How can we strengthen the quadriceps femoris in patients with patellofemoral pain syndrome?

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Summary

Purpose: **the aim of this article was to review the clinical approach of quadriceps strengthening programmes.**
Methods: **a literature search was carried out from 1980 up to September 2011. Eligible studies were those that: (1) evaluated the patients with patellofemoral pain syndrome (not healthy or asymptomatic subjects) (2) examined the effect of kinetic chain exercises (3) examined the effect of weight-bearing exercises (4) compared the effect of the combined exercises programme in the treatment of patients with patellofemoral pain syndrome.**
Results and conclusion: **patients with patellofemoral pain syndrome may tolerate a closed kinetic chain exercises programme better than open kinetic chain. Weight-bearing and non-weight-bearing quadriceps exercises can significantly improve subjective and clinical outcomes in patients with patellofemoral pain syndrome. Combining treatments as an initial approach to treating patellofemoral pain but developing individualized more functional, global treatments are essential.**

Key words: patellofemoral pain syndrome, quadriceps muscle, muscle strength, exercise.

Introduction

Patellofemoral pain syndrome (PFPS) is a common problem experienced by adolescent and active adult populations. PFPS is usually activity related and aggravated by functional activities such as stairs climbing, running, squatting (1, 2). Common causative factors are lower extremity weakness, especially in the quadriceps muscle, malalignment of the lower extremity, foot deformity such as increased subtalar pronation, tightness of the lateral retinaculum, iliotibial band, hamstring muscles and tensor fascia latae muscle (1-3). Correct alignment of the patella may depend in part upon the balance between the vastus medialis obliquus (VMO) and vastus lateralis (VL) muscles, so an imbalance in the activity of the VMO relative to the VL is one proposed mechanism for abnormal patellar tracking (4). Generalized quadriceps muscle weakness may result in malposition of the patella (5, 6), and altered timing of the VMO muscle activity may mean that the muscle will be at different lengths at contraction initiation, which will affect the muscle's ability to produce force (7). Besides decreased muscle strength of the quadriceps, decreased cross sectional area and total volume of the quadriceps muscle, atrophy of the VMO have been shown in the literature (8-10).
Conservative interventions of PFPS include patient education (11), mobility interventions and exercises for the soft tissue (*passive stabilizers of the knee*) and muscles (*active stabilizers of the knee*) around of the knee (12), strengthening exercises for quadriceps muscle (13), muscle training exercises for VMO and VL (14), patellar correction techniques such as taping and bracing (12), electrical stimulation to facilitate quadriceps femoris muscle - especially for the VMO and VL (15), modalities such as cold application for reducing both pain and edema (16).

Material and Methods

Total quadriceps strengthening has been shown to be effective for patients with *patellofemoral pain syndrome* (13, 17). Quadriceps weakness, specifically VMO weakness in comparison to the VL, can lead to lateral displacement of the patella causing the articulating pressure to be on the lateral facet (18). For this review, articles which investigated effects of the quadriceps exercises on quadriceps strength were selected. A total of five studies evaluated effects of exercises on quadriceps strength in patients with PFPS (1, 2, 19). Although two studies showed quadriceps weakness was a non-significant finding (19), three studies specified weakness to be a significant finding (1, 2, 19).

Discussion

The prescription of the quadriceps strengthening exercise for the patients with PFPS must be well-designed because the contact area between the patella and the femur changes throughout knee flexion and extension.

Kinetic chain exercise is a specific type of physical exercise that may be integrated into aerobics, circuit training, certain endurance training, weight lifting, pilates, yoga or kickboxing. It may also be used in knee rehabilitation. A kinetic chain is a chain of joints exercised together. For example the hip, knee, and ankle joints, when taken together, comprise the lower extremity kinetic chain. In *closed kinetic chain exercises*, movement at one joint produces predictable movements at all other joints. Weight bearing closed kinetic chain activities may increase joint compressive force and thus enhance joint stability. In contrast, *open kinetic chain exercises* use isolated joint and muscle function and the motion is uni-planer.

