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Core Strengthening Improves Pain in Women with Patellofemoral Pain: a Feasibility Interventional Trial

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SUMMARY

Background. Patellofemoral pain remains one of the major musculoskeletal disorders found in orthopedic and sports clinics. Despite the evidence of improvement in individuals undergoing hip and knee strengthening protocols, there are no studies that investigated the influence of a protocol with a single focus on the core muscle strengthening in the treatment of this condition. This study aimed to assess individuals with patellofemoral pain undergoing a core muscle strengthening treatment to determine any disparities in muscle activation, pain levels, and functionality after 12 weeks of intervention.

Materials and methods. Before and after 12 weeks of intervention, the volunteers were assessed for functionality; Electromyographic evaluation of the muscles: transverse abdominis/internal oblique, gluteus medius, vastus lateralis, and vastus medialis of the quadriceps.

Results. There was an increase in the resistance of core muscles ($p < 0.00$), a decrease in the pain levels during functional activities ($p < 0.00$). squatting ($p < 0.00$). descending stairs ($p = 0.03$) on the VAS ($p = 0.01$) and patellofemoral pain in the last 30 days ($p < 0.00$) and also a reduction in the presence of positive clinical signs of PFP ($p < 0.00$).

Conclusions. The study showed that a 12-week core strengthening protocol is effective for improving functionality, muscle activation and reducing pain in women with patellofemoral pain.

KEY WORDS

Core; electromyography; knee; patellofemoral pain; strengthening.

INTRODUCTION

Patellofemoral pain (PFP) is a clinical condition characterized by the presence of diffuse pain over the anterior surface of the knee. It can be aggravated by performing activities that increase the compressive forces on the patellofemoral joint, such as going up and downstairs, squatting, remaining seated for long periods of time, as well as repetitive activities such as running (1). It is frequently observed in physically active individuals and constitutes one of the most common knee disorders found in orthopedic clinics, with a prevalence of 23 to 29% in the adult and young population (2).

The literature indicates that PFP has a high incidence, which leads to a direct negative impact on the daily lives of individuals with this disorder (3-5). PFP is frequently diagnosed in adolescents and young adults and can affect up to 3 times more women than men (6, 7). Furthermore, data in the literature indicate a possible association of PFP with the development of knee osteoarthritis (8).

According to the World Health Organization (WHO), knee osteoarthritis is the fourth leading cause of functional disability in women and the eighth in men (9). PFP is also associated with the development of disorders with a greater degree of functional limitation, such as peripatellar tendinitis and bursitis (7). Based on these data, PFP can be considered a public health problem, as the performance of daily activities, such as going up and downstairs and ramps, squatting, sitting for a long time and the practice of sports will be severely limited in the medium and long term (3-5).

One of the characteristics reported as an etiological factor of PFP is the weakness of the quadriceps femoris, demonstrated by the decrease in the knee extensor torque peak, in addition to imbalances that may arise from the decrease in the torque peak or the atrophy of the muscles of the lower extremity in individuals with PFP (10).

The involvement of proximal factors in PFP has also been discussed in the literature. These factors are related to altered lower limb movement patterns, such as dynamic valgus, a biomechanical dysfunction that occurs due to weakness of the abductor, external rotator, and hip extensor muscles. Some authors consider that hip kinematics is altered during tasks such as running, jumping, and staying long periods of time with the knees bent (11-13).

Studies have shown that individuals treated with knee strengthening and/or hip strengthening protocols had improvements in pain, function, and strength after six weeks of treatment. Once the main clinical symptom in patients with PFP is the anterior pain on the knee during functional activities, some of the exercises focused on the knee and hip joints may be difficult to perform due to pain in acute stages. Thus, core strengthening exercises can be an effective way to improve functionality and reduce pain without stressing the knee joint. The core is a set of muscles of the trunk, hip, and pelvic floor that act to provide greater balance while performing dynamic activities (14, 15). Reports in the literature show that this musculature plays a fundamental role in the balance of the body, being the center of force that generates the necessary stability to perform the movements that occur in the extremities. It has been shown that, to produce greater stability and balance when moving, the core muscles contract in advance to make postural adjustments (16).

Despite the evidence of clinical improvement shown with the performance of hip and knee strength training, there are no studies that investigate individuals submitted to protocols with a single focus on core strengthening exercises for a better understanding of the influence of this training on clinical variables and muscle activation in individuals with PFP. In this context, we understand the need to verify the influence of a protocol for strengthening the core muscles in individuals with PFP. The hypothesis is that there is a deficit of neuromotor control.

