PHYSICAL THERAPY IN PATELLOFEMORAL SYNDROME PATIENTS: COMPARISON OF OPEN AND CLOSED KINETIC CHAIN EXERCISES

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SUMMARY

The aim of this study was to compare the efficacy of muscular strengthening in the functional recovery of patellofemoral syndrome (PFS) patients. Twenty female patients with PFS were divided into two groups: Group 1 (G1) performing quadriceps femoris strengthening exercises in open kinetic chain (OKC) and Group 2 (G2) in closed kinetic chain (CKC), twice a week for eight weeks. Pain, functional capacity, flexibility, hamstring tightness, Q angle and electromyography (EMG) were measured for vastus medialis (VM) and vastus lateralis (VL) muscles during isometric leg extension. The data obtained before and after treatment were analyzed by Wilcoxon test, and the data between groups by t-test for independent samples or Friedman Anova or Manova (<0.05). After treatment, the results showed a significant improvement in terms of functional capacity, hamstring tightness and flexibility. However, only G1 showed decreased pain and improved EMG activity of VL muscle, while both groups showed unchanged Q angles. These data suggest that treatments based on exercises for quadriceps femoris strengthening produced improvements on a number of PFS signals and symptoms, with no evidences of differences between OKC and CKC exercises.

Keywords: *Knee injuries/rehabilitation; Questionnaires; Pain measurement; Electromyography; Joint range of motion; Exercise therapy.*

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INTRODUCTION

The patellofemoral syndrome (PFS) is characterized by peri- or retropatellar pain[1], and affects athletes and non-athletes, representing a common knee problem for physically active teenagers and young adults[2].

Although not clearly established, its etiology may be correlated to several factors leading to patellar misalignment, such as an increased Q angle, high or low patella, excessive subtalar pronation, tibial lateral rotation, femoral anteversion, valgus or varus knees, and lateral retinaculum, ischiotibial and iliotibial tract muscles' shortening[1,3].

Currently, diagnosis is given based on clinical examination made by experienced professionals, including physical therapists, considering that a detailed evaluation is critical for suggesting future interventions[3,4].

Patients with PFS present with anterior or retropatellar diffuse pain that is exacerbated by activities such as climbing up and down stairs, remaining at sitting position for long periods of time, squatting or kneeling, in which there are increased compressive forces on patellofemoral joint. Other signs seen on these patients are patellar crepitation, edema and joint blockage[3].

Currently, conservative treatment has been recognized as providing symptoms relief in most of the patients with PFS[3,5]. This treatment usually includes strengthening exercises for femoral quadriceps muscle performed on open kinetic chain (OKC) and closed kinetic chain (CKC).

Several protocols exist for muscular strengthening in PFS rehabilitation; however, there are no objective data to determine the best conservative approach for this syndrome, since the biomechanics and the muscular function on OKC and CKC are considerably different. Steinkamp et al.[6] noticed that the patellofemoral response force is increased in leg extension exercises than in leg-press at zero and 30 degrees of flexion, with the opposite occurring at 60 and 90 degrees. Escamilla et al.[7] found that the exercises performed on OKC produced less compressive forces with legs flexed at approximately 90 degrees, and more compressive forces when they are flexed at less than 57 degrees, as compared to CKC exercises , which generate stronger forces at flexion above 85 degrees. Stensdotter et al.[8] showed that the amplitude of the electromyographic (EMG) signal normalized by maximum voluntary contraction of the oblique vastus medialis (OVM) muscle is greater on CKC, although lower than that of the vastus lateralis muscle in both exercises.

Escamilla et al.[7] suggest that the data reported by literature on the comparison of exercises on OKC and CKC are non-conclusive. In addition, the clinical benefits of applying such protocols on patients are not well documented[2], especially on those studies proposing exercises with the control of range of motion (ROM) for treatment[4,9].

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Thus, the objectives of this study were to compare the effectiveness of exercises intended to strengthen the quadriceps femoralis muscle, on OKC and CKC, for functional recovery of women with PFS.

