Mechanical Response of Hip and Knee Muscles Following Randomized Crossover Trials in Patellofemoral Pain Syndrome

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ABSTRACT

Background: Faulty hip kinematics during weight bearing activities is proposed to contribute to patellofemoral pain syndrome (PFPS). However, limited information exists to determine the effectiveness of exercises programs that not only act on the knee joint, but also on the hip joint in these patients. **Purpose:** The purpose of this study was to compare between the effect of the starting of hip strengthening exercises before knee exercises program and the starting of knee exercises program before hip strengthening exercises on pain intensity, Kujala questionnaire scale, Q angle, anteversion angle, and knee extensors, hip abductors and lateral rotators peak torques (PT) in patients with PFPS. **Materials and Methods:** Twenty four patients suffering from PFPS were randomly assigned into two equal groups of twelve. Group (A) mean age, weight, height and BMI values were 23.33±5.39 years, 71.16±13.05 kg, 164.75±4.5 cm, and 26.21±4.71 kg/m² respectively. They received hip abductors and external rotators strengthening exercises for three weeks followed by knee extensors strengthening exercises and stretching exercises for quadriceps, hamstring, gastrocnemus muscles and iliotibial band for another three weeks. Group (B) with mean age, weight, height and BMI values were 23.16±6.33 years, 69.41±18.14 kg, 164.66±7.27 cm, and 25.2±6.2 kg/m² respectively. They received knee extensors strengthening exercises and stretching exercises for quadriceps, hamstring, gastrocnemus muscles, and iliotibial band for three weeks followed by hip abductors and external rotators strengthening exercises for another three weeks. Both groups received three to four sessions per week for six weeks. Pain level, Kujala scale, Q-angle, anteversion angle, and isokinetic eccentric PT for hip abductors, hip external rotators, and knee extensors were recorded before, after three weeks, and after six weeks of exercises. **Results:** 2x3 Mixed Design MANOVA revealed that there was a significant reduction in level of perceived pain and improvement of Kujala scale in group (A) compared with group (B) after six weeks of

exercise ($p<0.05$). However, there was no significant difference in the Q angle, anteversion angle, and isokinetic eccentric PT for hip abductors, hip external rotators and knee extensors between the tested groups after six weeks of exercise ($p>0.05$). **Conclusion:** Starting rehabilitation program with hip strengthening exercises is more effective than starting with knee strengthening and stretching exercises in reducing pain and improving Kujala scale in patients with PFPS. Consequently, this may help physiotherapists in designing the most effective and efficient prevention and rehabilitation programs for patients suffering from PFPS.
Key words: Patellofemoral Pain Syndrome, Hip, Knee, Strengthening Exercises, Q-Angle, Anteversion Angle.

INTRODUCTION

Patellofemoral pain syndrome (PFPS) is a common complaint in athletes and general populations especially in which repetitive lower limb loading is involved. It is more prevalent in female than in male with reported incidence rates in physically active young adult greater than 25 %[1]. PFPS was known by such terms as anterior knee pain, patellofemoral dysfunction, patellar subluxation or patellar compression syndrome[2].

Although the etiology of PFPS was not exactly understood, repetitive loading of patellofemoral joint caused damage in retropatellar cartilage and subchondral bone[3]. Strength imbalance in extensor mechanism results in patellofemoral pain by stimulating nociceptive fibers in synovium and retinaculum[4]. Patellofemoral joint reaction forces increased on conditions like running, stair-climbing and descending, slope-climbing and descending, or sitting at flexion angles at 90° or more, and impose too much pressure on patellofemoral joint, therefore caused 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 include vastus medialis obliquus insufficiency, decreased flexibility of soft tissues around the knee[7].

Some theories for the origin of nontraumatic gradual onset of PFPS are: (1) neuromuscular imbalance of the vastus medialis obliqus (VMO) and the vastus lateralis (VL) muscles; (2) tightness of the lateral knee retinaculum, hamstrings, iliotibial band, and gastrocnemius; and (3) overpronation of the subtalar joint[8, 9]. Previous literatures suggested that, in the absence of direct trauma, the etiology of PFPS is multifactorial. Factors related directly to the patellofemoraljoint[10]and factors distal to the knee have also been frequently suggested to contribute to patellofemoral malalignment and pain[11, 12]. Proximal factors including hip muscle weakness have been proposed to contribute to patellofemoral malalignment and the development of PFPS[4, 13]. Hip musculature plays an important role in controlling transverse-plane and frontal-plane motions of the femur[14, 15, 16].

