EFFECT OF A CLOSED KINETIC CHAIN EXERCISE PROTOCOL ON PATELLOFEMORAL SYNDROME REHABILITATION

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The purpose of this study was to verify the efficacy of quadriceps femoris muscle strengthening exercises in a closed kinetic chain (CKC) in the treatment of patellofemoral syndrome (PFS). The following elements were evaluated: pain, knee functional injury level, Q angle and electromyographic activity of the vastus medialis and vastus lateralis muscles during isometric contractions. The 10 PFS patients performed quadriceps femoris strengthening exercises using a leg-press with progressive increase in resistance during eight weeks, twice a week. The data collected were analyzed by the Wilcoxon test ($\alpha<0.05$) and the results showed significant improvement in knee functional injury level ($p<0.05$), suggesting that the CKC proposed exercises may be prescribed for PFS patients, specially if accompanied by pain level control.

KEY WORDS: knee injuries, evaluation of results of therapeutic interventions, exercise therapy.

INTRODUCTION:

Patellofemoral syndrome (PFS) is one of the most common joint complaints (Sacco *et al.*, 2006) and affects athletes and non-athletes alike (Thomeé, 1997). PFS patients report symptoms of anterior or retropatellar pain, aggravated by functional activities. Patellar crepitation, swelling and locking are other symptoms (Tunay *et al.*, 2003a).

There is a commonly accepted concept that conservative rehabilitation induces symptom relief for PFS patients (Doucette and Child, 1996; Tunay *et al.*, 2003a). The treatment often includes quadriceps femoris muscle strengthening exercises in an open kinetic chain (OKC) or closed kinetic chain (CKC).

Patellofemoral joint biomechanics in OKC and CKC is quite different. For CKC exercises, Steinkamp *et al.* (1993) observed greater patellofemoral joint reaction force during leg-press exercises with knee flexion of 60 and 90 degrees, and a reduction of these forces at zero and 30 degrees of knee flexion. Escamilla *et al.* (1998) demonstrated larger compressive forces in CKC exercises at knee flexion angles greater than 85 degrees.

However the clinical benefits of strengthening exercises in PFS treatment are not well documented (Thomeé, 1997), mainly for exercises with range of motion (ROM) control (Stiene *et al.*, 1996; Cowan *et al.*, 2002).

Thus the purpose of this study was to verify the efficacy of quadriceps femoris muscle strengthening exercises in CKC in the physiotherapeutic treatment of women with PFS.

METHOD:

Subjects: The population studied consisted of 10 female patients with diagnosis of PFS, who performed quadriceps femoris muscle strengthening exercises in CKC using a leg-press.

The institutional review board (CAPPesq, The ethics committee for analysis of research projects of the Clinical Hospital of the University of São Paulo Medicine School) approved the study.

Patients were included if aged between 18 and 32, did not practice physical activity and showed a positive patellar compression test (Magee, 2002). Other inclusion criteria included symptoms of patellofemoral pain for at least six months, anterior or retropatellar pain during

or after at least two of the following activities: prolonged sitting, going up or down stairs, squatting, kneeling, running and jumping, and an insidious onset of symptoms unrelated to a traumatic incident (Cowan *et al.*, 2002).
Participants were excluded if they showed signs or symptoms of any other knee pathology or injury (Thomeé, 1997).

Evaluation: Before the evaluation, the subjects signed an informed consent form. In the first and last sessions, the following elements were evaluated: pain, knee functional injury level, Q angle and electromyographic activity (EMG) of the vastus medialis (VM) and vastus lateralis (VL) muscles. The lower limb showing the greater clinical complaint was chosen for evaluation.
Pain was measured using a visual analogue scale (VAS) with values between zero and 10 cm.
Knee functional injury level was evaluated using two scales: Lysholm knee scoring scale and Patellofemoral joint evaluation scale (Magee, 2002; Peccin *et al.*, 2006).
The Q angle was measured with a goniometer, with the patient in the supine position, feet in the neutral position and relaxed quadriceps femoris muscle (Magee, 2002).
EMG muscular activity was detected using an 8-channel EMG equipment with an analogical-digital converter (EMG System do Brasil) and resolution of 12 bits, interfaced with a computer and data collection software – AqDados 5.0 (Lynx Electronics Technologies), with an acquisition frequency of 1000 Hz per channel and band pass of 20-500 Hz; active differential surface electrodes (EMG System do Brasil); and self-adhesive electrodes (Meditrace).
The electrodes were placed on the muscle motor point, located by electrical stimulation, to allow the reproduction of this study after treatment. Self-adhesive electrodes were positioned on the muscle belly, 2 cm apart, and fixed with adhesive tape. The EMG activity of the VM and VL muscles was measured during three repetitions of isometric knee extension with the knee flexed at 90 degrees and anterior resistance applied at the distal tibia, with the subject in a sitting position. The EMG signal was collected for four seconds and the volunteers were asked to extend their knee as much as possible.

Intervention: The physical therapy intervention consisted of 16 sessions during eight weeks, twice a week. The patients performed the quadriceps femoris muscle strengthening using a leg-press (Righetto Fitness Equipment), placed in a sitting position with the trunk and hips flexed at 90 degrees and knees at total extension. The exercise consisted of knee flexion/extension between zero and 45 degrees of ROM, in five series of 10 repetitions and progressive increase in resistance, based on a modified pain monitoring system (Thomeé, 1997). In the first treatment session, the exercises were performed with a resistance of 5 kg and if the patient presented a pain level below 2 cm, the resistance was increased 5 kg in the next session.

