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Effect of muscle strengthening on perceived pain and static knee angles in young subjects with patellofemoral pain syndrome

Jorge Hugo Villafañe[1], Luciano Bissolotti[2,3], Roy La Touche[4,5,6,7], Paolo Pedersini[1,*], Stefano Negrini[1,8]

[1]IRCCS Fondazione Don Carlo Gnocchi, Milan, Italy
[2]Casa di Cura Domus Salutis, Brescia, Italy
[3]LARIN: Neuromuscular and Adapted Physical Activity Laboratory, Brescia, Italy
[4]Department of Physiotherapy, Centro Superior de Estudios Universitarios La Salle, Universidad Autónoma de Madrid, Madrid, Spain
[5]Motion in Brains Research Group, Institute of Neuroscience and Sciences of the Movement (INCIMOV), Centro Superior de Estudios Universitarios La Salle, Universidad Autónoma de Madrid, Madrid, Spain
[6]Instituto de Neurociencia y Dolor Craneofacial (INDCRAN), Madrid, Spain
[7]Instituto de Investigación Sanitaria del Hospital Universitario La Paz (IdiPAZ), Madrid, Spain
[8]Department of Clinical and Experimental Sciences, University of Brescia, Brescia, Italy

The purpose of this pilot study was to determine the effects of strength training of the knee muscles on perceived pain and static knee angles in young subjects with patellofemoral pain syndrome (PFPS). Ten patients, 100% female (mean age, 18.2±3.8 years), with unilateral PFPS (anterior knee pain for at least 3 months), received muscle strengthening of the hip and knee (10 sessions over a period of 3 weeks). The outcome measures were perceived pain (visual analogue scale, VAS) and static knee angles (knee rotation measurer). All measures were collected at pre-, postintervention, and at 1-month follow-up (VAS). Muscle strengthening reduced perceived pain after intervention in 90.8% in subjects and this result was maintained at 1-month follow-up (all, $P=0.001$). Regarding changes in static knee angles, no significant improvements were found in internal and external rotation; valgus and varus; flexion and recurvatum (all, $P>0.05$). There was no significant difference between the symptomatic and healthy sides (all, $P>0.05$). Analyses of the correlation coefficients indicated no significant associations between changes in perceived pain and static knee angles. The current study found that muscle strengthening addressed to the symptomatic knee reduced pain; however, perceived pain was not associated with static knee angles in young subjects with unilateral PFPS.

Keywords: Knee, Pain, Patellofemoral pain syndrome

INTRODUCTION

Patellofemoral pain syndrome (PFPS), also named anterior or retropatellar knee pain syndrome, is a clinical entity mainly affecting young, female and population involved in physical activity (Tigchelaar et al., 2015) and including several different conditions. Patellar tracking dysfunction, decreased flexibility of some myofascial structures muscles (quadriceps, hamstrings, iliotibial band, and gastrocnemius), decreased strength of the quadriceps and hamstrings, joint laxity, deviations in patellar mobility and tilting and increased quadriceps angle may be included in this syndrome (Waryasz and McDermott, 2008). Also synovial plicae, synovitis, neuromas, or referred pain can provoke symptoms in the same area, so the differential diagnosis among various abnormalities is quite complex (Tigchelaar et al., 2015). Psychological components (depression, fear-avoidance, and anxiety) are also reported as risk factors for the onset and persistence of PFPS (Piva et al., 2009), then, both contributing factors and pathophysiology of PFPS are considered multifactorial.

The most frequently cited aetiology for the PTPS is the abnor-

*Corresponding author: Paolo Pedersini https://orcid.org/0000-0003-0224-1783
IRCCS Fondazione Don Carlo Gnocchi, Piazzale Morandi, 6, Milan 20161, Italy
E-mail: Pedersini93@gmail.com
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mal patellar tracking that may increase the stress on the patellofemoral joint. Two distinct maltracking groups have been identified on the basis of patellofemoral lateral-medial displacement, but they are not evaluated based on standard clinical assessement (e.g., Q-angle, lateral hypermobility, and J-sign) (Sheerin et al., 2012). Clinical test employed to diagnose PTPS mainly assess pain in response to the stimuli, as compression test, medial and lateral tenderness, and passive gliding of the patella. These tests help to discriminate between knee-healthy subjects and knee-patients, but they do not allow to clearly identify different patient subgroups (Näslund et al., 2006). As a consequence, a clear identification of abnormal three-dimensional patellofemoral movement or a subclassification useful for the treatment is still lacking (Sheerin et al., 2012).