Strong evidence was reported for a decrease in hip external rotation, abduction, and extension strength and moderate evidence for a decrease in flexion and internal rotation strength, but no evidence for decrease in hip adduction strength in cases of PFPS compared with healthy controls[17]. Treatment of PFPS is varying and controversial. It is generally agreed that PFPS should be managed initially by conservative rather than surgical means[2]. However, no single intervention has been demonstrated to be the most effective. Conservative treatment include taping, strengthening of the quadriceps muscle, flexibility training, biofeedback, manual therapy to the lower quarter, and fitting of foot orthoses[18,19,20,21]. When treating patients with PFPS who demonstrate lack of control of hip adduction and internal rotation during weight-bearing activities, one goal may be to optimize hip muscle function to control these motions [22].

Rehabilitation programs focusing on knee strengthening exercises and the hip flexors, abductors, and external rotators strengthening were related to successful treatment as defined by at least 15% pain reduction on a pain visual analogue scale[23]. Program of isolated hip abductor and external rotator strengthening was effective in improving pain and health status in females with PFP compared to a no-exercise control group[24]. The incorporation of hip-strengthening exercises should be considered when designing a rehabilitation program for females with PFP. But to the author's knowledge, there is no previous study compared between the carry over effect of starting the isolated hip abductors and external rotators strengthening exercises before the knee strengthening and stretching exercises versus starting the knee strengthening and stretching exercises before the isolated hip abductors and external rotators strengthening exercises. So, in this study the researchers investigated the carry over effect of starting the isolated hip abductors and external rotators strengthening exercises before the knee strengthening and stretching exercises versus starting the knee strengthening and stretching exercises before the isolated hip abductors and external rotators strengthening exercises on pain level, Kujala questionnaire scale, Q angle, anteversion angle, and isokinetic eccentric peak torques of knee extensors, hip abductors and lateral rotators in patients with PFPS.

METHODS

Subjects

Twenty- four patients with PFPS with an age rang 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 assisstant who opened sealed envelopes that contained a computer generated randomization card. Group (A):study 1 consisted of twelve patients (10 females and 2 males) with mean ± SD age, weight, and height of 23.33±5.39 years, 71.16±13.05 kg, and 164.75±4.5 cm respectively. They started their rehabilitation program with hip strengthening exercises (hip abductors and lateral rotators) for three weeks then all dependent variables were measured. This is followed by open kinetic chain strengthening exercises for the knee (terminal knee extension and straight leg raisings) and stretching exercises for tight lower extremity soft tissues (quadriceps, hamstring, iliotibial band, and gastrocnemius) for another three weeks then measuring all dependent variables again.

Group (B):study 2 consisted of twelve patients (7 females and 5 males) with mean ± SD age, weight, and of 23.16±6.33 years, 69.41±18.14 kg, and 164.66±7.27 cm respectively. They started by open kinetic chain strengthening exercises for the knee (terminal knee extension and straight leg raisings) and stretching exercises for tight lower extremity soft tissues (quadriceps, hamstring, iliotibial band, and gastrocnemius) for three weeks after which all dependent variables were measured. Then hip strengthening exercises (hip abductors and lateral rotators) were conducted for another three weeks then measuring all dependent variables again.

. All participants were referred from the same orthopedic surgeon who was informed of patient inclusion and exclusion criteria. Patients were included if they had anterior or retropatellar knee pain from at least 2 of the following Activities[7]: (1) prolonged sitting; (2) stair climbing; (3) squatting; (4) running; (5) kneeling; and (6) hopping/jumping. Insidious onset of symptoms unrelated to a traumatic incident and Persistent for at least six weeks. Patients were excluded if they had history of any of the following condition: meniscal or other intra articular pathologic conditions; cruciate or collateral ligament involvement, patellar subluxation or dislocation, previous surgery in the knee and hip joints, Knee and hip joints osteoarthritis, fixed flat foot and a history of any conditions affects muscle strength as diabetes mellitus or rheumatoid arthritis. Of the intial