CASE SERIES AND METHOD

Subjects

Twenty-one female PFS patients participated on this study, being divided into two groups: Group 1 (G1), with 11 patients, was submitted to exercises for strengthening quadriceps femoralis muscle on OKC at the extension chair, and Group 2 (G2), with 10 patients, was submitted to exercises for strengthening quadriceps femoralis muscle on CKC at the leg-press.

Inclusion criteria were the following:

- Age between 18 and 32 years, sedentary (not practicing any physical activity on a regular basis);
- Presence of patellofemoral pain symptoms for at least six months, with no evidence of any other musculoskeletal condition on lower limbs; anterior or retropatellar pain during or after at least two activities among sitting for long periods of time, climbing up and down stairs, squatting, kneeling, running and jumping, and insidious onset of symptoms unrelated to trauma event[4];
- Ischiotibial muscles shortening, defined as a loss of more than 30 degrees of leg extension with thigh positioned at 90 degrees of flexion[10] and positive patellar compression test[11];
- Signed Informed Consent Term, at the moment the participation on the study was agreed. The research was approved by the committee of ethics of the Hospital das Clínicas, University of São Paulo Medical School (FMUSP – protocol number 635/03).

Exclusion criteria were the following:

- Presence of signs and symptoms of any other knee condition, ligament or meniscal injury, surgery or injury on the patellofemoral joint complex, chronic patellar dislocation or subdislocation, and persistent knee edema[2];
- Continuous absenteeism on treatment sessions, without replacement. A G1 patient could not complete therapy, thus, both groups were constituted of 10 patients.

Materials

For assessing the subjects, a physical evaluation file was employed, containing personal data, stance evaluation and flexibility measurements, muscular shortening and Q angle, an electromyographer with connecting cables and adhesive electrodes, a pulse-generator machine and pain and functional capacity assessment scales. For treatment, two muscle fitness equipment were used: the extensor chair and the leg-press.

EVALUATION

Patients were evaluated on the first and last sessions, concerning the following aspects:

- Stance evaluation: by visual inspection with a symmetographer, checking for stance changes on lower limbs;
- Pain: using the analogous visual scale (AVS) ranging from zero to 10 cm;
- Flexibility: measured with a measuring tape and using the third finger-ground test[12];
- Ischiotibial muscles shortening: by measuring the range of extension of the leg with a goniometer[10];
- Q angle measurement: with the individual at supine position, with feet positioned perpendicularly to the bed, and quadriceps femoralis muscle relaxed. The angle formed between the intersection of a line connecting the anterosuperior iliac spine to the center of the patella, and the other connecting tibial tuberosity to the center of the patella as well as measured with a goniometer[11];
- EMG activity: an 8-channel, 12-bit resolution amplifier and analogical-digital converser – CAD 12/32 (EMG *System* do Brasil), interfaced with a computer and a data acquisition software program (AqDados 5.0), with sampling frequency of 1000 Hz and band width determined with a 20-500 Hz band-pass; differential active surface electrodes (EMG *System* do Brasil), with 1000-x total pre-amplification and adhesive electrodes (*Meditrace*). In order to assure that the electrodes are consistently placed before and after treatment, the motion point of the vastus medialis (VM) and vastus lateralis (VL) muscles was determined using an electric stimulation current. Subsequently to that determination, the electrodes were connected to the individual's skin by means of adhesive surface electrodes, with a center-to-center distance of 2 cm, and fixed with *transpore* tape. The EMG activity for VM and VL muscles was captured in three repetitions of leg isometric extension exercises with the individual at sedestation on a bed and with the leg flexed at 90 degrees, with resistance provided at the anterior ankle region. Isometric contractions lasted for four seconds, and the patients were asked to do so as strongly as possible. The order of the exercises was randomly selected;
- Functional capacity: by *Lysholm* scoring scale and by the patellofemoral joint assessment scale[11]. For both scores, higher values (close to 100) correspond to a better knee function capacity.

In all evaluation procedures, whenever symptoms were reported bilaterally, the most affected knee was chosen, i.e., the one presenting the strongest signs and symptoms.