MATERIALS AND METHODS

This is a feasibility interventional trial, approved by the Brazilian Registry of Clinical Trials (ReBEC) and by the Research Ethics Committee of the Federal University of Santa Catarina (RBR-7fk9ww; No. 2.695.049 and CAAE No. 87988518.6.0000.0121 – date of approval: June 06, 2018).

Data collection and the intervention protocol were performed at the Laboratory for Assessment and Rehabilitation of the Locomotor Apparatus (LARAL), located at the Federal University of Santa Catarina, Araranguá – SC, Brazil.

Participants

The inclusion criteria were women aged between 18 and 30 years, presence of retropatellar or anterior knee pain during at least two of the following activities: sitting for a long time, climbing stairs, squatting, running, kneeling, and jumping; pain at patellar palpation; symptoms for at least 1 month, with insidious onset and unrelated to a traumatic accident; pain level of at least 3 on a 10 cm visual analog pain scale in the past week; the presence of at least 3 of the following clinical signs: positive Clarke's sign, positive McConnell's test, positive Waldron's test, positive Zohler's sign, Q angle greater than 18°, positive Noble's compression test, patella in lateral or medial position (17). The exclusion criteria were other specific pathologies of the knee, such as gonarthrosis, ligament injury, meniscus injury, patellar tendon injury, joint degeneration, osteoarthritis or referred pain coming from the spine; knee surgery; history of patellar dislocation or subluxation; knee treatments such as arthroscopy, use of anti-inflammatory drugs, analgesics, anesthetics, acupuncture or physiotherapy during the last 6 months; the presence of neurological diseases and inflammatory processes. The interventions started only after the volunteer signed the consent form. After the selection of volunteers, the evaluation process started. The main steps of the protocol are summarized in the flowchart (**figure 1**). Initially, 21 volunteers were recruited to participate in the study. Of these, three did not start treatment due to availability issues and four dropped out due to musculoskeletal injuries unrelated to the intervention protocol. In total, 14 volunteers completed all stages of the study.

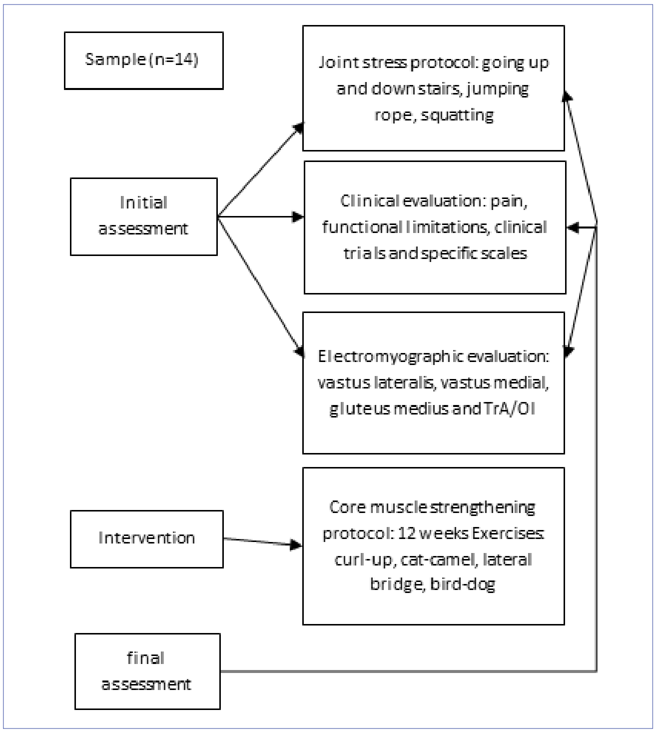

Figure 1. Flowchart of research steps.

TrA/OI: Transverse/internal oblique muscle of the abdomen.

Instrumentation

For the collection of electromyographic data, a signal conditioner (Miotec®, New Miotool model) was used; the acquisition and storage of signals in data files were performed using the Miotec Suite software (Miotec®). All channels had 1,000 times final gain and 2,000 Hz sampling frequency. To assess the muscle strength of knee extensors, a strain gauge load cell coupled to the electromyograph was used (Miotec®, SForce NM).