36 pateints recruited over 10-month period, two were excluded due to fixed flat foot and two refused to participate in the study for work reasons, four participants were evaluated before intervension and took treatment then unabled to come for evaluation after treatment due to political reason and four participants were evaluated before intervension but did not receive any treatment immediately after pre evaluation due to their work reason so we decide to exclude them as shown in figure 1 . So only twenty-four were included in this study and analyzed in our statistical test. We estimated our sample size depending on the work of Khayambashi et al[24] who assessed twenty-eight participants and demonstrated that program of isolated hip abductor and external rotator strengthening was effective in improving pain and health status in females with PFP compared to a no-exercise control group.

Study design

The study was designed as a prospective randomised clinical trial and patients were assigned to either group A or group B were randomly by a blinded and independent research assisstant who open sealed envelopes that contained a computer generated randomization card . Randomization was used to prevent bias.

Outcome measures

Before treatment, after 3 weeks, and 6 weeks of intervention, pain level and Kujala questionnaire for patellofemoral joint pain were recorded. A10-cm visual analogue scale (VAS) range from zero as "no pain" to 10 as "the worst pain possible". The participants were asked to rate their response based on the average pain in the knee during the previous week. The procedure is valid, reliable and responsive in assessing the outcome in persons with PFPS[25,26].

The participants function status was assessed using Kujala questionnaire for patellofemoral joint pain[26]. It is a 13-items knee specific self-report questionnaire, it documents response to six activities thought to be associated specifically with anterior knee pain syndrome (walking, running, jumping, climbing, stairs, squatting, and sitting for prolonged peroids 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 shows high test-retest reliability, moderate responsiveness, and adequate validity[26].

The Q angle was measured by the same physical therapist,while the subject was in a weight-bearing position with feet in neutral position and quadriceps relaxes during measurement. The Q angle was measured by placing the goniometer axis at the center of the patella, with the stationary arm aligned to the anterior superior iliac spine and the movable arm aligned to the tibial tuberosity[27]. This method of assessing Q-angle, however with the use of universal goniometer, has been reported to have an ICC of 0.89 to 0.98 for intratester reliability[28].

As described by Ruwe et al[29] , femoral neck anteversion is assessed while the pateint lying prone, the examiner stood on the contralateral side: the left hand was used to palpate the greater trochanter while the right hand internally rotates the hip, with the patient's knee flexed to 90 degrees. At the point of maximum trochanteris prominence, the femoral neck was horizontal. The angle subtended between the tibia and the true vertical, represents the femoral neck anteversion. The angle was measured with a goniometer.This method with the use of standard goniometer has been reported to have an interclass correlation co-efficient (ICC) of 0.77 to 0.97 for intratester reliability[28].

- **Hip abduction strength test:**

The seat and dynamometer attachment were adjusted as in hip external rotation except that seat orientation was 0º, and seatback tilt fully reclined. The participants laid in side-lying position on the reclined chair of the apparatus with his back facing the dynamometer, the tested leg was the upward one, and the thigh of the non tested leg and trunk was stabilized with straps. The axis of rotation of the dynamometer was aligned superior and medial to greater trochanter of the tested leg. The seat height and position was adjusted for accurate alignment. The thigh pad was connected to the hip attachment and its length was adjusted to be proximal to the patient's lateral femoral condyle then its strap secured the thigh pad. The dynamometer ROM was set at 30º hip abduction to 0° (neutral position) and neutral position was used as starting position. After two trial repetitions, the test was conducted.

- **Hip external rotation strength test:**

The positions of the seat and the dynamometer was adjusted for measuring hip joint for external rotators: dynamometer orientation 0º, dynamometer tilt 0°, seat orientation 90°, and seatback tilt 85°. The attachment of the hip (of the involved side) was attached to the dynamometer. The participant sat on the chair of the apparatus with the hip and knee flexed 90°. The axis of rotation of the dynamometer was aligned with the longitudinal axis of the femur. The seat height and position were adjusted for accurate alignment. The calf pad was connected to the hip attachment and its height was adjusted to be proximal to the patient's lateral maleolus then the calf pad was secured by its strap. Shoulder and thigh stabilization straps were fastened. The dynamometer ROM was set at 30º external rotation to 0º (neutral position) and neutral position was used as starting position. After two trial repetitions, the test was conducted. The patient was verbally encouraged to maintain muscle contraction through the test.

