Acta Biomed 2016; Vol. 87, Supplement 1: 60-68 © Mattioli 1885

Original article

Long term effect of selective muscle strengthening in athletes with patellofemoral pain syndrome

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Summary. *Background and aim of the work:* The purpose of the study was to examine the long term effects of a selective muscle strengthening program in reducing pain and improving knee function and strength in athletes with Patellofemoral Pain Syndrome. *Methods:* A total of one hundred and thirty four athletes were enrolled in the study. All patients were evaluated with Isokinetic Test, Cincinnati Knee Rating System and Visual Analogue Scale. The selective muscle strengthening consisted of 8 weeks of exercises performed 3 times in the first 4 weeks and twice in the last 4 weeks. The muscle strengthening program was performed between 30-90° of knee flexion. During the first 4-weeks treatment we used closed kinetic chain exercises with 3 sets of 8 repetitions at 80% of maximum load. In the last 4-weeks we added open kinetic chain exercises at 70% of maximum load with 3 sets and 10 repetitions to improve the resistance. *Results:* Analyzing data at the beginning and at the end of the treatment for Isokinetic test, Cincinnati and Visual Analogue Scale we observed a significant scores improvement. At 1 year follow-up the clinical improvements were maintained and everyone followed the recommended program because did not perform the maintenance program. At 2 years follow-up no athletes presented relapses; only four patients were excluded from program. *Conclusions:* We believe that our program of selective muscle strengthening should resolve pain and improve knee function and strength as results in obtained scores and could be critical to avoid painful relapses. (www.actabiomedica.it)

Key words: patellofemoral pain syndrome, selective muscle strengthening, open kinetic chain, closed kinetic chain

Introduction

Patellofemoral Pain Syndrome (PFPS), which accounts for the 25% of all sports-related knee injuries (1), affects almost young people aged between 15-30 years and it's more common complaint for female (20%) than male (7,4%) (2).

PFPS consists of anterior knee, peripatellar, and sometimes retropatellar pain usually associated to crepitations. The clinical presentation of PFPS varies between individuals, but the highest incidence is evident in young physically active populations (3,4).

Pain is typically exacerbated with prolonged sitting, ascending and descending stairs, squatting and activities requiring high levels of quadriceps activity and increasing patellofemoral (PF) compressive forces (volleyball, basket, jump activities) (5-7).

The exact aetiology of PFPS is unknown, but a combination of factors such as acute trauma, overuse, ligaments surgery, femoro-tibial and patellar instability may be considered critical factors (5).

In 2000 the European Rehabilitation Panel (8) showed major frequent contributing factors increasing the risk of developing PFPS:

- Malalignment of lower extremity, due to excessive foot pronation, tibial extrarotation and femoral neck anteversion, may result in a high Q angle and increased valgus stress;

- Malalignment of PF joint due to patellar and troclear dysplasia, retinaculum thigtness and muscular dysfunction of the quadriceps;
- Dysfunction of knee extensor is due to muscular imbalance of the quadriceps, Vastus Medialis Obliquus (VMO) and Vastus Lateralis (VL). A selective hypotrophy and altered activation of the VMO can contribute to a laterally directed force on the patella (6,9-11);
- Loss of flexibility of the hamstrings including gastrocnemius, rectus femoris and iliotibial band (8).

Dye (12) states that the function of PF joint can be characterized by load/frequency (the envelope of the function) that defines a range of painless loading that is compatible with the homeostasis of the joint tissues.

If excessive loading as load or as frequency is placed across the join, loss of tissue homeostasis can occur resulting in microtrauma, pain and joint dysfunction (8,12).

PFPS is a common complaint in athletes, it may be due to training overactivity and extreme loading and is one of the most frequent overuse knee injury (13,14).

Our aim in the present study was to examine the effects of a selective exercise treatment of strengthen in reducing pain and improving knee function in athletes with PFPS.

Materials and methods

A total of one hundred and thirty four athletes (49 Males; 85 Females) competitive volleyball-players, soccer-players and basketball players, between 16 and 24 years of age (mean: 21,42 +/- 6,56) were enrolled in the study.