Patellofemoral joint stress

It is known that PFP is a condition that can cause varying degrees of pain at different times, depending on various factors such as activities that increase pressure on the patella (18). The presence of the pain and different physical activity levels seems to change the recruitment patterns of the muscles and may be a potentially confounder parameter during the clinical assessments. In this way, a protocol for the physical activity level standardization may be an alternative to equalize pain in women with PFP and to enhance the methodological quality of our study (19, 20). All participants performed a protocol of exercises in order to standardize the physical activity level standardization previous the data collection. The protocol for the physical activity level standardization consisted of 6 stair climbing repetitions, 3 sets of rope jumps over 30 s and 5 series of 8 squats with 20% of body mass To standardize the subjects' conditions before the collection of surface electromyography and clinical evaluation, an exercise protocol was used to put all subjects in the same condition by stressing the knee joint. The exercise protocol consisted of 6 sets of going up and down stairs (20 steps), 3 sets of 30-second jumping rope, and 5 sets of 8 repetitions of squats with 90° of knee and hip flexion with an addition of 20% of body weight. To ensure the correct execution of the squat exercise, all volunteers performed it with the support of a Swiss ball 55 cm in diameter that was positioned between the volunteer's lumbar region and the wall. After this standardization protocol, the clinical and electromyographic data were collected.

Clinical evaluation

The clinical evaluation consisted of the following dimensions: 1) symptoms related to the presence of pain; 2) functional limitations; 3) specific clinical tests to characterize the presence of PFP. In total, these dimensions encompass 16 actions, divided into scales and physical tests. In addition to the clinical assessment protocol, an endurance test (in seconds) of the core muscles was performed with the volunteer in a prone position, supporting the body on the surface with the elbows, forearms, and toes (plank exercise). Before the clinical evaluation, the following scales and questionnaires were applied: the anterior knee pain scale (EDAJ-AKPS), the patellofemoral pain syndrome intensity scale (EISDF-PSS), and the function index questionnaire (QIF-FIQ). These instruments were previously translated, culturally adapted, and tested (21). Before, during, and after the evaluations, a visual analog pain scale was applied with a scale from zero to 10 cm, with zero being the absence of pain and 10 being the worst pain perceived.

EMG signal collection protocol

After the clinical evaluation, the volunteers proceeded to the electromyographic evaluation and the intervention protocol. Initially, the individuals received instructions regarding the assessments and familiarization with the equipment and collection environment. Ag/AgCl surface electrodes were placed on the vastus medialis (VM) and vastus lateralis (VL) muscles of the quadriceps, gluteus medius (GM), and transverse abdominis/internal oblique (TRA/IO) muscles. All electrodes were placed in the hemibody ipsilateral to the knee with the highest pain report. For standardization, the placement of the electrodes was performed following the SENIAM recommendations (22); before positioning, trichotomy, abrasion, and cleaning of the site were

performed. The reference electrode was placed in the ulnar styloid process ipsilateral to the evaluated lower limb.
To normalize the data and measure the maximum strength, a maximum isometric voluntary contraction (MVC) was performed during the knee extension at 45° of flexion for 6 seconds (**figure 2**). Participants received verbal stimulation to perform the maximum contraction. They were positioned in the test position and a load cell was coupled to an inextensible current and the EMG system, to simultaneously collect the force and EMG values.
After five minutes of rest, squat test was performed with three repetitions. The squats were performed with no additional weight, using a 55 cm Swiss ball as support (**figure 3**). The volunteers were instructed to perform the squat with a self-controlled speed while the electromyographic signal was collected; there was an interval of one minute between each attempt. The same data collection protocol was applied before and after the intervention period.

Figure 2. Data collection of maximum isometric voluntary contraction (MVC).

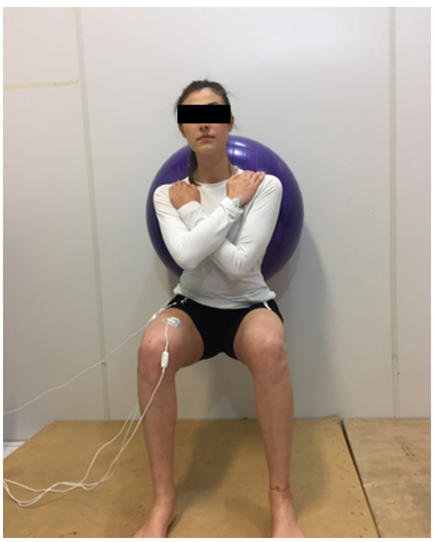

Figure 3. Data collection of EMG during squat.