- **Knee extensors muscles strength test:**

All strength testing was performed with concentric/eccentric mode of muscle contraction at an angular velocity of 90º/sec. Patients with anterior knee pain should perform isokinetic eccentric contraction of the knee extensors at an angular velocity 90º/sec. This will avoid high compressive forces on the articular surfaces of the knee joint when using angular velocities below 90º/sec (Alfonso, 2011). So, the researcher selected this angular velocity. The dynamometer orientation was adjusted according to the standard instructions for knee testing so that the dynamometer head and chair were rotated to 90º. The biodex system was powered on, and the dynamometer was initiated. Then the knee attachment was secured on the dynamometer head. Each participant sat on the chair with hip flexion approximately 110º. Shoulder and waist straps were secured for stabilization and prevention of trunk motion.

The dynamometer seat back was inclined to 100º. With the tested knee positioned at 90º flexion, the axis of rotation of the dynamometer was aligned with the axis of rotation of the knee which is located at the posterior aspect of the lateral femoral condyle. A gap of 3-cm were left between the popliteal fossa and the seat cushion to permit free knee extension. The calf pad was connected to the knee attachment and its height was adjusted to be placed 4-cm proximal to the medial malleous and secured with the padded shin.

The subject was asked to grasp the dynamometer seat with both hands. Limits of knee ROM were set from 0º to 90º knee flexion so that the knee was extended from approximately 90º flexion to full knee extension. This ROM was selected to include the ROM where most functional knee activities occur such as sitting, standing, and walking (Doucette & Child, 1996).

Treatment procedure:

Each patient in both groups received 9-12 sessions (3-4 sessions per week for 3weeks) of hip strengthening exercises in group (A) and knee program exercises for group (B). Each strengthening exercise was performed for 3 sets of 10 repetitions with 3 sec rest between repetitions and 1 minute rest after each set. Each patient was trained at 60% of 10-repetition maximum(the amount of weight that was lifted and lowered through available range of motion exactly 10 times) [30]. 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 muscle begin to fatigue. A new 10 repetition maximum was established at the end of each week of training[30].

Hip strengthening exercises for hip abductors and external rotators[31,32] : While lying on the nonaffected side, the pateint was asked to bend the knee of nonaffected side and extend the affected knee,while the therapist stabilizing the pelvis. A sandbag was wrapped just proximal to lateral malleolus and the patient was asked to raise his limb in abduction, hold for 6 sec count, then lowering his limb slowly through 6 sec and return to starting position and relax[31,32].

Hip external rotation strengthening exercise: 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 nonaffected side, hold for 6 sec count, then return to starting position slowly through 6 sec and relax[31,32].

Knee exercises program**:** The exercise protocol included strengtning and stretching exercises[33,34]. 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 90^{o} of flexion. 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 sec count, then return to starting position slowly through 6 sec and relax[33,34].

Terminal knee extension exercise **(**short arc movements from 15° of knee flexion to terminal extension): While the patient lying supine lying position 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 sec count, then return to starting position slowly through 6 sec and relax[33,34].

Stretching exercises program (for quadriceps, hamstring, iliotibial band and gastrocnemius)[30, 34]: 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 release with 3 times repetition and rest for 10 sec 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 sec then release with 3 times repetition and rest for 10 sec between each repetition[30, 34].

Iliotibial band stretching exercise: The patient assuming the previous position. The therapist stabilized the pelvis by one hand and the other hand adduct the upper-most limb cross the other limb. For all stretching exercises, the stretch position was maintained for 30 sec and repeated 3 times with a rest period of 10 seconds between each two repitition[30, 34].

Gastrocnemius stretching exercise: From 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 sec then release with 3 times repetition and rest for 10 sec between each repetition[30, 34].

Statistical analysis

All statistical measures were performed using the Statistical Package for Social science (SPSS) program version 18 for windows. 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 difference and analysis of relationship measures. To determine similarity between the groups at base line, subject age, height, BMI and body weight were compared using independent t tests.