The correlation between PFPS and changes in the rotation of the femoral bone was investigated by several authors. Magalhães et al. (2010) reported that adduction and internal rotation affect the patellofemoral kinematics, resulting in alterations of physiological areas of contact and pressure. Evidence suggests that hip strengthening and a coordination program may be useful in a conservative treatment for PFPS (Meira and Brumitt, 2011).

This therapeutic concept has partially modified previous conservative approaches to PFPS, which employed vastus medialis oblique (VMO) retraining, open kinetic chain and isokinetic strengthening, patellar realignment orthoses, patellar mobilization, sacroiliac manipulation, low-level laser, acupuncture, and patellar taping (Lima et al., 2018). These procedures are supported by little evidence, inducing only short-term pain reduction and being not more effective than a simply home exercise program (Crossley et al., 2001; Shariat, 2017).

Based on previous studies (Hollman et al., 2009; Janyacharoen et al., 2018; Narouei et al., 2018; Sheerin et al., 2012), we hypothesized that muscle strengthening program not only may reduce pain in PFPS, but also change muscle power output in some static knee angles, due to the modified balance and length among different muscles.

Therefore, the purpose of this pilot study is to determine the effects of strength training of the knee muscles on perceived pain and static knee angles in subjects with PFPS.

MATERIALS AND METHODS

Study design

This research protocol has been approved by the Local Ethical Committee of IRCCS Fondazione Don Carlo Gnocchi, Italy (2016-05-18). Informed consent was obtained from all participants, and all procedures were conducted according to the Declaration of Helsinki.

Participants

Ten consecutive patients, 10 women, from 13 to 24 years old who presented unilateral PFPS were recruited from the waiting list in a Physical Therapy Department. The initial diagnosis was established combining medical records by computed tomography (CT) or magnetic resonance imaging and the presence of anterior knee pain (Ayala-Mejias et al., 2017; Bolgla et al., 2011; Powers, 2003). Patients were included in this study if the following criteria were fulfilled: onset of pain longer than 3 months; positive clinical signs of PTPS (i.e., retro patellar pain, crepitation, pain in patellar grinding, Clarke sign, active patellar grind test, direct patellar compression, palpation of the lateral-medial articular border of the patella) (Malanga et al., 2003); no history of physical therapy for PFPS. The exclusion criteria were a previous surgery in the affected lower limb, knee instability, previous meniscal and/or ligamentous injuries, or musculoskeletal disorders related to lower limbs. Subjects with a lower limbs dismetry (more than 1 cm) and with cardiac, neurologic, or vision dysfunctions were also excluded from the present study.

Intervention

Each patient received 10 sessions of muscle strengthening addressed to the hip abductors, hip external rotators, and knee extensors by 30 min per day, at same time of each day. The treatment was carried over a period of 3 weeks and the sessions were scheduled on separate days, at least 48 hr apart. All patients received treatment by a physical therapist (PT) specialized in manual therapy with more than 10 years of clinical experience. Initially the PT slowly and passively moved the affected limb, with emphasis on decreasing the tone and the limbs resistance to motion. After this, the PT applied passive end-range motion and stretched the knee connective tissues without causing pain. Then, the patients were submitted to strengthening exercises addressed to the knee extensors, hip lateral rotators and abductors (Rabelo et al., 2014; Villafañe et al., 2017).