Exercises

The exercises were performed three times a week during 12 weeks. The progression with the number of sets and repetitions is described in **table I**.
Cat-camel: the patient was positioned with both hands and knees on the treatment table and asked to perform flexion and extension movements of the lumbar spine, associated with abdominal contraction (**figure 4**).
Curl-up: the patient was positioned in dorsal decubitus with hands under the lumbar region, keeping one of the lower limbs in extension and the other in flexion to provide pelvic stability. Then, they were asked to perform the trunk flexion movement. The difficulty progression was made by placing both hands behind the neck with the arms in abduction (**figure 4**).
Lateral bridge: patient was positioned in lateral decubitus, with knees flexed, elbow resting on the treatment table and the contralateral arm supporting the shoulder while performing lateral trunk flexion. The progression was made with the lower limbs supported by the feet and the hand positioned on the hip, in addition to rotation movements alternating the supporting sides (**figure 4**).
Bird-dog: patient was positioned with both hands and knees on the treatment table and asked to perform the movement of raising one leg and the contralateral arm in a horizontal position (**figure 4**).

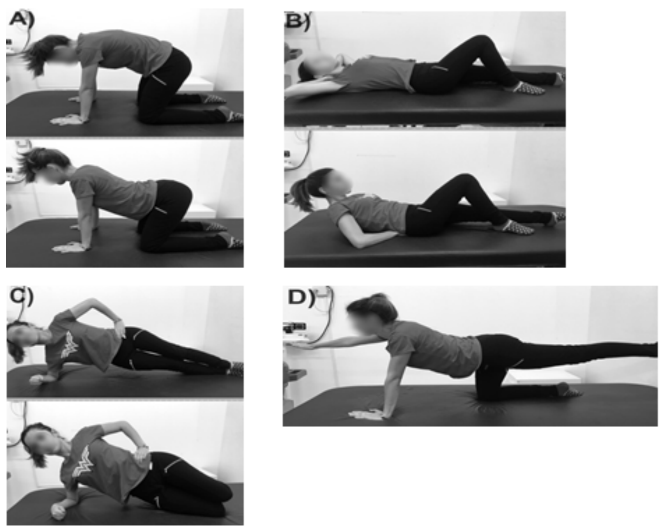

Figure 4. (A) Cat-camel; **(B)** Curl-up; **(C)** Lateral bridge; **(D)** Bird-dog.

Table I. Progression of exercises.

Week	Exercises	Repetitions	*Isometric contraction (seconds)
1	- Abdominal contraction - Cat-camel - *Curl up – hands on the lower back	5 × 8	20
2	- Abdominal contraction - Cat-camel - *Curl up – hands on the lower back	5 × 8	20
3	- Cat-camel - *Curl up - hands on the lower back - *Lateral bridge – knee support, hand on contralateral shoulder	5 × 8	20
4	- Cat-camel - *Curl up - hands on the lower back - *Lateral bridge – knee support, hand on contralateral shoulder	5 × 8	20
5	- *Curl up – hands on the back of the head - *Lateral bridge – knee support, hand on the hip	6 × 10	40
6	- *Curl up – hands on the back of the head - *Lateral bridge – knee support, hand on the hip	6 × 10	40
7	- *Curl up – hands on the back of the head - *Lateral bridge – foot support, hand on the hip - *Bird dog	6 × 10	40
8	- *Curl up – hands on the back of the head - *Lateral bridge – foot support, hand on the hip - *Bird dog	6 × 10	40
9	- *Curl up – hands on the back of the head - *Lateral bridge – foot support, hand on the hip, rotating - *Bird dog	8 × 12	60
10	- *Curl up – hands on the back of the head - *Lateral bridge – foot support, hand on the hip, rotating - *Bird dog	8 × 12	60
11	- *Curl up – hands on the back of the head - *Lateral bridge – foot support, hand on the hip, rotating - *Bird dog	8 × 12	60
12	- *Curl up – hands on the back of the head - *Lateral bridge – foot support, hand on the hip, rotating - *Bird dog	8 × 12	60

*Exercises with isometric contraction.

