotibial band, and gastrocnemius; and (3) increased pronation of the subtalar joint^{8, 9}).

Research findings suggested that without direct injury, the etiology of PFPS is multifactorial. Components related mainly to disorders at the level of the patellofemoral joint¹⁰, and other variables distal to the knee have additionally been accused to the patellofemoral malalignment and pain^{11, 12}). Other proximal components including hip muscle weakness have been suspected to increase patellofemoral malalignment and the advancement of PFPS signs and symptoms^{4, 5}). Hip musculature assumes an important part in controlling transverse-plane and frontal-plane movements of the femur^{13–15}). Strong evidence was accounted for the decrease in hip external rotation, abduction, and extension strength and moderate evidence for the decrease in flexion and internal rotation strength; however no confirmation for reduction in hip adduction quality in instances of PFPS contrasted with sound controls¹⁶). Treatment of PFPS is varying and controversial. It is generally agreed that PFPS should be managed initially by conservative rather than surgical means¹). However, no single intervention has been demonstrated to be the most effective. Conservative treatment included taping, strengthening of the quadriceps muscle, flexibility training, biofeedback, manual therapy to the lower quarter, and fitting of foot orthoses^{17–20}). When treating patients with PFPS demonstrating lack of control of hip adduction and internal rotation during weight-bearing activities, special considerations were assumed to optimize hip muscles function to control these motions²¹).

Rehabilitation programs focusing on knee strengthening exercises in addition to hip flexors, abductors, and external rotators strengthening were related to successful treatment as defined by at least 15% pain reduction on a pain through visual analogue scale²²). So the aim of this work was to investigate the carryover effect of hip and knee exercises program on functional performance (hopping performance test and Kujala score) in PFPS, in addition to the difference between either starting with hip exercises then ending by knee exercises or starting with knee exercises and ending by hip exercises on hopping performance test and Kujala score in patients with PFPS.

SUBJECTS AND METHODS

Thirty patients with unilateral PFPS aged between of 18–35 years signed an informed consent to participate voluntarily in the study. After a brief orientation session about the nature of the study and the tasks to be accomplished, they were randomly assigned into two equal groups by a blinded and an independent research assistant who opened sealed envelopes that contained a computer generated randomization card. Patients were considered eligible to participate in the study if they had anterior or retropatellar knee pain aggravated by at least two of the following activities, (1) prolonged sitting; (2) stair climbing; (3) squatting; (4) running; (5) kneeling; and (6) hopping/jumping⁷). Participants chosen were also suffering from insidious knee pain not related to a traumatic incident, and persisted for at least 6 weeks. Patients were excluded if they have history of meniscal or ligamentous involvement, patellar subluxation or dislocation, knee or hip joints arthritis, fixed flat foot, and previous surgery in the lower extremity. Patients with conditions which might affect muscle strength such as diabetes mellitus or rheumatoid arthritis were also excluded from the study.

The study was designed as a crossover trial and patients were assigned into either group A or group B (Fig. 1). The study was approved by the Research Ethical Committee, Faculty of Physical Therapy, Cairo University with number: P.T.REC/012/0014.

Group (A): consisted of 15 patients (12 females and 3 males) with mean values \pm standard deviation of age, weight, height and BMI values of 23.33 ± 5.39 years, 71.16 ± 13.05 kg, and 164.75 ± 4.5 cm and 26.21 ± 4.71 kg/m², respectively. In this group, patients started by strengthening hip exercises (hip abductors and lateral rotators) for 4 weeks then measuring all variables followed by knee strengthening exercises program using open kinetic chain exercises program (terminal knee extension and straight leg raisings) and stretching exercises for tight lower extremity soft tissues (quadriceps, hamstring, iliotibial band, gastrocnemius) for additional 4 weeks then measuring all variables again.