Intervention

Treatment was provided for eight weeks, twice a week. G1 performed quadriceps femoralis muscle strengthening on extensor chair (*Righetto Fitness Equipment*) with the individual seated, trunk flexed at 60 degrees and flexed legs at 90 degrees. The exercise was completed by performing an extension and flexion movement of the leg at a range of 90-45 degrees.

G2 performed exercises for strengthening the quadriceps femoralis muscle on the leg-press (*Righetto Fitness Equipment*), with the individual seated on the equipment chair, with trunk and thighs flexed at 90 degrees and legs at full extension. The exercise was made by flexing and extending the leg at 45 degrees. Each group performed 5 series of 10 extension and flexion repetitions each, with the ADM being monitored with a goniometer and with a progressive load increase, using the modified pain monitoring system of the study by Thomeé[2]. In the first treatment session, a 5 kg load was used, which was increased at 5gs increments since the patient presented pain intensity < 2 cm.

When the patient could not perform the exercise with a heavier load, even if pain intensity was below 2 (as measured by AVS), the same weight as the previous session was used, respecting the limits of the strength increase on that patient.

Data analysis

Stance misalignment and most affected knee (i.e., the one presenting stronger signs and symptoms) rates were calculated, as a percentage, for each group.

AVS measurements were made with a rule ranging from zero to 10 cm, and, for the statistical analysis, data obtained before the first session and after the 16th session were used. The answers to functional assessment scales were summed up, reaching a value between zero and 100.

For assessing EMG data, the root mean square (RMS) value was calculated on *Origin* (6.0) software, as follows: the acquired signal was adjusted, filtered with 5-Hz low-pass filter, obtaining the linear envelope. By visually inspecting the envelope, a 1-second period was selected where muscular activation peak occurred, with the lowest variation possible and calculated the RMS value for the adjusted signal and with 20-500 Hz band-pass filter for the selected period. This procedure was conducted on the three extension attempts, then calculating the mean value, which was subsequently assessed.

For flexibility, before and after treatment on each group, the difference between values obtained before and after treatment was calculated by modules, and the zero medians difference was tested. In the intergroup analysis, indexes were created for functional capacity, flexibility and ischiotibial muscles shortening variables intending to normalize data obtained and to consider a relative improvement, since each individual presented a distinguished status at baseline.

Statistical analysis

The whole statistical analysis was conducted by adopting a 5% significance level, and it can be considered as two phases: comparison of the variables before and after treatment on each group and between groups.

For the first phase, the Anderson-Darling test was primarily used with the purpose of checking for data normality. As the distribution of most of the variables did not follow a normality curve, the Wilcoxon non-parametric test was selected aiming to compare the values of the following variables: pain severity, functional capacity, ischiotibial muscles shortening, Q angle, flexibility, and RMS of the VM and VL muscles.

Between the groups, the following variables were assessed: pain severity, functional capacity scales'indexes, flexibility, and ischiotibial muscles shortening. Initially, variance homogeinity was investigated by using the Lavene's test. When homogeneity was present, the t-test was employed for independent samples. When absent, the variable was transformed by its square root or $\log_{10}$, and, once this objective was accomplished, the same analysis as described above was employed. In cases when, even after transformation, homogeneity could not be achieved, the Friedman's ANOVA was used.

For demographic data such as: age, mass, height, and body mass index (BMI), the same procedure described on previous paragraph was performed for measurements obtained prior to treatment.

The comparison of the Q angle and mean RMS values of VM and VL muscles was provided by the multivariate variance analysis (MANOVA) and by the Duncan's test, intending to investigate if the kind of treatment and/or intervention had any effect over the variables.

RESULTS

The analysis of demographic data (Table 1) did not evidence statistically significant difference between groups, showing that these were both homogeneous in terms of age, mass, height and BMI. In addition, the main signs and symptoms show that 100% of the patients had a positive compression test, pain at functional activities and ischiotibial muscles' shortening. The rates for other misalignment signs on lower limbs found during the stance evaluation are also described on Table 1, emphasizing the fact that the patients usually presented more than one misalignment.