Open kinetic chain exercises are performed typically where the foot is free to move. These exercises are typically non-weight bearing, with the movement occurring at the knee joint. If there is any weight applied it is applied to the distal portion of the lower extremity (20). During the open kinetic activities such as knee extension, patellofemoral joint reaction force increases as the knee move throughout 90º flexion to full knee extension (21), especially 30º knee flexion to full extension (22). *Closed kinetic chain exercises* are performed where the foot is fixed on the ground (Fig. 1). The foot remains in constant contact with the surface, usually the ground or the base of a machine. These exercises are typically weight bearing exercises, where the patient uses his/her own body weight and/or an external weight. They are also multi-joint movements, and are labelled as being sport-specific exercises (20). During the closed kinetic activities such as squat, patellofemoral joint reaction force increases with the increased knee flexion, especially 30º knee flexion to full flexion (22). Contractions of the quadriceps muscle can either be isometric, concentric, eccentric or isotonic. *An isometric contraction*, is one in which the muscle is activated, but instead of being allowed to lengthen or shorten, it is held at a constant length. This is where the internal force of the muscle is such that the muscle stays at constant length, the intrinsic force being equal to the extrinsic force applied (23).

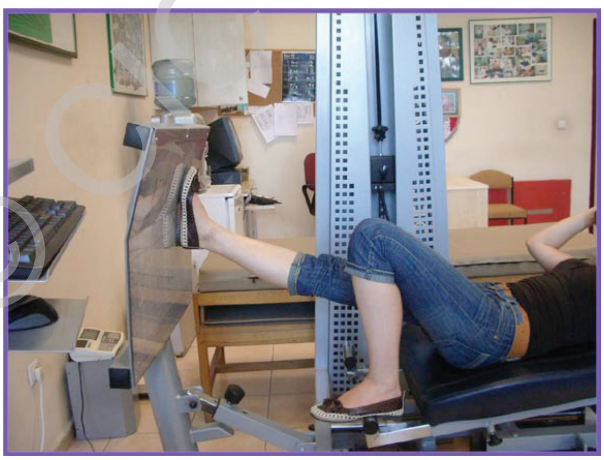

Figure 1. Leg-press exercise (closed kinetic chain exercise).

A concentric contraction is a type of muscle contraction in which the muscles shorten while generating force. The muscle actively alters in length by shortening, as the intrinsic forces created by the contracting muscle are greater than any extrinsic forces, e.g. quadriceps femoris extending the knee. This occurs throughout the length of the muscle, generating force at the musculo-tendinous junction, causing the muscle to shorten and changing the angle of the joint (23).

During an *eccentric contraction*, the muscle elongates while under tension due to an opposing force being greater than the force generated by the muscle. Rather than working to pull a joint in the direction of the muscle contraction, the muscle acts to decelerate the joint at the end of a movement or otherwise control the repositioning of a load. The muscle alters in length by lengthening, as the extrinsic forces acting on the muscle are greater than those generated intrinsically. A muscle which is being lengthened while it is contracting can maintain greater tension then it can develop at any given equivalent static length, e.g. Quadriceps Femoris during knee flexion in standing. This can occur involuntarily (when attempting to move a weight too heavy for the muscle to lift) or voluntarily (when the muscle is 'smoothing out' a movement) (23).

During the *isotonic contraction* the effects of the load are maximal in only one small part of the range. This involves the production of the constant force or tension as the muscle changes in length. However, this is an inaccurate description as tension never remains constant throughout range. Isotonic contractions require a constant strain without changes in the length of the muscle (e.g. during wall squats with knees flexed in 90 degrees and the back against the wall). During the isokinetic contraction the contraction is where the velocity of the contraction remains constant. Isokinetic exercise requires equipment to control the velocity with which the knee moves through a large range of motion. This type of devices can also measure the concentric as well as eccentric force applied by knee extensors (quadriceps) or flexors (hamstrings) at predetermined velocities. The velocity spectrum for these dynamometers ranges from 0 to 360 degrees per second (23).