Data processing and statistical analysis

The collected signals were processed using algorithms developed in the MatLab® software, according to the following order of analysis: 1) bandpass digital filter with a cut-off frequency of 20 to 500Hz; 2) determination of the strength of knee extensors exerted during the MVIC test; 3) normalization of the signal during the squat test by the signal obtained in the MVIC test of the respective muscle, considering the two seconds of greater stability of the MVIC signal; 4) determination of the RMS (root mean square) value normalized for each muscle; 5) determination of temporal parameters of the signals for each muscle: delay between the activation onset of the vastus medialis and vastus lateralis; and gluteus medius and TrA/IO muscles; time elapsed from the beginning to the peak of activation and the signals duration of each muscle (23); 6) determination of muscle co-activation between the muscles evaluated through cross-correlation (1).

After obtaining the variables of interest, statistical analysis was performed using SPSS software version 18.0

for Windows (Statistical Package for the Social Sciences). Statistical comparison was performed between the pre-intervention and post-intervention evaluation using the t-test for paired samples. After verifying the normality of the data, the Wilcoxon test was performed for data that did not present normality, considering a P-value < 0.05 as significant. Effect sizes for pre- and post-intervention comparisons were calculated and interpreted as: small (> 0.2), medium (> 0.5), and large (> 0.8) (24).

RESULTS

In total, 14 volunteers completed all stages of the study. All participants presented a clinical report of anterior knee pain, and the mean age was 23.3 (± 3.7) years. Study participants showed improvement in most clinical and some of the electromyographic variables. The results of the analyzed questionnaires and outcomes are shown in **tables II-V**. The proposed intervention protocol proved to be effective in improving clinical variables ($p < 0.05$), represented by the reduction in pain levels in the last month, pain during functional activities, pain when squatting up to 90°, pain when going down a step, decreased number of positive clinical signs for PFP, increased core muscle resistance and decreased visual analog scale (VAS) score (**table II**).

Table III presents the data regarding the questionnaires and specific scales for the PFP through the mean and standard deviation before and after the intervention. There was a significant improvement in pain levels reported on the EISDF-PSS and the VAS, in addition to an increase in the Global Perceived Effect Scale (EPEG-GPE) score. Scores in the Anterior Knee Pain Scale (EDAJ-AKPS) and Function Index Questionnaire (QIF-FIQ) did not show significant differences between assessments.

The normalized Root Mean Square (RMS) values and coactivation between the vastus medialis (VM) and vastus lateralis (VL) muscles and between the gluteus medius (GM) and transverse abdominis/internal oblique (TrA/IO) muscles during the squat movement are shown in **table IV**. There was a significant decrease in the means of RMS VM, VL and VM coactivation, RMS TrA/IO, and GM and TrA/IO coactivation.

Table V shows the mean and standard deviation values for the electromyographic variables related to the temporal parameters of the EMG signal. There was no statistical difference for these variables.

Table II. Mean values of clinical variables.

	Mean pre-intervention (SD)	Mean post-intervention (SD)	P-value	Cohen's d
Patellofemoral pain (last 30 days)	5.64 (1.69)	2.21 (1.88)	< 0.001*	1.92
Pain during functional activities	5.07 (1.43)	2.21 (1.71)	< 0.001*	1.81
Pain during squatting (90°)	3.92 (2.33)	0.71 (1.13)	< 0.001*	1.75
Pain when descending stairs	2.14 (2.38)	0.35 (1.08)	0.035*	0.97
Positive clinical signs	5.64 (1.15)	3.28 (1.43)	< 0.001*	1.82
Core muscles resistance (s)	41.25 (24)	70.41 (22.52)	< 0.001*	1.25
VAS	4.28 (2.78)	0.92 (1.49)	0.010*	1.51

s: seconds; VAS: Visual Analogue Scale; SD: standard deviation; *p < 0.05.

Table III. Scales and questionnaires for patellofemoral pain.

	Mean pre-intervention (SD)	Mean post-intervention (SD)	P-value	Cohen's d
AKPS	79.28 (5.16)	85.85 (10.87)	0.034	0.77
PSS	36.78 (17.38)	14.78 (14.38)	< 0.001*	1.38
FIQ	12.78 (2.57)	13.85 (2.40)	0.430	0.43
GPE	-0.78 (1.42)	2.21 (2.48)	< 0.001*	1.48

AKPS: Anterior Knee Pain Scale; PSS: Pain Severity Scale; FIQ: Functional Index Questionnaire; GPE: Global Perceived Effect Scale; SD: Standard Deviation; *p < 0.05.