Demographic Data	G1 (n=10)	G2 (n=10)	p
Age (years)	21.00 (1.00)	20.00 (1.00)	0.136
Mass (kg)	55.57 (5.04)	57.65 (10.08)	0.600
Height (m)	1.61 (0.04)	1.62 (0.07)	0.640
BMI (kg/m^2)	21.62 (2.38)	22.21 (4.93)	0.791
Most affected knee	10% R 90% L	50% R 50% L	--- ---
Disalignment			
Valgus knees	40%	50%	---
Varus knees	30%	40%	---
Hyper extended knees	40%	10%	---
Medialized patellas	50%	80%	---
Lateralized patellas	10%	0%	---
Tibial medial rotation	40%	30%	---
Tibial lateral rotation	40%	40%	---
Subtalar pronation	80%	80%	---

(R: right lower limb; L: Left lower limb)

***Table 1** – Averages and standard deviation for age, mass, height, body mass index (BMI) and p values, knee most affected and lower limb misalignment found on the stance evaluation in both groups.*

Table 2 describes the results of G1, where a statistically significant difference ($p<0.05$) was found for all variables after treatment, except for Q angle and VM muscle's EMG activity. All patients started the exercises with a 5-kg load and finished them with a mean load of 36.50 kg, ranging from 45 kg (maximum) to 25 kg (minimum).

The results for G2 are listed on Table 3. For all items, a statistically significant difference was found after treatment ($p<0.05$), except for pain severity, Q angle and EMG activity. Concerning the load used during treatment, the exercises were also started with 5 kg, and finished with a mean load of 77.50 kg, ranging from 80 kg (maximum) to 70 kg (minimum).

Figure 1 shows the values for flexibility represented by the difference found before and after treatment. A statistically significant difference was found on both groups ($p=0.006$).

Variables	Before	After	p
Analogous Visual Scale (cm)	2.83 (1.95)	0.57 (0.62)	0.013*
Training load (kg)	5.00 (0.00)	36.50 (5.80)	---
Lysholm scoring scale	67.90 (8.61)	83.50 (15.44)	0.009*
Assessment scale for PFJ	70.80 (10.98)	82.70 (13.18)	0.024*
Ischiotibial shortening (degrees)	57.00 (11.01)	46.90 (11.27)	0.008*
Q angle (degrees)	17.90 (3.93)	15.80 (3.55)	0.093
RMS of the VM muscle (μV)	51.96 (32.46)	66.25 (49.50)	0.508
RMS of the VL muscle (μV)	29.23 (26.07)	63.71 (24.75)	0.013*

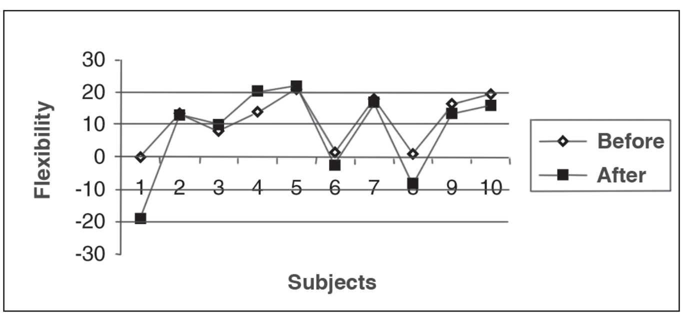
* statistically significant difference between values obtained before and after treatment ($p<0.05$). (PFJ: patellofemoral joint; RMS: root mean square)

***Table 2** – Averages and standard deviation of the values obtained before and after treatment for G1 and p values (n=10)*

Variables	Before	After	p
Analogous visual scale (cm)	0.85 (1.52)	0.22 (0.24)	0.529
Training load (kg)	5.00 (0.00)	77.50 (3.54)	---
Lysholm scoring scale	69.10 (14.00)	83.70 (11.28)	0.028*
Assessment scale for PFJ	69.80 (10.66)	81.50 (8.68)	0.036*
Ischiotibial shortening (degrees)	54.10 (10.21)	42.90 (13.92)	0.008*
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

* statistically significant difference between values obtained before and after treatment ($p<0.05$). (PFJ: patellofemoral joint; RMS: root mean square)