Safe ranges for exercises: Doucette and Child found improved congruence angles with closed kinetic chain exercises from 0º to 20º flexion and open kinetic chain exercises from 30º to full flexion (24). These findings are consistent with Steinkamp et al. who hypothesized that the optimal range for open kinetic chain peri-patellar muscle, strengthening is from 90º to 60º, while the best range in a closed kinetic chain position is from 0º to 30º flexion (25). These ranges caused the lowest patellofemoral joint reaction forces.

Open Kinetic Chain Exercise

Isometric Quadriceps Exercise: Pain-free quadriceps exercise is an important component of the successful treatment programme in patients with PFPS (26). Isometric quadriceps exercises were advocated for patients with PFPS as well as eccentric muscle contraction (27), but recently there have been recommendations for vastus medialis muscle training and functional lower-extremity training (28). Laprade et al. evaluated VMO:VL ratio during the 5 different isometric extension exercises (29). Their result showed that the VMO:VL proportions for internal knee rotation and knee extension combined and knee extension alone were significantly greater than for the other three isometrics.

Isometric quadriceps exercises such as straight leg raises can facilitate quadriceps activation without stressing the patellofemoral joint and minimizes patellofemoral joint reaction forces, because the patella has no contact with the femoral condyles in the full extension position (30).

In the literature, researchers demonstrated that patients with PFPS can benefit from isometric quadriceps exercises and straight leg raise exercises (31, 32). Roush et al. investigated the effects of the modified straight leg raises exercises (called the 'Muncie method') for patients with PFPS (32). The authors evaluated pain, functional level and isokinetic strength of the quadriceps muscle at the beginning and end of the treatment (32). They noticed that patients who performed the quadriceps-strengthening home exercises programme and modified straight leg raises exercises reported significantly improvements regarding pain and functional level (32).

These results showed that patients with *patellofemoral pain syndrome* can benefit from isometric quadriceps-strengthening and straight leg raises exercises. Rehabilitation programme including isometric and straight leg raises exercises could positively enhance function in patients with PFPS.

Isokinetic Exercise: Isokinetic exercises differ from isometrics in that it allows subjects to move the tibia over the femur through a selected range of motion and velocity (Fig. 2). Closed-chain exercises are safest in the 0- to 45-degree range. In contrast to closed-chain exercises, open-chain exercises (leg curls and knee extension), are most safely carried out from 25 to 90 degrees for patients with patellofemoral pain syndrome (25, 33). These researchers agree with the potential for excessive pressure when performing active exercise near terminal knee extension.

Hazneci et al. evaluated 24 patients with patellofemoral pain syndrome and 24 male healthy individuals without symptoms (34). An isokinetic exercise protocol was carried out at angular velocities of 60 degrees/sec and 180 degrees/sec. These sessions were repeated three times per week and lasted for 6 weeks. At the beginning and after 6 weeks strength of the quadriceps and hamstring muscles were compared. After the isokinetic exercise, peak torque and total work of quadriceps and hamstrings improved significantly in the patellofemoral pain syndrome group. Authors emphasized that isokinetic exercises have positive effects on passive position sense of knee joints, by increasing the muscular strength and work capacity. Their findings showed that prescription of the isokinetic exercises in rehabilitation protocols of the patients with patellofemoral pain syndrome not only improves the knee joint stabilization but also the proprioceptive acuity (34).

McMullen et al. designed a 2-phases isokinetic programme for patients with chondromalacia patellae (30). *Phase 1* included a low-speed (30º, 60º, 90º, and 120/sº), short-arc (30º to 0º) angular velocities. If the patients could perform the *phase 1* exercises without pain, they continued phase 2 which included high speed (180º, 240º, and 300/sº), full-arc (90º to 0º) angular velocities. They reported some patients did not tolerate an aggressive isokinetic programme (30).