Outcome measures

Assessment of the patient's response to therapy included the following assessment tools: visual analogue scale (VAS) for the intensity of knee pain (Ferreira-Valente et al., 2011; Freedman et al., 2014) and knee rotation measurer (KRM) (Posturalmed S.A, Milan, Italy), for the static knee angles. All measures were collected at pre-, posttreatment (5 min after the end of final session) and at 1-month follow-up.

Statistical analysis

Data were analyzed using IBM SPSS Statistics ver. 22.0 (IBM Co., Armonk, NY, USA). Normal distribution of the sample was analyzed by using the Kolmogorov–Smirnov test. A one-way analysis of variance with repeated measurements and Bonferroni was used as *post hoc* test to evaluate statistical significance in KRM over each point and determine the difference between the symptomatic and asymptomatic sides as the within-subjects factor. Within-group effect sizes were calculated using the Cohen *d* coefficient interpretation. Cohen effect size greater than 0.8 was considered large, around 0.5 moderate, and less than 0.2 small. The relationship between pain symptoms and knee angles was evaluated with the Pearson correlation coefficient test. For all the data of the study, P-values lower than 0.05 were considered significant.

RESULTS

The baseline characteristics of the subjects are described in Table 1. No subjects dropped out during the different phases of the study, and no adverse effects were detected during or after the application of the treatments. None of the subjects took drug therapy during the course of this study.

Table 1. Baseline demographics

Characteristic	Value
Age (yr)	18.2±3.8
Female sex	10
Pain (VAS)	5.5±2.2
Pain, symptomatic side (VAS)	6.4±2.3

Values are presented as mean±standard deviation or number.
VAS, visual analogue scale.

Pain intensity

Regarding the results on pain intensity measured with the VAS, a significant interaction for time ($F=61.728$, $P=0.001$) in the affected knee was observed. In addition, there were significant differences between pre- vs. posttreatment ($P<0.001$) and pre- vs. 1-month follow-up ($P<0.001$). A small within-group effect size ($d<0.2$) was found between pretreatment vs. posttreatment and follow-up.

Static knee angles

No significant interaction for time and between side for KRM on the internal (time: $F=0.195$, $P=0.7$ and side: $F=0.978$, $P=0.3$) and external rotation (time: F=errors, P=errors and side: F=errors, P=errors), valgus (time: $F=1.0$, $P=0.5$ and side: $F=1.0$, $P=0.5$) and varus (time: $F=0.943$, $P=0.4$ and side: $F=0.021$, $P=0.9$), flexion (time: F=errors, P=errors and side: F=errors, P=errors) and recurvatum (time: $F=0.176$, $P=0.7$ and side: $F=0.114$, $P=0.8$) angles was observed (Table 2).

Correlations between pain intensity and static knee angles

Analyses of the correlation coefficients indicated no significant associations between perceived pain and static knee angles, both on symptomatic and asymptomatic sides (all, $P>0.05$) (Table 3).

DISCUSSION

This prospective pilot study showed that muscle strengthening on the symptomatic knee reduces perceived pain, however pain change was not associated with knee angles change in young sub-

Table 2. Outcomes at all study visits for each time, difference within group, difference between sides

Outcome	Time				Difference within time		Difference between side	
	Pre		Post		Symptomatic side (n=10)	Asymptomatic side (n=10)	Pre (n=10)	Post (n=10)
	Symptomatic (n=10)	Asymptomatic (n=10)	Symptomatic (n=10)	Asymptomatic (n=10)				
Internal rotation	21.7±6.3	20.4±7.3	21.7±6.6	19.5±5.4	0.0±1.3	-0.9±1.0	-1.3 (-4.9 to 2.2)	-2.2 (-6.9 to 2.6)
External rotation	-	-	-	-	-	-	-	-
Valgus	12.3±6.7	16.8±13.1	11.3±5.3	17.3±13.8	-1.0±1.0	-0.5±0.5	4.5 (-52.7 to 61.7)	6.0 (-70.2 to 82.2)
Varus	115.4±24.7	115.3±26.9	113.0±2.9	111.8±19.5	-2.4±1.9	-3.5±4.4	-0.1 (-14.3 to 14.0)	-1.3 (-18.8 to 16.3)
Flexion	-	-	-	-	-	-	-	-
Recurvatum	45.0±12.0	42.6±8.0	46.6±23.2	46.6±17.6	1.6±8.6	4.0±5.1	-2.4 (-16.6 to 11.8)	0.0 (-9.2 to 9.2)

Values are presented as mean±standard deviation or 95% (confidence interval).