Athletes were recruited for the study from the teams of district of Parma and checked for the eligibility by the clinical investigator.

Inclusion criteria for this study were:

- peripatellar or retropatellar pain for at least 4 weeks;
- pain after physical activity;
- absence of patellar tendonitis, meniscal pathologies, apophysitis, ligamentous instability;
- crepitations in the PF joint while flexing and extending the knee.

The participants were informed on the scope and procedures of the study. All individuals provided written informed consent before participating in the study. The Institutional Ethic Review Board of our University Hospital approved the study in accordance with the National Health Council Resolution No. 196/96 and with the Helsinki Declaration of 1975, as revised in 2000.

We prescribed for two patients with great pain and intra-articular effusion, to use intermittent cryotherapy, knee brace with open patella area and NSAIDs for 10 days; then they performed the selective strengthening program.

The evaluation of patients, at beginning and at the end of rehabilitation program, included a structured interview, isokinetic test and scoring according to Cincinnati Knee Rating System and Visual Analogue Scale.

Cincinnati Knee Rating System (Table 1) included a functional assessment based on 6 abilities (walking, ascending and descending stairs, running, squatting/kneeling, jumping and landing, hard twists cuts pivots). The score was from 120 (inability to perform activity caused by pain) to 420 (no pain and any functional limitation) (15).

Visual Analogue Scale (VAS) evaluated subjective pain and used a 10-cm VAS to determine subjects' worst pain, and 0-cm VAS to determine subject's no pain.

Isokinetic knee tests was performed using the Biodex System 3 Pro dynamometer (BIODEX Medical Systems, Shirley, NY, USA). These tests were carried out with a precise number of operations in order to reproduce equal test conditions in all subjects. Before beginning the test, each subject warmed up for 5 min and performed 5 repetitions of each action to familiarize them with the machine and prevent damage. Flexion/extension of the painful knee was evaluated in concentric contractions in all movements. The parameter tested was Quadriceps and Hamstrings Peak Torque (PT; measured in Newton meters). All patients performed 5 repetitions in flexion/extension at an angular speed of 90°/s (strength test).

The rehabilitation program with selective muscle strengthening consisted of 8 weeks-exercises perfor-

Table 1. Cincinnati Knee Rating System

CINCINNATI KNEE RATING SYSTEM			
Functional measures			
(1) walking	(3) squatting and kneeling	(5) jumping and landing	
(2) using stairs	(4) straight running	(6) hard twists cuts and pivots	
walking			
normal unlimited	some limitations	only 3-4 blocks possible	less than 1 block possible
40	30	20	0
stairs			
normal unlimited	some limitations	only 11 – 30 steps possible	only 1 – 10 steps possible
40	30	20	0
squatting and kneeling			
normal unlimited	some limitations	only 6 – 10 possible	only 0 – 5 possible
40	30	20	0
running			
full competitive	some limitations guarding	half-speed definite limitations	not able
100	80	60	40
jumping and landing			
fully competitive	some limitations guarding	half-speed definite limitations	not able
100	80	60	40
hard twists cuts pivots			
fully competitive	some limitations guarding	half-speed definite limitations	not able
100	80	60	40
Functional assessment score = SUM (points for all 6 activities)			
Interpretation • minimum score: 120 • maximum score: 420 • The goal is to have the highest possible function in each of the 6 categories			

med 3 times in the first 4 weeks and twice in the last 4 weeks.

For each training session, after 10-15 minutes exercise bicycle (with low saddle to 20° of knee flexion) (Fig. 1) as warm up, the training was performed with stretching exercises of the hamstrings, quadriceps, gastrocnemius, iliotibial band and thigh adductors and abductors (Fig. 2). Stretching exercise were carried out for 20 seconds, for 4 times with 15 seconds of rest between repetitions.

During the first 4-weeks treatment we used closed kinetic chain (CKC) exercises whereas in the last 4-weeks treatment we added to CKC exercises open kinetic chain (OKC) exercises (Table 2).