Werner and Eriksson designed a study to evaluate the effect of eccentric quadriceps training in patients with unilateral patellofemoral pain and to compare the effects of eccentric and concentric quadriceps training in patients with bilateral patellofemoral pain (3). Fifteen patients and nine age-sex matched healthy controls participated in this study. Nine of fifteen patients had unilateral pain and trained their painful leg eccentrically, while six had bilateral pain and trained one leg eccentrically and the other concentrically. Quadriceps muscle training was performed on a Kin-Com dynamometer at 90 degrees/s and 120 degrees/s angular velocity twice a week for 8 weeks. Before and after the treatment period the thigh muscle torques were measured at 60 degrees/s, 90 degrees/s, 120 degrees/s and 180 degrees/s for quadriceps and at 60 degrees/s and 180 degrees/s for hamstrings. For functional evaluation, a knee score was calculated before training, after 8 weeks of training and at a mean of 3.4 years after completion of the training. After 8 weeks of training and at follow-up times of 1 and 3.4 years the patients were also questioned regarding whether or not they felt improvement from the training programme. Authors evaluated the degree of knee pain during the training using Borg's pain scale. The results of the this study showed that, compared with the controls, the patients with patellofemoral pain had a significantly lower knee extensor torque in their painful leg at all velocities measured. The greatest difference was found during eccentric quadriceps actions. After training there was a significant increase particularly in eccentric but also in concentric torque of the knee extensor in the painful leg of the eccentrically trained group. Of the six patients in the bilateral training group there were five who increased their concentric knee extensor torque and three who increased

Figure 2.Isokinetic exercise.

their eccentric torque. Patients in both groups reported no pain or mild pain during the training sessions (3).
Results from these studies verified that patients with patellofemoral pain syndrome can benefit from isokinetic exercises if the patients perform all exercises in a pain-free range of knee motion.

Closed Kinetic Chain Exercise

In closed kinetic chain exercises, more selective vastus medialis obliquus activation can be obtained at 60 degrees knee flexion (35). Maximal vastus medialis obliquus/vastus lateralis ratio was observed at this knee flexion angle, and muscle contraction intensity was also greatest (35).
Witvrouw et al. compared the efficacy of open kinetic chain versus closed chain exercises in patients with patellofemoral pain syndrome (PFPS) (36). Sixty patients were separated randomly into two groups such as open kinetic chain and closed kinetic chain group. Patients performed their exercises programme during 5 weeks. Isokinetic muscle strength, Kujala patellofemoral score, flexibility and functional tests were evaluated pre-treatment, end of the treatment and after 3 months of the pre-treatment. Although patients improved functionally, authors did not find any difference between open kinetic chain and closed kinetic chain exercises group (36). Their study showed that both open and closed kinetic chain exercise programs lead to an improved subjective and clinical outcome in patients with PFPS patellofemoral pain syndrome. The few significantly better functional results for some of the tested parameters in the closed kinetic chain group suggest that this type of treatment is a little more effective than the open kinetic chain programme in the treatment of patients with patellofemoral pain syndrome (36).
The authors of this study followed up these patients after approximately 5-years and published their results (37). Both groups demonstrated maintenance of good subjective and functional outcomes achieved immediately after the conservative treatment. No significant difference between both groups was observed at the 5-year follow-up for the majority of the examined parameters. However, on 3 of the 18 visual analogue scales, the open kinetic chain group showed significantly less complaints compared to the closed kinetic chain group. The authors concluded that both open kinetic chain and closed kinetic chain programs lead to an equal long-term good functional outcome (37).
Stiene et al. evaluated the results of the closed kinetic chain exercises versus isokinetic exercises (33). During the 8 weeks, patient groups performed one of these two types of exercises. After one year, their statistical analysis showed that both groups had significant improvement in peak torque at all speeds, but only the closed kinetic chain group showed significant improvement in closed kinetic chain testing and perceived functional status. The authors concluded that closed kinetic chain training may be more effective than joint isolation exercise in restoring function in patients with patellofemoral dysfunction (33).
Thomee showed no difference between isometric exercises and open and closed chain exercises (31). Patients in the isometric group performed isometric contractions exercises. The patients in the other group performed open and closed kinetic chain exercises that focussed on eccentric contraction. After 12 weeks, pain levels decreased, while functional level and muscle strength increased in both of the groups (31).
Bakhtiary and Fatemi designed their study to compare the effect of straight leg raise and semi-squat exercises on the treatment of patellar chondromalacia (38). 32 patients with patellar chondromalacia were randomly assigned two groups: a straight leg raises exercises group and a semi-squat exercises group. Patients in the both groups performed a 3-week programme of quadriceps muscle strengthening exercises starting with 20 exercises twice a day and increasing each session by 5 exercises every 2 days. Reduced Q angle and crepitation, and an increase in the maximum isometric voluntary contraction force of the quadriceps muscle and thigh circumference were found in the semi-squat group compared with the straight leg raises group. However, patellofemoral pain was decreased significantly in both groups. The results of this study indicated that semi-squat exercises (closed kinetic chain) are more effective than straight leg raises exercise (open kinetic chain) in the treatment of patellar chondromalacia (38).
During a lunge exercise (a type of closed chain exercise) the VMO:VL ratio is nearest to 1:1 ratio (39). Although this exercise has been shown not to produce as much muscle activity as the double leg squat with hip adduction exercise, this exercise may be advantageous in the initial stage of PFPS rehabilitation when sufficient VMO muscle strength has not been regained yet and the priority is to establish a balanced patella tracking. Little research has been undertaken regarding different stages of rehabilitation; therefore, this is an area that warrants further investigation.