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Table 3. Correlations with knee angles

PFPS	*F*-value	*P*-value
Internal rotation		
Right	-0.31	0.2
Left	-0.092	0.7
External rotation		
Right	errors	errors
Left	errors	errors
Valgus		
Right	errors	errors
Left	errors	errors
Varus		
Right	-0.913	0.07
Left	-0.548	0.3
Flexion		
Right	errors	errors
Left	errors	errors
Recurvatum		
Right	-0.527	0.2
Left	-0.488	0.1

PFPS, patellofemoral pain syndrome.
Correlation is significant at the 0.05 level.

jects with PFPS. The reduction of pain can be explained by a higher neuromuscular activation of quadriceps derived by the exercise protocol (Villafañe, 2018). As previously shown by other authors (Boling et al., 2010; Ismail et al., 2013), the involvement of abductors and external rotators in the exercise program was able to promote a better quadriceps activation and consequently a clinical relevant result in reducing anterior knee pain intensity. From a biomechanical point of view, the explanation of the clinical effect may be related to a better recruitment of hip muscles or even a change in lower limb alignment.

Nevertheless, in our study no significant modification on symptomatic knee angles as compared to the contraateral ones was observed. This data supports the hypothesis that exercise protocols for lower limb muscles do not change the biomechanical alignment of bony segments, but they mainly improve quadriceps activity.

Another interesting result is represented by the fact that we obtained a clinical and statistically significant pain reduction just only after three weeks of treatment. Usually, as described by the literature, relevant clinical results can be obtained at the end of more prolonged or more intensive programs, delivered from 3 to 6 weeks.

As described by Jacobs et al. (2007), the decreased strength of the hip abductors can be associated with increased knee joint medial displacement and this mechanism may be associated with a raised Q-angle in an unilateral stance and an increased patellofemoral joint overload. Consequently, as presented in this study, a program including proximal muscles strengthening may improve the control of lower limb biomechanics during this crucial phase of gait cycle. A previous study demonstrated that the patients first performed a non–weight-bearing exercise program, and only progressively partial and full weight-bearing exercises were introduced (Lee et al., 2014).

Rabelo et al. (2011) demonstrated that this exercise program, using elastic band resistance, was effective in helping patients to perform weight-bearing exercise in a closed kinetic chain (CKC) model. The results of this study suggest that weight-bearing strength exercises with elastic band in CKC decreased knee pain without changing the alignment of the knee during post-treatment evaluation. The differences in knee alignment between the two different times of evaluation were not noted after the weight-bearing exercises, nor significant differences between sides (healthy side used as control) were observed (Rabelo et al., 2011). Even if not measured, we can speculate that the posttest muscle activity of quadriceps was different than the pre-test one. It is possible that, as previously demonstrated by other researchers, the VMO muscle earlier activation may medially move the patella and induce a reduction in patellofemoral pain. A previous study has in fact shown that even a little delay in VMO activation may cause an increase in the lateral compressive forces on the patellofemoral joint (Chang et al., 2014). Moreover, the study of Boling et al. (2010) showed that weight-bearing exercises performed by subjects with PFPS resulted in significant differences in vastus lateralis and VMO onset time. The results of the this study showed that the lower limb alignment was not changed in normal adults.

The main limitation of this prospective pilot study was the small sample size, but the number of included subjects was sufficient to determine significance. Moreover, a control group lacked and the measure of Q-angle was not performed.

The current study found that muscle strengthening on the symptomatic knee reduces perceived pain and pain change was not associated with knee angles change in young subjects with PFPS. Measurement techniques that are both reliable and sensitive to detect potential group differences need to be established.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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