Data analysis: The VAS values were measured in the first (before) and last (after) sessions, obtaining values between zero and 10 cm.
The scores obtained using the functional assessment scales were added up, obtaining values between zero and 100.
The EMG signal was processed by means of the software Origin 6.0 routines and transformed into root mean square (RMS) values as follows: the wave acquired was rectified and filtered through a 5 Hz band pass filter to obtain a linear envelope. After a visual inspection of the envelope, the 1-second period showing least variation and maximum EMG activity was selected and the RMS value of the rectified signal calculated with a band pass filter of 20 to 500 Hz in the selected period. The mean of the three attempts was analyzed.

Statistical analysis: The significance level was set at $\alpha<0.05$. All the variables were analyzed as to normality using the Anderson-Darling test. Since almost all data were non parametric, the Wilcoxon test was used to comparisons before and after intervention.

RESULTS:

The mean (SD) age, weight, height and body mass index of the patients were 20.00 (1.00) years, 57.65 (10.08) kg, 1.62 (0.07) m and 22.21 (4.93) kg/m^2 respectively.
Table 1 shows the results obtained before and after treatment. There was a statistically significant difference in the Lysholm knee scoring scale (p=0.028) and Patellofemoral joint evaluation scale (p=0.036), but no difference was found for the other data (p>0.05).
With respect to the training resistance applied during exercise, the patients started with 5 kg and ended with 77.50 kg mean resistance (maximum value = 80 kg, minimum value = 70 kg).

Table 1 Means (standard deviation) and p-values (n=10) for the variables collected

Variables	Before	After	p
Visual analogue scale (cm)	0.85 (1.52)	0.22 (0.24)	0.529
Lysholm knee scoring scale	69.10 (14.00)	83.70 (11.28)	0.028*
PFJ evaluation scale	69.80 (10.66)	81.50 (8.68)	0.036*
Q angle (degrees)	17.80 (3.71)	16.70 (2.63)	0.123
RMS of the VM muscle (μV)	43.05 (16.42)	44.56 (20.30)	0.878
RMS of the VL muscle (μV)	44.95 (15.04)	40.98 (12.06)	0.445
Training resistance (kg)	5.00 (0.00)	77.50 (3.54)	---

*Statistically significant difference (p<0.05) before and after treatment
(PFJ: patellofemoral joint; RMS: root mean square)

DISCUSSION:

The results showed no significant change in pain level. The patients initiated treatment with pain values below 1 cm, so a significant pain reduction after treatment was not expected.
An important improvement in knee functional level was found. Thomeé (1997) suggested that PFS pain during functional activities resulted in altered physical activity and decreased force production by the knee extensors muscles. We were unable to show any increase in knee extension force after intervention, but the improvement in knee functional level and increase in training resistance suggested that muscle intervention was efficient for functional activities and blocked the cycle described by Thomeé (1997).
The Q angle showed no significant alterations after intervention. Tunay *et al.* (2003b) observed a significant improvement in the Q angle in PFS patients after different treatments. However, these benefits could not be explained because the exercises performed were not described. The authors reported similar Q angle values before and after treatment in relation to the present study, even though both male and female subjects were evaluated. Sacco *et al.* (2006) obtained different results, with no changes in Q angle after five weeks of treatment, but the Q angles were very small, between five and eight degrees, in a study of physically active male and female subjects.
For a correct measurement of the Q angle, the determination of the reference points is essential. In the present study, the lower limb position and location of the anatomical structures were very carefully controlled. Thus, the mean Q angle values before treatment were similar to those found by Boucher *et al.* (1992), who observed mean Q angles of approximately 21 degrees in PFS patients, using an automated two-dimensional video-based motion analysis system.
Finally, there was no significant change in EMG activity after treatment. The mean RMS values for the VM and VL muscles before and after intervention were similar. However, despite the absence of significant differences, the treatment was shown to maintain the muscle balance between the two most important dynamic patellae stabilizers.
Some factors deserve attention with respect to the proposed muscle strengthening protocol. The first concerns the proposed control of ROM at 0 and 45 degrees during knee flexion, since according to the literature these kinds of exercise generate low patellofemoral joint reaction and compressive forces (Steinkamp *et al*., 1993; Escamilla *et al*., 1998).

Moreover, Steinkamp *et al.* (1993) reported that CKC exercises recruit the quadriceps femoris muscle in a more functional maneuver, with the ROM simulating that of daily activities, the knee joint being in more extended positions.
The training resistance was increased as the pain level decreased, based on a modified pain monitoring system (Thomeé, 1997). In the first strengthening muscular session, most of the patients showed difficulty in performing the proposed exercises, even with the leg-press fixed in its minimal resistance position. Since the resistance could not be further reduced, the pain monitoring system was essential to protect the joints from excessive loads, and we believe that the increases in resistance made were extremely safe, only occurring when the patient signaled a pain level below 2 cm.

CONCLUSION:

The results of the present study permit the suggestion that the proposed quadriceps femoris strengthening exercises with ROM control should be prescribed for PFS patients since they improve the knee functional level. Moreover, progressive resistance increases according to the pain level should be used in patients with muscle skeletal disorders, to protect the joints.

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