Group (B): consisted of 15 patients (9 females and 6 males) with mean values \pm standard deviation of age, weight, height

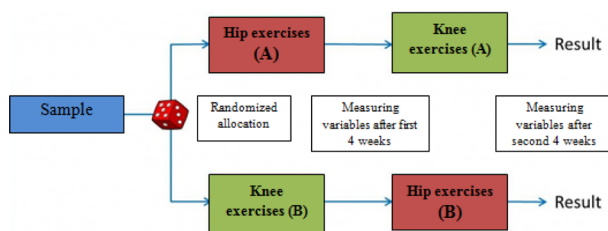


Fig. 1. Sample is randomized into two different treatments (A and B) Group A receives hip exercises during the first period of the study; group B receives knee exercises. After the first period is over, all dependent variables were measured. Group A then receives knee exercises for the second period of the study while group B receives hip exercises. After the second period is over, all dependent variables were measured again.

and BMI values of 23.16 ± 6.33 years, 69.41 ± 18.14 kg, 164.66 ± 7.27 cm and 25.2 ± 6.2 respectively. Patients started by knee exercises program open kinetic chain exercises program (terminal knee extension and straight leg raisings) and stretching exercises for tight lower extremity soft tissues (quadriceps, hamstring, iliotibial band, gastrocnemius) for 4 weeks then measuring all variables followed by strengthening hip exercises (hip abductors and lateral rotators) for another 4 weeks then measuring all variables.

Evaluation for all participants was done as follows. Functional abilities and knee muscles performance using Kujala questionnaire and single-legged hop test respectively pre and after the completion of the first 4 weeks then after 8 weeks for both groups

The participant's functional status was assessed using Kujala questionnaire for patellofemoral joint pain²³). It is a 13-items knee specific self-report questionnaire, it documents response to 6 activities thought to be associated specifically with anterior knee pain syndrome (walking, running, jumping, climbing, stairs, squatting, and sitting for prolonged periods with knees bent), as well as symptoms such as limp, inability to bear weight through the affected limb, swelling, abnormal patellar movement, muscle atrophy, pain and limitation of knee flexion. The maximum total score of this assessment tool is 100, with higher scores indicating greater levels of function with lower levels of pain. This scale was considered as having high test-retest reliability, moderate responsiveness, and adequate validity²³).

Single-legged hop tests are performance-based measures used to assess the combination of muscle strength, neuromuscular control, confidence in the limb, and the ability to tolerate loads related to sports-specific activities²⁴). These tests are commonly used to quantify knee performance in patients after reconstruction surgeries²⁴⁻²⁶).

Patients performed 4 single-legged hop tests: the single hop for distance (single hop), crossover hop for distance (crossover hop), triple hop for distance (triple hop), and 6-meter timed hop (6-m timed hop)²⁷). These 4 tests have demonstrated good test-retest reliability in normal, young adults and in patients after ACL reconstruction²⁴). The single hop for distance was performed with the patient standing on the leg to be tested, hopping as far as possible, and landing on the same leg. The total distance hopped forward was recorded. The single hop was considered successful if the landing was stable. To be considered a valid trial, the landing was insisted to be on 1 limb, under complete control of the patient. If the patient landed with early touchdown of the contralateral limb, had loss of balance, touched the wall, or had additional hops after landing, the hop was repeated. Patients were instructed to begin with the painful leg, with their tip toe behind a marked starting line. The hop distance was measured to the nearest centimeter from the starting line to the patient's heel with a standard tape measure. All single-legged hop tests were conducted by physical therapists that had undergone detailed training in the test procedures. The test was repeated three times and the average was taken as the result for more accuracy.

Each patient in both groups received 12 sessions (3 sessions per week for 4 weeks) of hip strengthening exercises in group (A) and knee program exercises for group (B). Each strengthening exercise was performed for three sets of 10 repetitions with 3 seconds rest between repetitions and 1 minute rest after each set. Each patient was trained at 60% of 10 repetitions maximum which is the amount of weight that was lifted and lowered through available range of motion exactly 10 times²⁸). To determine the 10 repetition maximum, the therapist selected a specific amount of resistance and document how many repetitions can be completed through the full range before the participants reported to fatigue. A new 10 repetition maximum was established at the end of each week of training²⁸).