***Table 3** – Averages and standard deviation of the values obtained before and after treatment for G2 and p values (n=10)*



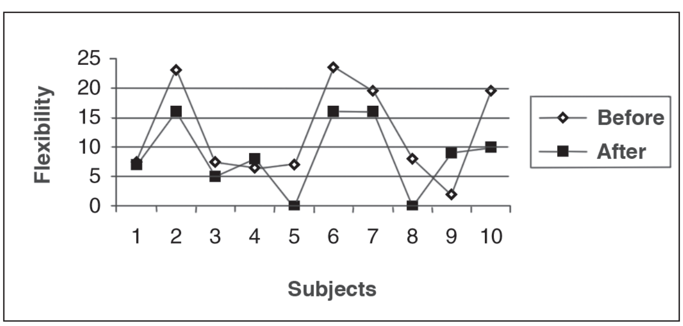


***Figure 1** – Values for flexibility (cm) of each volunteer on Groups 1 and 2 before and after treatment.*

By comparing the variables between both groups, a significant difference was found for pain severity (p=0.024), with the G1 mean values before treatment being higher than the others. For Q angle, we found that the kind of treatment (p=0.719), intervention (p=0.156), or the interaction between both factors (p=0,653) had no effect. For EMG activity of VM muscle, no effect was also seen for treatment (p=0,590), but for intervention (p=0.024) and interaction between both (p=0.005).
For functional capacity indexes, ischiotibial muscles' shortening and flexibility, no significant difference was evidenced (Table 4).

Variables	G1 (n=10)	G2 (n=10)	p
Lysholm scoring scale (%)	17.06 (12.64)	15.93 (20.98)	0.880
Assessment scale for PFJ (%)	13.18 (15.15)	13.48 (15.96)	0.970
Ischiotibial shortening (%)	16.69 (16.68)	20.06 (21.10)	0.740
Flexibility (%)	11.95 (26.28)	8.39 (15.23)	0.720

(PFJ = Patellofemoral joint)

***Table 4** – Averages and standard deviation for rates, as percentage, of the Lysholm scoring scale, assessment scale for the femoropatellar joint, ischiotibial muscles shortening and flexibility for both groups, and p values.*

DISCUSSION

On the studied sample, a number of common stance misalignments in patients with PFS were found, particularly at frontal plane. The main changes noticed throughout our study, such as knee and/or patellar deviations, are also mentioned by other authors as typical characteristics of stance alignment in PFS[1,3]. Only Sacco et al.[13] studied these misalignments on patients with PFS, achieving similar results to ours, before the treatment. The referred authors have also treated individuals with valgus and rotated knees, either medially or laterally, having observed a reduction of these changes after treatment.
By comparing the variables on each group, the results showed a significant improvement on pain severity only for G1. G2 was shown to be atypical regarding mean pain severity, starting the treatment with values below 1 cm. Thus, this group was not really expected to show changes on this variable after treatment.
For intergroup analysis, a trend was seen towards mean pain severity values for G1 before treatment being higher.
For functional capacity, the groups presented a significant improvement after treatment. However, no significant difference was found between them, with improvement rates ranging from 13 to 17%.
The presence of pain when performing functional activities is common among patients with PFS[3], so that treatments providing pain relief can be regarded as effective, such as muscle strengthening on OKC. Thomeé[2] reported that the pain experienced in PFS when performing activities leads to a reduced physical activity and, as a result, interferes on the strength produced by quadriceps femoralis muscle. In this study, we could not state that a stronger muscular force occurred after exercises on OKC, because this was not measured. However, we found an improved ability to perform functional activities and pain relief, which can suggest that muscular drills have benefitted patients in performing their activities and stopped the cycle described by Thomeé[2].

For the patients included in G2, no difference was found for pain severity, but a significant increase was seen for scale scores after treatment. One of the questions asked by the functional scales employed is associated to the presence of pain during or after performing activities. However, when pain severity was assessed alone, no difference was found, which suggests that muscle strengthening on OKC may lead to improved ability to perform functional activities, but with patients not necessarily feeling no pain during these tasks.