The muscle strengthening program, during the first 4 weeks, was based on following CKC exercises:

- leg press (Fig. 3);
- ¼ squat (Fig. 4);
- lateral (Fig. 5) and frontal lunges;
- thigh adductors (only for lateral PFPS) (Fig. 6);
- thigh abductors (only for medial PFPS) (Fig. 6).

For each exercise, patients performed 3 sets of 8 repetitions at 80% of maximum load.

In the last 4-weeks we added to the 4 weeks initial program the following OKC-CKC exercises with 70% of maximum load, and we maintained 3 sets and increased to 10 repetitions to improve the resistance:

- leg extension (Fig. 7);

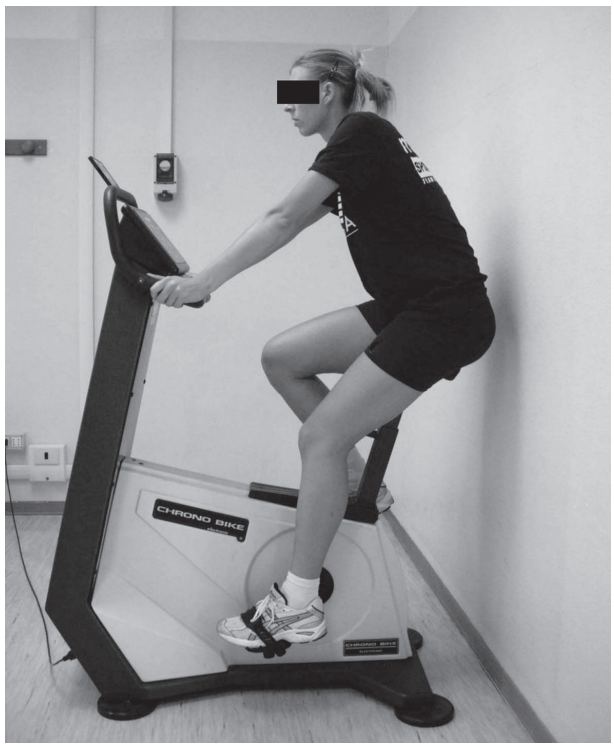

Figure 1. Exercise bicycle

Figure 2. Quadricep stretching

Figure 3. Leg press with extrarotate tiptoe

Figure 4. 1/4 Squat with intrarotate tiptoe.

• leg curl (Fig. 8);
• leg calf (Fig. 9).

The muscle strengthening program was performed between 30-90° of knee flexion. The tiptoe was turned to the painful compartment in order to avoid

Table 2 - Rehabilitation program

Patellofemoral pain syndrome Rehabilitation program			
Warm up: Exercise bike 10-15 min with low saddle Stretching: Hamstrings, Quadriceps, Gastrocnemius, Thigh adductors and abductors, iliotibial band			
Isotonic strength in closed kinetic chain (CKC) • 3 times a week in the first 4 weeks • 80% of maximum load • Between -30° knee extension 90° knee flexion • Tiptoe turned to the painful compartment (INT-EXT)			
	Sets	Ripetitions	Rest
Leg press	3	8	1 min
¼ squat	3	8	1 min
Frontal and lateral lunges	3	8	1 min
Thigh adductors (lateral PFPS)	3	8	1 min
Thigh abductors (medial PFPS)	3	8	1 min
Isotonic strengh in closed kinetic chain (CKC) and open kinetic chain (OKC) • 2 times a week in the last 4 weeks • 70% of maximum load • Between -30° knee extension 90° knee flexion • Tiptoe turned to the painful compartment (INT-EXT)			
	Sets	Ripetitions	Rest
Leg press	3	10	1 min
¼ squat	3	10	1 min
Frontal and lateral lunges	3	10	1 min
Thigh adductors (lateral PFPS)	3	10	1 min
Thigh abductors (medial PFPS)	3	10	1 min
Leg extension	3	10	1 min
Leg curl	3	10	1 min
Leg calf	3	10	1 min

overloading involved compartment. Each athlete added one in weekly a session training of maintenance with the program of the last 4 weeks.