Open versus closed kinetic chain exercises

Open-chain leg extension exercises are often a routine method of selectively targeting VMO in clinical practice (29, 40) but their mechanism is unclear. The established definition of an open kinetic chain exercise is a single joint movement that is performed in a non-weight-bearing position with a free distal extremity. Conversely, closed-chain exercises are considered multi-joint movements performed in a weight-bearing or simulated weight-bearing position with a fixed distal extremity (41). In summary, results of the above mentioned studies showed that closed kinetic chain exercises are more tolerable than open kinetic chain exercises for patients with patellofemoral pain syndrome PFPS.

Weight-bearing versus non-weight- bearing exercises

Both weight-bearing and non-weight-bearing exercises are considered appropriate for strengthening the quadriceps and are a key element in the treatment of PFPS.
Brownstein et al. reported that VMO is most active at 60 to 90 degrees of knee flexion in a non-weight-bearing position (42). Tang et al. showed that the greatest activation of VMO

is actually achieved at 60 degrees of flexion in a weight-bearing position (squat to stand CKC) (35).

Herrington and Al-Sherhi designed a randomized controlled trial to compare the efficacy of single-joint non-weight-bearing quadriceps exercise (SJNWBE) versus multiple-joint weight-bearing quadriceps exercise (MJWBE) for individuals with PFPS patellofemoral pain syndrome (43). Forty-five patients with PFPS patellofemoral pain syndrome between the 18 and 35 years of age were randomized into one of 3 groups. Patients in group 1 performed knee extension exercises (SJNWBE), patients in group 2 performed seated leg press exercises (MJWBE), and patients in group 3 (control group) received no treatment. Subjective symptoms, knee extensor muscle strength, and functional performance were evaluated at the time of the initial examination and at the end of the 6 weeks of treatment period. Patients in both exercise groups demonstrated a statistically significant decrease in pain and an increase in muscle strength and functional performance, as compared to the control group. All measures showed no significant differences between the 2 exercise groups. Their study demonstrates that both weight-bearing and non-weight-bearing quadriceps exercises can significantly improve subjective and clinical outcomes in patients with patellofemoral pain syndrome PFPS (43).