Table IV. RMS and coactivation.

	Mean pre-intervention (SD)	Mean post-intervention (SD)	P-value	Cohen's d
Force (kgf)	22.20 (10.70)	19.18 (5.61)	0.158	0.35
RMS VM (n)	0.52 (0.33)	0.38 (0.19)	0.006*	0.52
RMS VL (n)	0.40 (0.25)	0.46 (0.29)	0.788	0.22
Coactivation VM/VL	0.73 (0.19)	0.63 (0.24)	0.001*	0.46
RMS GM (n)	0.14 (0.04)	0.14 (0.04)	0.832	0.00
RMS TrA/IO (n)	0.15 (0.05)	0.13 (0.05)	0.024*	0.40
Coactivation GM/TrA/IO	0.65 (0.08)	0.57 (0.17)	0.006*	0.60

RMS: Root Mean Square; VM: Vastus Medialis; VL: Vastus Lateralis; GM: Gluteus Medius; TrA/IO: Transverse Abdominis/Internal Oblique; SD: Standard Deviation; kgf: kilogram-force; n: normalized; *p < 0.05.

Table V. EMG time parameters.

	Mean pre-intervention (SD)	Mean post-intervention (SD)	P-value	Cohen's d
Duration VM (s)	3.82 (0.75)	3.94 (0.92)	0.807	0.14
Duration VL (s)	4.02 (0.71)	3.88 (0.76)	0.266	0.19
Time until the peak - VM (s)	1.88 (0.54)	2.02 (0.61)	0.167	0.24
Time until the peak - VL (s)	1.93 (0.55)	1.84 (0.53)	0.449	0.17
Delay between VM and VL (ms)	-2.05 (23.17)	13.91 (70.97)	0.696	0.30

VM: Vastus Medialis; VL: Vastus Lateralis; s: seconds; ms: milliseconds; DS: standard deviation.

DISCUSSION

This study aimed to verify the influence of a core muscle strengthening protocol in women with PFP. Previous studies have obtained positive results using intervention protocols associating the strengthening of core muscles with other muscle groups such as hip and knee in the treatment of PFP (25-27), however, studies that used an exercise protocol with a single focus on core strengthening for the treatment of this condition have not been found yet.

Our intervention consisted of a 12-week exercise protocol, which was performed three times a week. Interventions with a greater number of sets and repetitions have already shown good efficacy in the treatment of individuals with PFP (28). Findings from a previous study with frequency and intensity similar to our study suggest that the clinical effects in the medium and long term are more evident after training with high doses and repetitions, corroborating our results (29). In the same approach, progressive exercise programs with heavy slow resistance training were related as the most recommended intervention for athletes with patellar tendinopathy (30).

In this study, the proposed protocol was effective in improving most clinical and some of the electromyographic outcomes analyzed. At the end of twelve weeks of intervention it was possible to identify a significant increase in core muscle strength, associated with a reduction in pain levels in the last month before the final assessment, a reduction in pain when performing squats and when descending a step, in addition to a lower presence of clinical signs indicative of PFP. As suggested in other studies (31, 32), this finding shows that strengthening the core muscles significantly contributes to an increase in core stability, which can result in improved neuromuscular control and consequently lower risk of injury and pain. It is known that pain is one of the main clinical manifestations in PFP, presenting itself in different intensities during the performance of activities, directly impacting the functionality of affected subjects (31-33). In this study, the results showed that the mean values scored on the VAS had a significant reduction after treatment, which can be observed both in the clinical evaluation and in the self-reports through the questionnaires.

The findings of this study showed that there was a positive influence of the treatment on the scores of the questionnaires and scales that were used. The Patellofemoral Pain Syndrome Intensity Scale specifically assesses pain intensity in subjects with PFP and has ten questions with scores ranging from zero to ten points, reaching a maximum of 100, which represents greater pain intensity (21). In the present study, there was a significant reduction in the mean score on this scale, which may indicate a possible improvement in the functionality of the volunteers due to the decrease in the level of pain during the performance of functional activities. The Global Perceived Effect Scale is an instrument used to assess the evolution of the clinical condition from its onset and has scores ranging from -5 ("extremely worse") to +5 ("completely recovered") (21). When comparing the general status of PFP in volunteers from the onset of symptoms to the time of evaluations using the EPEG, a significant increase in the score was observed, representing a positive evolution of the condition that reflects a clinical improvement in these volunteers.