At the end of the treatment patients were evaluated with Isokinetic knee test, Cincinnati Knee Rating System Scale and VAS to observe outcomes.

We performed 1 and 2 years follow-up to observe the maintenance results.

Results

All patients completed the recommended program of selective muscle strengthening. One patient was excluded from the protocol due to a medial meniscal injury occurring at the end of program and required a surgical treatment.

Student's t-test for independent parametric data and U-Mann Whitney Test for non parametric independent data were used to compare the gender with the age and with the Isokinetic Test, Cincinnati and VAS initial scores of the sample. No statistically significant difference (p=0,96; p=0,56; p=0,659) was found between the data and consequently the sample was considered homogeneous.

All statistic evaluations were performed using the IBM SPSS software (version 20 for Windows). The results of initial and final valuation were compared with paired Student's t-test (Table 3) using a significance level of $p < 0,005$.

Figure 5. Frontal lunge

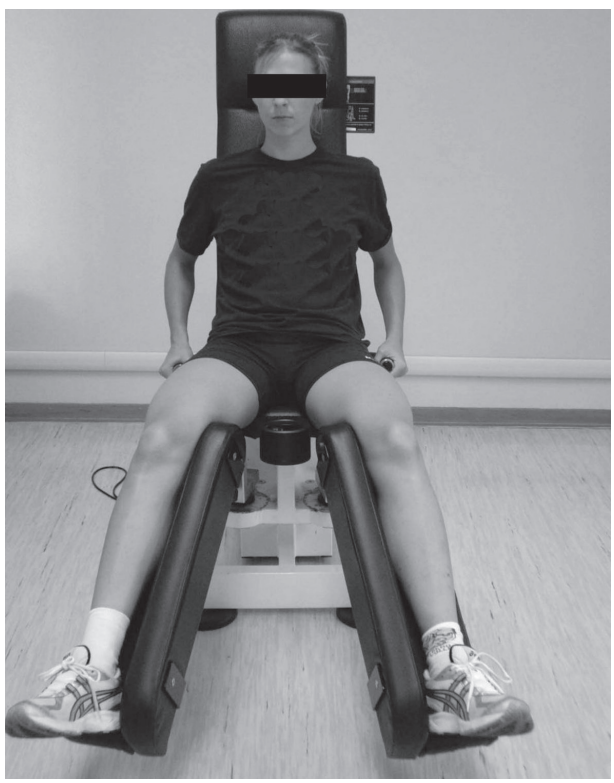

Figure 6. Thigh adductors and abductors strengthening

Figure 7. Leg extension

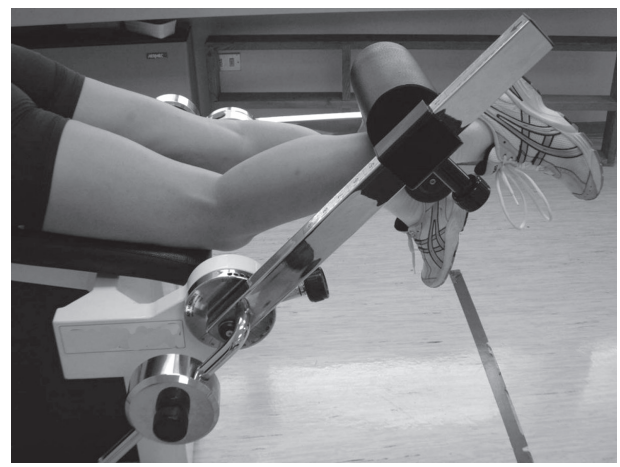

Figure 8. Leg curl

Analyzing data at the start and at the end of the treatment for Isokinetic Test, Cincinnati and VAS we observed a significative scores improvement (Table 3).

At 1 years follow-up no athletes presented relapses and anyone stopped the recommended program. At 2 year follow-up the clinical improvements were maintained, only four patients were excluded from program because did not perform the maintenance program.