Boling et al. evaluated the effects of a weight-bearing rehabilitation program on quadriceps electromyographic activity, pain, and function in subjects diagnosed with patellofemoral pain syndrome PFPS (44). Fourteen patients diagnosed with PFPS patellofemoral pain syndrome and 14 healthy control subjects volunteered to participate in their study. Patients participated in a 6 week rehabilitation programme. The rehabilitation programme consisted of weight-bearing exercises that focused on strengthening the quadriceps. Electromyographic onsets of the vastus medialis oblique (VMO) and vastus lateralis and were collected during a stair-stepping task that was performed during the pre-test and post-test. A visual analogue scale (VAS) and Functional Index Questionnaire (FIQ) were administered at pre-test and post-test and each week of the intervention. The authors (44) found that vastus lateralis (VL) and vastus medialis obliquus (VMO) onset timing differences (vastus lateralis electromyographic onset minus vastus medialis obliquus electromyographic onset) and VAS and FIQ scores significantly improved in patients diagnosed with PFPS. Vastus lateralis and VMO onset timing in the patients were significantly different from those in the control group at baseline and were not significantly different from the control group after the intervention. The authors emphasized that patients responded favourably and quickly to a therapeutic exercise program that incorporated quadriceps strengthening (44).

Combined programme

Our previous study investigated the effect of an exercise program in conjunction with short-period patellar taping on pain, EMG activities, and isokinetic knee extension torque in patients with PFPS (45) (Tab. 1) for sample exercises programme. Patients usually prefer shorter periods of taping rather than taping all day. Our home exercise program was designed to improve VMO activation. Neuromuscular retraining exercises included isometric quadriceps sitting, straight leg raise with ankle weights, terminal knee extension in a sitting position with ankle weights, wall squats with ball between the knees, step-down exercises (20 cm; backward, forward, and sideways), and single-leg balance exercises in different knee angles with Thera-Band Stability Trainer (blue; Hygenic Corporation, Akron, Ohio). Static stretching exercises were prescribed for the quadriceps, iliotibial band, hamstrings, and gastrocnemius muscles. Patients performed 4 sessions of 25 repetitions of each isometric exercise per day. Isotonic and stretching exercises were performed 3 sessions of 10 repetitions per a day. Hold time of isometric and isotonic exercises was 5 seconds. Hold time of stretching exercises was 10 seconds. There were significant differences in electromyogram activity (P = .04) and knee extensor muscle strength (P = .03) between involved and uninvolved sides before treatment. After treatment, pain scores decreased, and there were no significant differences between involved and uninvolved sides in electromyogram activity (P = .68) and knee extensor strength (P = .62). Before treatment, mean VMO activation started significantly later than that of vastus lateralis, as compared with the matched healthy control group (P = .00). After treatment, these differences were non-significant (P = .08).This study demonstrated that an exercise program in conjunction with short-period patellar taping for 3 months was efficacious (45).

In another prospective double-blind randomized control study, Mason et al. treated 41 subjects with 60 knees diagnosed with patellofemoral pain. The knees were randomized in four groups (46). The four groups were randomized as taping, quadriceps strengthening, quadriceps stretching and control. Following one week of single modality treatment, all four groups received one week of treatment combining taping, quadriceps strengthening and quadriceps stretching. The taping was worn continually for the week; the strengthening group followed a programme of non-weight-bearing terminal range quadriceps exercises, the stretching group performed rectus femoris stretches. The control group did not receive treatment. Results showed significant changes over time ($p < 0.01$) in two out of seven measures for the taping group, in five out of seven for the strengthening group and five out of seven for the stretching group and none in the control group. In conclusion, the authors recommended combining treatments as the initial approach to treating patellofemoral pain but further individualized more functional, global treatment is essential (46).

Chiu et al. investigated effect of weight training on hip and knee muscle strength in patients with patellofemoral pain syndrome (47). Weight bearing quadriceps extension exercises were performed using a weight machine and a leg-press machine for a leg-press exercise. Each exercise involved four sets of ten repetitions. Isometric and concentric quadriceps muscle strengths were evaluated by Cybex Norm®. The authors found increased isometric quadriceps strength (pre/post training difference: 22.44±5.61 N) and isokinetic quadriceps strength (pre/post training difference: 9.33 ± 4.61 N) after their exercise program (47).