2x3 Mixed Design MANOVA was conducted to compare PT (Nm) values of the hip abductors and external rotators, knee extensors, Q angle, anteversion angle , VAS, and AKPS among different training periods for group (A) and group (B). In addition, it was conducted to compare between group (A) and group (B) for the tested dependent variables in the different training periods. This design involved two independent variables. The first one was the (tested group); between subject factor which had two levels (Group A and Group B). The second one was the (training periods); within subject factor which had three levels (pre, post three weeks, and post six weeks). In addition, this test involved seven tested dependent variables (eccentric torques of hip abductors, external rotators, and knee extensors, VAS, AKPS, Q angle, and anteversion angle). Accordingly, 2×3 Mixed design MANOVA was used to compare the tested variables of interest at different tested groups and training periods. The alpha level was set at 0.05.

RESULTS

Baseline and demographic data

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

Table 1: Descriptive statistics and unpaired t-tests for the mean age, weight, height, and BMI of the patients with patellofemoral pain syndrome for both groups.

	Age (years)	Weight (kg)	Height (cm)	BMI (kg/m²)
Group (A)	23.33±5.39	71.16±13.05	164.75±4.5	26.21±4.71
Group (B)	23.16±6.33	69.41±18.14	164.66±7.27	25.2±6.2
t-value	0.186	0.391	0.034	0.446
p-value	0.854	0.699	0.973	0.660

Statistical analysis revealed that there were significant within subject effect (F = 12.741, p = 0.000) and treatment*time effect (F= 3.135, p = 0.045) but there were no significant between subject effect (F = 0.623, p = **0.73**). The descriptive statistics showed increasing in the mean peak torque values of hip abductors and external rotators, knee extensors, and in AKPS score in both groups at 3 and 6 weeks post tests. Moreover, there were a decreasing in the Q angle, femoral anteversion angle, and level of pain in both groups 3 ad 6 weeks post tests (Table 2 and 3).

Table 2.
Descriptive statistics for the isokinetic PT values (Nm) of the hip abductors, external rotators and knee extensors in the eccentric mode of muscle contraction at angular velocities 60°/sec and 90°/sec respectively for both groups at different training periods.

Isokinetic PT (Nm)	Group A			Group B		
	Pre	Post 3 weeks	Post 6 weeks	Pre	Post 3 weeks	Post 6 weeks
Hip abductors PT (Nm)	44.08±13.96	61.16±19.9	63.5±23.99	49.91±18.25	64.25±21.8	76.33±30.33
Hip external rotators PT (Nm)	25±5.18	29.91±4.9	32.58±8.08	31.08±11.88	32±10.19	34.08±9.66
Knee extensors PT (Nm)	39.41±6.9	49.25±18.31	55.25±29.21	42.75±13.32	45.08±9.92	61.16±32.92

Table 3.
Descriptive statistics for the Q angle, femoral anteversion angle (FAA), VAS and AKPS for both groups at different training periods.

Dependent variables	Group A			Group B		
	Pre	Post 3 weeks	Post 6 weeks	Pre	Post 3 weeks	Post 6 weeks
Q angle	20.64±3.726	15.29±1.68	15.2±1.43	20.11±4.57	18.1±3.98	15.13±2.09
FAA	18.33±5.04	14.5±3	14.4±2.7	19.35±2.96	17.57±2.65	13.97±1.13
VAS	6.5±1.97	3.83±2.03	0.633±0.88	6.87±1.38	3.41±1.72	2.2±1.69
AKPS	69.83±9.85	84.16±7.75	94.75±5.27	68.16±13.8	82.41±10.58	86.41±10.58

Multiple pairwise comparison tests (Post hoc tests) revealed that there were significant increase in the mean value of the hip abductors' PT between (pre versus post 3 weeks and pre versus post 6 weeks) ($p<0.05$) and insignificant between (post 3 weeks versus post 6 weeks) ($p>0.05$) in group (A). In addition, there were significant increase in the mean value of the hip abductors' PT among training periods (pre versus post 3 weeks, pre versus 6 weeks and post 3 weeks versus post 6 weeks) ($p<0.05$) in group (B) (Table 4).