Hip strengthening exercises for hip abductors and external rotators were performed while lying on the non affected side, the patient was asked to bend the knee of the non affected side and extend the affected knee, while the therapist stabilized the pelvis. A sandbag was wrapped just proximal to the lateral malleolus and the patient was asked to raise his limb in abduction, hold for 6 seconds count, then lowering his limb slowly through 6 seconds and return to starting position and relax^{29, 30}).

Hip external rotation strengthening exercise were performed as follows: The patient was sitting at the edge of the bed with the hip and knee joints flexed to 90 degree, and his hand behind him for support while the therapist was stabilizing the patient's thigh. Sandbag was wrapped just proximal to lateral malleolus, then the patient was asked to rotate the leg inward toward the non affected side, hold for 6 seconds count, then return to starting position slowly through 6 seconds and relax^{29, 30}).

Regarding the Knee exercises program: The exercise protocol included strengthening and stretching exercises^{31, 32}). Strengthening exercises program included straight leg raisings exercise. In this exercise, the patient laid supine with the knee in zero degree of flexion and the uninvolved leg was resting on the plinth with 90° of flexion for stability. Sandbag was wrapped just proximal to the ankle joint, the patient was asked to contract the quadriceps and lift the involved leg up to the level of uninvolved knee as much as possible then hold for 6 seconds count, and finally return to starting position slowly through 6 seconds and relax^{31, 32}).

Terminal knee extension exercises (short arc movements from 15° of knee flexion to terminal extension): While the patient lying supine with both knees fully extended, the therapist placed a rolled up towel under the involved knee. Sandbag was wrapped just proximal to the ankle joint. The patient was asked to lift the involved foot up by straightening the knee as far as possible (still supported by the roll) and hold for 6 seconds count, then return to starting position slowly through 6 seconds and relax^{31, 32}).

Stretching exercises program (for quadriceps, hamstring, iliotibial band and gastrocnemius)^{28, 32}): For hamstring stretching exercise, the patient laid supine, with the knee fully extended. The patient's leg was supported over the therapist's arm or shoulder. The therapist stabilized the patient's opposite extremity along the anterior aspect of the thigh by a belt. This position was maintained for 30 sec then released with 3 times repetition and rest for 10 seconds between each repetition.

Quadriceps stretching exercise: The patient laid side lying on the nonaffected limb, the therapist stood behind the patient while grasping the flexed knee, and the pelvis was stabilized by the other therapist's hand. The therapist pulled the limb backward, and held this position for 30 seconds then released with 3 times repetition and rest for 10 seconds between each repetition^{28, 32}. In the same position, the Iliotibial band stretching was done. The therapist stabilized the pelvis by one hand and the other hand adducted the upper-most limb cross the other limb. For all stretching exercises, the stretch position was maintained for 30 seconds and repeated 3 times with a rest period of 10 seconds between each two repetitions^{28, 32}.

Gastrocnemius stretching exercise: patient supine lying position, the therapist stood at the affected side with one hand fixing the leg and the other hand cupping the patient heel. The therapist applied a stretch force by his hand, and maintained this position for 30 seconds then released with 3 times repetition and rest for 10 seconds between each repetition^{28, 32}.

Data analysis was performed using (SPSS, Inc. Chicago, IL, USA) program version 20 for Windows. The sample size (30 patients) was calculated to yield an 80% power and $\alpha=0.05$. Prior to final analysis, data were screened for normality assumption and presence of extreme scores. This exploration was done as a pre-requisite for parametric calculation of the analysis of differences and of relationship measures. 2×2 Mixed design MANOVA was used to compare the tested variables of interest at different tested groups and training periods.

RESULTS

There were no statistically significant differences ($p>0.05$) between subjects in both groups concerning age, body mass, height, and BMI (Table 1).