Table 1. Exercises Programme for Patients with PFPS (Kaya D, et al., Sports Health, 2010).

Exercises	Duration
Stretches (All sessions)	3 sets of 10 repetitions/10-s hold
● Hamstring stretch	
● Quadriceps stretch	
● Calf and iliotibial band stretch	
Weeks 1-2	
● Wall squat (0°- 40° of knee flexion)	15 repetitions/10-s hold
● Quadriceps isometric	4 sets of 25 repetitions
● Straight leg raises	3 sets of 10 repetitions
Weeks 3-4	
● Wall squat (0°- 60° of knee flexion)	15 repetitions/10-s hold
● Quadriceps isometric	4 sets of 25 repetitions
● Straight leg raises	3 sets of 10 repetitions
● Terminal knee extension	3 sets of 10 repetitions
Weeks 4-5	
● Cont. Exerc	
● Mini-squat (0°- 30° of knee flexion)	
● Lateral step down	3 sets of 10 repetitions
	3 sets of 10 repetitions
Weeks 6 to 8	
● Mini-squat (0°- 45° of knee flexion)	3 sets of 10 repetitions
● Lateral step down with Thera-band resistance behind knee pulling anteriorly	3 sets of 10 repetitions
● Backward walk with Thera-band resistance around ankles (subjects stand with slight knee flexion and take steps backward with resistance between ankles)	3 sets of 10 repetitions
● Lateral step down off 4-in step with Thera-band resistance behind knee pulling anteriorly	3 sets of 10 repetitions
● Single-leg stance	3 sets of 10 repetitions
Weeks 8 and 10	
● Mini-squat (0°- 60° of knee flexion)	3 sets of 10 repetitions
● Anterior step down with Theraband® resistance behind knee pulling posteriorly	3 sets of 10 repetitions
● Side stepping with Thera-band resistance around ankles	3 sets of 10 repetitions
● Forward lunges with push-off (subjects lunge onto step to 40° of knee flexion and push off to starting position	3 sets of 10 repetitions
Weeks 10 to 12	
● Single-leg mini-squat (0°- 30° to 0°-45° of knee flexion)	3 sets of 10 repetitions
● Anterior/Lateral and sideway steps with Thera-band resistance behind knee pulling	3 sets of 10 repetitions
● Split squat with Theraband® Stability Trainer (blue)	
● Forward lunges to ground level	3 sets of 10 repetitions
	3 sets of 10 repetitions

Conclusion - Important note for the readers

Clinicians must adapt the strengthening program depending on the degree of knee flexion at which exercise is accomplished. Steinkamp et al. documented the fact that patellofemoral joint reaction forces are minimized during closed kinetic chain exercises performed from 0º to 40º of the knee flexion (25) The authors emphasized that patients with patellofemoral pain syndrome may tolerate a closed kinetic chain exercises programme, between 0º to 40º knee flexion, better than one focussing on open kinetic chain exercises, because of the lower patellofemoral joint reaction forces and stresses (25). In addition during 60° to 90° of knee flexion, patellofemoral joint stress is *greater* using leg-press exercise (25). The leg press exercise in early knee flexion and leg extension exercise past 60° of knee flexion should be basic guide for the clinicians. This is particularly important since patients with lesions more distal on the patella will need to exercise in more knee flexion to reduce contact stress on the distal patella. Leg press exercise in 0- to 30-degree knee range of motion is most appropriate here. The level of articular lesion is the single greatest factor in determining the degree of flexion in which exercises should be carried out (25).

General strengthening of other muscle groups around the knee should be introduced to *balance* quadriceps power and flexibility. Maintaining a normal Hamstring- Quadriceps ratio of approximately 65% is desirable. Much of this muscle balancing may be accomplished through closed chain exercises and through the aerobic conditioning part of the rehabilitation process.

Authors note for the readers
*You can select open and/or closed kinetic chain exercises for the patients with patellofemoral pain syndrome.
* Be careful! **Pain** is the most important guide in the treatment process.

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