Also, there were significant increase in the mean value of the hip external rotators' PT between pre test and post 6 weeks and insignificant differences between (pre test and post 3 weeks and post 3 weeks and post 6 weeks) at group (A). In addition, there were no significant differences in the mean value of the hip external rotators' PT among the training periods at group (B). Also, there were no significant differences in the mean value of the knee extensors' PT among the training periods in both groups ($p>0.05$) (Table 4). Regarding between subject effects multiple pairwise comparison tests (Post hoc tests) revealed that there were no significant differences in the mean values of the hip abductors' and external rotators' and knee

Table 4.
Multiple pairwise comparison tests (Post hoc tests) for hip abductors, external rotators, and knee extensors PT strength at different training periods for both groups.

Multiple pairwise comparison tests (post hoc tests) for hip abductors, external rotators, and knee extensors PT strength at different training periods for both groups						
	Group A			**Group B**		
	Hip abductors	**Hip external rotators**	**Knee extensors**	**Hip abductors**	**Hip external rotators**	**Knee extensors**
Pre Vs. post 3 weeks	**0.013***	**0.165**	**0.12**	**0.042***	**1.00**	**1.00**
Pre Vs. post 6 weeks	**0.007***	**0.004***	**0.178**	**0.000***	**0.475**	**0.091**
Post 3 weeks Vs. post 6 weeks	**1.00**	**0.267**	**1.00**	**0.011***	**0.530**	**0.07**

	Pre			**Post 3 weeks**			**Post 6 weeks**		
Group A Vs. B	**Hip Abd.**	**Hip Ext. Rot.**	**Knee Ext.**	**Hip Abd.**	**Hip Ext. Rot.**	**Knee Ext.**	**Hip Abd.**	**Hip Ext. Rot.**	**Knee Ext.**
P- value	**0.389**	**0.118**	**0.450**	**0.722**	**0.530**	**0.496**	**0.263**	**0.713**	**0.646**

Abd: abduction, Ext. Rot: external rotation, Ext: extensors.
***Significant at alpha level <0.05**

Multiple pairwise comparison tests (Post hoc tests) revealed that there were significant reduction in the mean value of the Q angle between (pre versus post 3 weeks and pre versus 6 weeks) ($p<0.05$) and insignificant between (post 3 weeks versus post 6 weeks) ($p>0.05$) in group (A). In addition, there were significant reduction in the mean value of the Q angle among training periods ($p<0.05$) in group (B). Also, there were significant reduction in the mean value of the femoral anteversion angle between (pre versus post 3 weeks and pre versus post 6 weeks) ($p<0.05$) and insignificant between (post 3 weeks versus post 6 weeks) ($p>0.05$) in group (A). In addition, there were significant reduction in the mean value of the femoral anteversion angle between (pre versus post 6 weeks and post 3 weeks versus post 6 weeks) ($p<0.05$) and insignificant between (pre versus post 3 weeks) ($p>0.05$) in group (B). Additionally, there were significant reduction in the mean value of the VAS scale among training periods ($p<0.05$) in group (A).

As well, there were significant reduction in the mean value of the VAS scale between (pre versus post 3 weeks and pre versus 6 weeks) ($p<0.05$) and insignificant between (post 3 weeks versus post 6 weeks) ($p>0.05$) in group (B). Moreover, there were significant increase in the mean value of the AKPS score among training periods ($p<0.05$) in group (A). Also, there were significant increase in the mean value of the AKPS score between (pre versus post 3 weeks and pre versus 6 weeks) ($p<0.05$) and insignificant between (post 3 weeks versus post 6 weeks) ($p>0.05$) in group (B) (Table 5). Regarding between subject effects multiple pairwise comparisons revealed that the mean values of the Q angle and femoral anteversion angle declined significantly in group (A) at post 3 weeks compared with group (B) ($p<0.05$). In addition, the mean values of the VAS scale declined significantly in the group (A) at post 6 weeks compared with group (B) ($p<0.05$) and the mean values of the AKPS score improved significantly in the group (A) at post 6 weeks compared with the group (B) ($p<0.05$) (Table 5).

Table 5.
Multiple pairwise comparison tests (Post hoc tests) for Q angle, femoral anteversion angle (FAA), VAS and AKPS at different training periods.