Sacco et al.[13], after suggesting a treatment based on muscular strength and stretch exercises, also found an improved functional capacity on patients without concurrent pain relief. Those results are consistent to those observed for G2, although those authors have not prescribed different exercises during therapy and, in the current study, only one kind of muscular strengthening exercise was employed for each group.

Still regarding functional capacity, we calculated indexes that allowed us to assess each subject's relative gain, enabling us to visualize a mean improvement rate of approximately 15%. Although we haven't found a significant difference between treatments, we regard them as effective, because they enabled a more functional performance of daily movements, such as squatting and climbing up stairs (questions present in the scale).

At first, the assessment of ischiotibial muscles' shortening and flexibility was justified only for characterizing the patient sample. However, we noticed a significant reduction of the shortening and an increased flexibility after muscular strengthening. Between the groups, no significant difference was found for these variables.

An ROM may be reduced for a number of reasons, including muscular shortening and strength loss[14]. On studied patients, we can infer that the reduced muscle shortening occurred because leg extension was more easily performed after treatment, since shortening assessment was made through patients' active contraction.

The study conducted by Tunay et al.[15] has also assessed the ischiotibial muscles shortening on patients with PFS, and their results showed a significant improvement after treatment, which is consistent to our findings. However, those authors did not describe which exercises were done by patients, therefore, a direct comparison becomes jeopardized.

Data show that the Q angle did not change after treatment. Between both groups, no significant differences were found as well, without knee and/ or patellar realignment following muscular strengthening therapy.

Some literature studies have also assessed the Q angle in patients with PFS after treatment, although with some methodology differences. Tunay et al.[15] found a significant Q angle improvement in patients submitted to different treatments. However, they did not describe which exercises were performed, making difficult to find the reasons for realignment. Regarding Q angle values, these were very similar to ours, both before and after treatment, even with half of the sample being constituted by male patients. Different results were found by Sacco et al.[13], who did not found differences for Q angle after treatment for 5 weeks. The angle values before and after treatment were quite lower, between five and eight degrees, but most of the sample studied by those authors was constituted of men, and a large portion of the patients was physically active.

The procedure for measuring Q angle can also cause variation between values. In our assessment, the patient was positioned at supine position with quadriceps femoralis muscle at rest, while the studies by Tunay et al.[15] and Sacco et al.[13] do not describe patients'positioning or the quadriceps femoralis muscle status.

Determining the reference points for a correct assessment of the Q angle is also essential, particularly the ones at the center of the patella. In this study, we were very rigorous regarding the position of patients' lower limbs and to the location of the bone structures. Thus, the mean Q angle values before treatment are very close to the ones found by Boucher et al.[16], who used a video system for assessing the angle and found mean values of approximately 21 degrees in PFS patients.

Finally, for EMG activity of the VM muscle, no difference was found between both groups after treatment. For VL muscle, a significant increased activity was seen on G1 subjects. Between both groups, no differences were found in none of the muscles assessed.

The fact that the VM muscles do not show differences after treatment is expected, because this is the first muscle of the quadriceps femoralis group to lose strength in patients with PFS and to provide the latest response to the effects of rehabilitation[17]. However, by observing the mean RMS values obtained for this muscle after treatment compared to those of the VL muscle, we can see that these were very close in the groups. Thus, although no significant difference was found for VM muscle, we consider that the treatments led to a muscular rebalancing between both main dynamic stabilizers of the patella.

On G1, where the VL muscle showed differences after treatment, again, we believe that a muscular rebalancing existed, since the mean values for this muscle were very close to those for the VM muscle. In addition, we must consider that the exercise on OKC applied in this study has favored the contraction of all portions of the quadriceps femoralis muscle at a ROM of 90-45 degrees of leg extension and, even with Doucette e Child[5] stating that the OVM muscle produces higher EMG activity between 60 and 90 degrees ROM, this was tested by means of isometric contraction, which may have not favored a stronger activity of the VM muscle.