Discussion and conclusions

In literature there are many different treatment protocols on PFPS rehabilitation (3-6,8,20-24). In absence of malalignments of lower extremity and

Figure 9. Leg calf (CKC)

observable dysplasias, different Authors are in agreement that the anterior knee pain must be controlled with conservative treatment and without surgery treatment (17-19).

Kettunem et al. (26) argued that, in a randomized and controlled trial involving 56 patients with chronic PFPS, the arthroscopy did not provide any overall additional advantage when provided in addition to 8-week home exercise program.

The purpose of rehabilitation program in our study was to restore quadriceps and VMO muscular balance, to improve flexibility and to reduce PF joint stress. So we suggest to perform selective stretching exercises because a lot of Authors showed that loss of flexibility of the hamstrings, including gastrocnemius, rectus femoris, iliotibial band adductors and abductors can modify PF joint biomechanics and contribute to overload the joint (8,10, 22-24).

We used before CKC exercises and then we added OKC exercises. There is no clear consensus in literature concerning PFPS treatment. Traditionally CKC have become more popular than OCK exercises because it has been suggested that CKC exercises are more functional and place minimal stress on the PF joint (16-19).

Table 3 - Analysese of the results [Student's t-test (t-test paired $\alpha = 0,05$)]

	Mean	Standard Dev.	P Value
Isokinetic Test			
Initial Quadriceps PT	135,36	5,760	
Final Quadriceps PT	168,24	10.060	<0,005
1 Year Follow Up Q. PT	164,18	9,770	>0,005
2 Years Follow Up Q. PT	166.33	11,020	>0,005
Initial Hamstrings PT	74,12	8,920	
Final Hamstrings PT	96.30	15,530	<0,005
1 Years H. PT Follow Up	98,12	14,442	>0,005
2 Years H. PT Follow Up	95,52	15,064	>0,005
Cincinnati Knee Scale			
Initial Score	290,83	13,356	
Final Score	398,06	13,695	<0,005
1 Year Follow Up	409,72	9,407	>0,005
2 Years Follow Up	406,52	11,24	>0,005
Visual Analogic Scale			
Initial Score	8,22	0,898	
Final score	0,64	0,762	<0,005
1 Year Follow Up	0,44	0,211	>0,005
2 Years Follow Up	0,32	0,167	>0,005

Witvrouw et al. (19), Stiene et al. (32) and Fagan and Delahunt's (33) latest review showed that both OKC and CKC lead to significant reduction in pain and improvements in knee function.

The examined group performed muscular strengthening between 30°-90° of knee flexion with submassimal load, in order to avoid activities which can increase PF joint compressive reaction forces (16,28,29). Although Escamilla (28,29) showed that PF compressive forces increase as maximum knee flexion, PF stress is greatest between 0°-30° knee flexion because PF reaction forces are concentrated in a minimal contact area (16,28).

Furthermore Tang et al. (34) reported that the VMO activation is present during the full range of motion, and that especially VMO/VL ratio, which were determined by surface Electromyography (EMG) during eccentric and concentric exercises, is maximum at 60° of knee flexion while VMO/VL ratio is less than 1 between 0°-45° of knee flexion.

During exercises we suggested to turn the tiptoe to painful compartment, in order not to overload this compartment. The purpose was to decrease chondral stress, subchondral bone pressure and resulting pain (2,8,35).

We preferred the strengthening of thigh abductors in medial PFPS, and the thigh adductors in lateral PFPS, even though in literature it remains unknown which should be the better hip position (36-39).

In our study at the end of treatment all patients reduced pain and improved knee and strength function (Table 3).

At 1 year follow-up the clinical improvements were maintained. All athletes showed further functional improvements demonstrating greatest score at Cincinnati Knee Rating System. At 2 years follow-up no athlete presented relapses; only four patients were excluded from program.

We believe that our program of selective muscle strengthening should resolve pain and improve knee strength and function as results in obtained scores and could be critical to avoid painful relapses. Therefore according to other studies, the maintenance of improvements should be influenced by adding a specific session of selective muscle strengthening in the weekly training (8,9,21,33,40).

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