Multiple pairwise comparison tests (post hoc tests) for Q angle, femoral anteversion angle (FAA), VAS, and AKPS at different training periods for both groups								
	Group A				**Group B**			
	Q angle	**FAA**	**VAS**	**AKPS**	**Q angle**	**FAA**	**VAS**	**AKPS**
Pre Vs. post 3 weeks	**0.000***	**0.000***	**0.000***	**0.000***	**0.015***	**0.05**	**0.000***	**0.000***
Pre Vs. post 6 weeks	**0.000***	**0.000***	**0.000***	**0.000***	**0.000***	**0.000***	**0.000***	**0.000***
Post 3 weeks Vs. post 6 weeks	**1.00**	**1.00**	**0.000***	**0.000***	**0.000***	**0.000***	**0.132**	**0.258**

	Pre				**Post 3 weeks**				**Post 6 weeks**			
Group A Vs. B	**Q angle**	**FAA**	**VAS**	**AKPS**	**Q angle**	**FAA**	**VAS**	**AKPS**	**Q angle**	**FAA**	**VAS**	**AKPS**
P-value	**0.76**	**0.55**	**0.59**	**0.73**	**0.03***	**0.01***	**0.59**	**0.64**	**0.91**	**0.61**	**0.00***	**0.02***

***Significant at alpha level <0.05**

DISCUSSION

It was previously reported that weakness of the hip musculature could lead to increase femoral adduction, medial rotation, anteversion angle, and Q angle during dynamic weight-bearing activities, which would increase the lateral patellofemoral joint vector, leading to patellar facet overload [38]. The findings of the present study support the growing body of literature which suggest that hip strengthening may be a viable intervention for PFP. An explanation to this finding is that, proximal lower extremity strength is believed to be vital for control of hip joint position and the resultant alignment of the distal segments[38]. During athletic performance, the hip musculature provides a protective mechanism through its influence on lower extremity alignment. For example, weakness of the iliopsoas and the posterior fibers of the gluteus medius may place the femur in a more medially rotated position, allowing for abnormal movement of the patella within the trochlear groove and increasing susceptibility to PFPS[40].

The findings of this study showed that patients with PFPS who received hip abductors and external rotators strength program had significant lower Q angle and anteversion angle compared to patients who received knee exercises. These finding were supported by several authors[23,35,36] who recommended addition of hip abductors and lateral rotators strengthening to the rehabilitation program for patients with PFPS. The importance of hip abductor and lateral rotator muscles strengthening in the treatment of PFPS is based on several studies that have demonstrated weakness of the hip abductors and lateral rotators in patients with PFPS[16,22,37].

The current study reported a decrease in pain and improvement in knee function (though non significant) in both group. This result is somehow similar to the results of a study conducted by Razeghi et al[23] who found that the maximum improvement of pain and function activities occurs in participants, who received the hip strengthening exercise in addition to traditional exercise program. Also, Khayambashi et al.,[24] examined the effectiveness of isolated hip abductor and external rotator strengthening on pain, health status, and hip strength in females with patellofemoral pain (PFP). Twenty-eight females with PFP were sequentially assigned to an exercise (n = 14) or a no-exercise control group (n = 14). The exercise group completed bilateral hip abductor and external rotator strengthening 3 times per week for 8 weeks. Pain (visual analog scale), health status, and hip strength (handheld dynamometer) were assessed at baseline and post intervention. Pain and health status were also evaluated at 6 months post intervention in the exercise group. The authors revealed that there was significant group-by-time interactions for each variable of interest. Post hoc testing revealed that pain, health status, and bilateral hip strength improved in the exercise group following the 8-week intervention but did not change in the control group. Improvements in pain and health status were sustained at 6-month follow-up in the exercise group. The authors concluded that a program of isolated hip abductor and external rotator strengthening was effective in improving pain and health status in females with PFP compared to a no-exercise control group. The incorporation of hip-strengthening exercises should be considered when designing a rehabilitation program for females with PFP.

Additionally Dolak et al[41]confirm the results of present study as they reported that 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. So both rehabilitation approaches led to improvements in self-reported function, pain, and hip strength, but treatment of PFPS, targeting hip strengthening initially may be more efficient, allowing for muscle training while reducing exacerbation of patellofemoral symptoms.