Between both groups, our results were different from those presented by Stensdotter et al.[8], who found a greater amplitude of the OVM muscle's signal on CKC exercises than on OKC, while in this study no difference is found for VM muscle activation. However, the same authors, when studying healthy young individuals, found that the EMG signal of the OVM muscle is lower than the one of the VL muscle, both on OKC and CKC. Those results are partially consistent with ours, in which the mean RMS values for VM and VL muscles after muscular strengthening programs, allow us to infer their similarity. But we must highlight that the authors assessed clinically healthy individuals, while in our study, this was made on patients with musculoskeletal syndrome.

Several factors must be discussed regarding the muscle strengthening program employed in this study. The first one is the ROM control proposed when performing the exercises, since it is well established in literature that these generate weaker response forces and patellofemoral stress[6,7]. On CKC, the exercises performed at the first degrees of flexion also cause weaker patellar lateral traction[5].

Although Steinkamp et al.[6] may advocate that CKC exercises are more functional because they occur in a ROM more closely corresponding to typical daily activities, leg extension exercises on OKC are routinely prescribed at the initial phases of PFS rehabilitation. Thus, we regard its study as paramount, and we believe that its application has produced favorable results to patients, especially for pain relief and increased functional capacity. Other authors also treated patients with PFS using CKC exercises in a specific ROM. Stiene et al.[9] proposed a therapy with squatting exercises at a ROM of zero to 45 degrees of leg flexion and climbing up/ down short-step stairs, which do not require a great flexion range of the leg, and Cowan et al.[4] used squatting from 0 to 40 degrees.

Frequency and intensity of the muscular strengthening exercises are also important variables. By checking literature, we found that no consensus exist for these variables among the different protocols. Reynolds et al.[18] proposed a 6-week strengthening program, five times a week, incrementing loads and intensity levels by the number of repetitions and step heights. Bandy and Hanten[19] recommended exercises for eight weeks, three times a week, without load increments, because that was a maximum isometric strengthening. Stiene et al.[9] suggested an eight-week program, three times a week frequency, progressively incrementing exercises loads should the patients did not report pain. Cowan et al.[4] recommended six weeks, once a week, and do not report the number of repetitions or load increments. In our study, we tried to adjust the protocol to enable a better treatment compliance, and we also took into account that patients reported pain during functional activities, so that an excessive training program could increase pain intensity or even contribute to dropout cases.

In addition, the load of the OKC and CKC exercises was incremented with the reduced pain severity, using a monitoring system for pain, modified from the study by Thomeé[2]. We found, as early as the first muscle strengthening session, that most of the patients found difficult to perform the exercises recommended, even when minimal loads were applied, some of them reported insufficient strength, while others reported pain. As we could not reduce the loads on the devices, we thought that monitoring pain would be essential for protecting subjects' joints against excessive loads, and we believe that the increased load was extremely safe only when patients reported pain below 2 cm.

Still regarding load, G1 showed a mean value of 36.5 kg on the last session, while G2 ended drills with a mean load value of 78 kg, i.e., twice the amount. According to Lutz et al.[20], in OKC exercises, the segment movement occurs alone, and, in CKC, many segments are moved, with different muscles contracting at the same time. Thus, we believe that G2 patients were able to perform the exercises with a heavier load because these were performed on CKC, where not only the quadriceps femoralis muscle was activated, but it was also followed by the contraction of ischiotibial and gluteus maximum muscles. Furthermore, this load proportion on OKC and CKC is similar to that of the study by Escamilla et al.[7], who reported that individuals experienced with muscle fitness practicing were able to bear a load of approximately 146 kg on 12 maximum repetitions for squatting and leg-press exercises, while the load for leg extension with the same number of repetitions was only 78 kg.

CONCLUSIONS

The results of this research, within the experimental environment applied to the studied sample, allow us to infer that patients with PFS experience pain during functional activities, muscle shortenings and flexibility loss. In addition, treatments based on strengthening quadriceps femoralis muscles enabled important improvements on key signs and symptoms reported by patients, with no clear difference between exercises performed on OKC and CKC. Finally, regarding lower limb realignment, both treatments were shown to be effective.

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