Statistical analysis revealed that there were significant within subject effect ($F=30.565, p=0.0001$) and treatment*time effect ($F=3.222, p=0.039$) but there were no significant between subject effect ($F=1.427, p=0.265$). Table 2 represents the mean \pm SD and multiple pairwise comparisons for all dependent variables in both groups in different measuring periods. Multiple pairwise comparison tests revealed that there were significant increase in hopping test and Kujala questionnaire in the post 4 weeks treatment condition compared with the pre-treatment one with percentage of improvement (15.13% and 20.5%) for group A and (11.5% and 20.9%) for group B ($p<0.05$) respectively. Additionally, there were significant increase in hopping test and Kujala questionnaire in the post 8 weeks treatment condition compared with the pre-treatment one with percent of improvement (15.24% and 35.7%) for group A and (21.3% and 26.7%) for group B ($p<0.05$) respectively. Significant increase in Kujala questionnaire in the post 8 weeks treatment condition compared with the post 4 weeks treatment with percent of improvement (12.6%) while there was no significant difference in hopping test in the post 8 weeks treatment condition compared with the post 4 weeks treatment with percent of improvement of (0.096%) for group A. Another recording was that there was significant increase in hopping test in the post 8 weeks treatment condition compared with the post 4 weeks treatment with percent of improvement (8.81%) contrasted with no significant difference in Kujala questionnaire in the post 8 weeks treatment condition compared with the post 4 weeks treatment with percent of improvement of (4.85%) for group B.

Regarding between subject effects, multiple pairwise comparisons revealed that there were significant increase ($p<0.05$) in Kujala questionnaire in group A compared with group B. While, there were significant increase ($p<0.05$) in hopping test in group B compared with group A, with no significant differences in hopping test and Kujala questionnaire between both groups at the pre and post 4 weeks of treatment.

Table 1. Demographic characteristics of the patients with patellofemoral pain syndrome for both groups

Characteristics	Group A (n=15)	Group B (n=15)
Age (years)	23 \pm 5.4	23 \pm 6.0
Weight (kg)	71 \pm 13	69 \pm 18
Height (cm)	164.8 \pm 4.6	164.7 \pm 7.3
BMI (kg/m ²)	25 \pm 4.8	25.4 \pm 6.2

Table 2. Dependent variables in patients with patellofemoral pain syndrome in pre, post four weeks and post eight weeks of exercises for both groups

	Group A (N=15)			Group B (N=15)		
	Pre exercises	Post 4 weeks	Post 8 weeks	Pre exercises	Post 4 weeks	Post 8 weeks
Hopping test (cm)	89.8 \pm 28.5	103.4 \pm 27.7*	103.5 \pm 26.2 [#]	103.4 \pm 25.2	115.2 \pm 21.5*	125.4 \pm 23.6 ^{#Ω}
Kujala questionnaire (score)	69.8 \pm 9.8	84.1 \pm 7.7*	94.7 \pm 5.2 [#]	68.1 \pm 13.8	82.4 \pm 10.5*	86.4 \pm 10.5 ^{#Ω}

*significant ($p<0.05$) difference between pre and post 4 weeks, [#]significant ($p<0.05$) difference between pre and post 8 weeks, ^Ωsignificant ($p<0.05$) difference between post 4 weeks and post 8 weeks, ^Ωsignificant ($p<0.05$) difference between both groups at post 8 weeks

DISCUSSION

This is the first crossover trial to investigate the carry over effect of starting the isolated hip abductors and external rotators strengthening exercises for group A and knee strengthening and stretching exercises for group B for four weeks then crossing over the treatment for another 4 weeks where group A received knee strengthening and stretching exercises and group B received isolated hip abductors and external rotators strengthening exercises on performance and functional activity (hopping test and Kujala questionnaire) of PFP patients. The results of this crossover trial revealed that the group A showed marked improvement in hopping test while group B had higher percent of improvement in Kujala questionnaire at the first 4 weeks. On the other hand, group A had higher percent of improvement in Kujala questionnaire compared with group B that showed higher percent of improvement in hopping test at the second 4 weeks. Such results can implicate that hip strengthening exercises could potentially be the main responsible for improving hopping test at both groups while knee exercises program could be the main responsible for improving Kujala questionnaire. Additionally, the carry over effect showed significant increase in Kujala questionnaire in group A compared with group B. While, there were significant increase in hopping test in group B compared with group A.