On the other hand Fukuda et al[36] found no significant difference in function activities improvement between the patients received strength exercise for hip muscles in addition to traditional exercise program and patients received traditional exercise program only, however there was significant improvement in pain. Also, Khayambashi et al[46] evaluated the efficacy of posterolateral hip muscle strengthening versus quadriceps strengthening in reducing pain and improving health status in persons with patellofemoral pain (PFP). Patients were alternately assigned to a posterolateral hip muscle strengthening group (9 men and 9 women) or a quadriceps strengthening group (9 men and 9 women). The posterolateral hip muscle strengthening group performed hip abductor and external rotator strengthening exercises, whereas the quadriceps strengthening group performed quadriceps strengthening exercises (3 times a week for 8 weeks).Pain (visual analog scale) and health status were assessed at baseline, post intervention, and 6-month follow-up. The authors revealed that there was significant improvements in VAS and health status in both groups from baseline to post intervention and baseline to 6-month follow-up. Improvements in VAS and health status in the posterolateral hip exercise group were superior to those in the quadriceps exercise group post intervention and at 6-month follow-up. The authors concluded that although both intervention programs resulted in decreased pain and improved function in persons with PFP, outcomes in the posterolateral hip exercise group were superior to the quadriceps exercise group. The superior outcomes obtained in the posterolateral hip exercise group were maintained 6 months post intervention.

In the study by Nakagawa et al[35] the results of the pain assessment were obtained using visual analogue scales, the intervention group showed a significant improvement in pain. The result of this study are also supported by many researchers**.**Tyler et al[7] results confirmed those of Mascal et al[42] who said that for more improve of pain and function activities of patients with PFPS should adding strengthening to hip abductor, lateral rotator muscles to traditional exercise program. Other similar studies supported these effect, like of those of Boling et al[43],andEarl &Hoch[44].

Mascal et al[42] reported pain symptom and function improvement after 14 weeks of treatment associated with increases in the gluteus medius and gluteus maximus isometric muscle force production and improved motor control of hip motion during functional weight-bearing activities. Based on the findings of Mascal et al[42] it is reasonable to suggest that improvements in hip abduction and external rotation strength, which ranged from 32% to 56%, might have resulted in changes in hip kinematics during functional activities. Given that excessive hip adduction and internal rotation have been postulated to adversely affect patellofemoral joint kinematics and kinetics[45], it is possible that the changes in hip muscle performance might have resulted in a decrease in patellofemoral joint loading and, therefore, pain. However, care must be taken in attributing changes in patellofemoral symptoms to improved hip kinematics after strengthening in isolation, as recent research suggests that changes in hip kinematics may be more related to skill acquisition (skilled practice) as opposed to improvements in hip strength. There are several limitations of our study. First, small sample size may limited generalization but we recruited 12 pateints in each group based on previously published data[24] to detect difference in pain and functional scale with power analysis 80 % and at alpha level of 0.05. second, we did not assess the long term effect of the isolated hip strengthening exercises and isolated knee strengthening and stretching exercises on pain, kujala score, Q angle and anteversion angle. A third limitation was the absence of control group of PFPS patients who received no treatment as the author did not want to leave pateints untreated through this period of time. Further research should include a greater sample size and a follow-up period.

CONCLUSION

Hip strengthening exercises are more effective than knee strengthening exercises in reducing Q-angle and anteversion angle. Consequently, this may help physiotherapists in designing the most effective and efficient prevention and rehabilitation programs for patients suffering from PFPS.

Implication

The incorporation of hip strengthening exercises should be considering when desiging a rehabilitation program for pateints with patellofemoral pain syndrom.

Author contributions

Author (1) contributed in the conception and design of the study, collection and assembly of data, analysis and interpretation of data, writing the manuscript, conducting exercises program and final approval of the article. Author (2) contributed in the conception and design of the study, analysis and interpretation of data, critical revision of the article and screening the pateints for inclusion and exclusion criteria. Author (3) contributed in acquisition of data, critical revision of the article, reporting outcome measures, and conducting statistical analysis. Authors (4) contributed in the conception and design of the study, analysis and interpretation of data, critical revision, correcting and revising manuscript, sampling selection and screening, and final approval of the article.

Conflict of interest

The authors declare that they have no conflicts of interest.

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