This carry over effect reflected that starting with hip strengthening exercise before knee exercises program improved functional activity (Kujala questionnaire) more than starting with knee exercises program; while starting with knee exercises program before hip strengthening exercise improved hopping test (performance test) more than starting with hip strengthening exercise.

Based on the obtained results, it is thought that the muscles that directly influence the hip have also an effect on the knee. Specifically, the abductor and lateral rotators that might help control forces applied to the knee joint, and help control femoral medial rotation and adduction during dynamic daily activities³³). The hip external rotator and abductor muscles contribute to pelvic stability and leg alignment by eccentrically controlling femoral internal rotation and influencing the hip adduction during weight bearing activities³⁴). It is hypothesized that weakness of these muscles may increase the medial femoral rotation and valgus knee movement. These deviations may alter the abduction/adduction moment at the hip or might lead to an increase in the Q angle, which may subsequently alter tracking of the patella, increase compressive forces on the patellofemoral joint, and ultimately lead to knee pain⁴).

In this means, strengthening these muscles might have reversed this effect and reduced pain at knee level and might contributed to improve in functional activity. These findings are compatible with Long-Rossi and Salsich³⁴) who reported that pain during unilateral squat explained 22% of the variance in function, suggesting that the level of pain a person has during weight-bearing task influences functional status since the Kujala questionnaire includes questions about pain and its impact on tasks such as stair climbing, running, jumping and squatting. However, the fact that only 22% of the variance in function was explained by pain suggests that factors other than pain might have an impact on function.

Additionally, Long-Rossi and Salsich³⁴) revealed that hip lateral rotator muscle strength explained an additional 14% of the variance in Kujala score, beyond the variance already explained by pain. The authors concluded that pain during unilateral squat and hip lateral rotator muscle strength contributed to functional status in females with PFP, suggesting that rehabilitation strategies aimed at improving pain and increasing hip lateral rotator strength may improve functional outcomes in females suffering from this common pain condition. Previous studies have also reported strong correlation between restoration of quadriceps strength and improvement in pain and functional outcome³⁵).

Mascal et al.³⁶) were the first to demonstrate that an exercise program addressing hip and trunk strength was effective in decreasing pain, improving hip kinematics, and restoring function in 2 patients with PFP. Subsequent studies by Tyler et al.⁷) demonstrated that exercise programs incorporating hip strengthening resulted in improved pain and functional outcomes in females with PFP. On the other hand, Dolak and colleagues³⁷) reported that 4 weeks of isolated hip strengthening prior to the initiation of 4 weeks of weight-bearing exercise reduced self-reported symptoms earlier than when 4 weeks of quadriceps strengthening were performed prior to the same weight-bearing program. In the same track, Khayambashi et al.³⁸) concluded that a program of isolated hip abductor and external rotator strengthening was effective in improving pain and health status in females with PFP.

On the basis of our results, it can be deduced that strengthening of hip abductor and lateral rotator muscles might play an important role in patellofemoral treatment. One limitation of this study was that it did not include a controlled follow-up period, so no conclusions can be drawn regarding long-term benefits of such treatment intervention. Another issue is that this study had some sort of construct under representation as the program of treatment was performed in non-weight bearing position while all dependent variables were measured in weight bearing status implicating that potential future. So that future studies should focus on weight bearing strengthening exercises for both hip and knee muscles rather than non-weight bearing exercises. Also, future studies might need to incorporate multiple measures of muscle performance and functional tasks such as concentric or eccentric muscle force, torque or power, or time to peak torque are more closely related outcome measures related function.

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