PFP is also known to cause functional limitations resulting from pain, in addition to favoring the occurrence of other musculoskeletal problems such as knee osteoarthritis (3-8). It is known that physical exercise is the most used intervention method and one of the most effective for the treatment of this condition. However, most treatments are based on exercises that directly involve the knee joint (34-37) and, since the PFP can be aggravated by the performance of activities that promote the increase of compression forces in the patellar region, subjects who are in more acute clinical conditions may have difficulty in carrying out these protocols. In this context, our results confirm that an intervention based on exercises focused on the core muscles becomes a viable and effective alternative to reduce pain and increase functionality in this population.

Studies with electromyographic analysis suggest the existence of a relationship between altered neuromuscular control patterns involving the hip and knee muscles and the occurrence of PFP (38, 39). The literature highlights the importance of core muscles and their role in the prevention and rehabilitation of lower limb injuries (15, 16, 27, 40). Our findings indicated that the strengthening of this musculature resulted in a reduction in the RMS values of the VM and TrA/IO muscles. This result indicates that, after treatment, there was a need to recruit fewer motor units to produce strength and movement, resulting in better motor control and, consequently, less risk of injury. Despite this improvement in the activation of VM and TrA/IO, it was observed that there was no significant change in the RMS values for the VL and GM muscles. This finding may explain the occurrence of a decrease in coactivation between the VM and VL and GM and TrA/IO muscles.

Previous studies indicate that individuals with PFP tend to have a delayed activation of the VM in relation to the VL, which can result in patellar misalignment and changes in motor control (41, 42). In our study, despite an increase in the mean value, no significant difference was found between the activation time of these muscles. In addition, it was observed that the mean values for the duration of VM and VL were closer. These findings indicate that, after strengthening the core muscles, individuals with PFP may have a tendency towards greater synchrony of activation between these muscles.

As well as other studies that associated core muscles strengthening with exercises for the hip or knee (25, 26, 36), our study showed that an exercise protocol with a single focus on the core muscles can also improve clinical aspects related to pain and functionality, in addition to providing more adequate motor control through the improvement of the VM and TrA/IO muscle activation. As practical implications, we suggest that physiotherapists should implement this exercise protocol for patients with PFP.

This study had as methodological limitations the small sample formed by convenience and the absence of a control group for comparisons. Furthermore, due to the use of questionnaires, individuals may be subject to recent memory bias. The absence of imaging tests made it impossible to diagnose possible chondropathy; conventional radiography may suggest cartilage damage; magnetic resonance imaging (MRI) can identify lesions of the soft tissues, including VM; and dynamic MRI can be used to study dynamically the patellofemoral joint (43). It is suggested for future studies to carry out a follow-up to monitor the evolution of the volunteers and MRI for the detection of the presence or absence of condropathy and the degrees of it. Furthermore, to extrapolate data, future studies should be conducted with a large population of individuals with and without PFP.

CONCLUSIONS

In summary, at the end of the intervention, the individuals showed an improvement in their general clinical status, a reduction in the level of pain, and better scores on specific questionnaires for PFP. In addition, it was possible to identify an increase in the resistance of the core muscles and changes in the electromyographic parameters of the vastus medialis and transverse abdominis/internal oblique muscles. In this context, it is concluded that a 12-week protocol for strengthening the core muscles is effective for the treatment of PFP concerning clinical variables and electromyographic parameters of the VM and TrA/IO muscles.

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DATA AVAILABILITY

Data are available under reasonable request to the corresponding author.

CONTRIBUTIONS

RAPB, JSF, BSR: participants analysis, data and evaluation, statistical analysis, writing – original draft. RIB, AMM: writing – original draft. HUK: supervision.

CONFLICT OF INTERESTS

The authors declare that they have no conflict of interests.

REFERENCES

1. Witvrouw E, Callaghan MJ, Stefanik JJ, et al. Patellofemoral pain: consensus statement from the 3rd International Patellofemoral Pain Research Retreat held in Vancouver, September 2013. Br J Sports Med. 2014;48(6):411-4. doi: 10.1136/bjsports-2014-093450.
2. Smith BE, Selfe J, Thacker D, et al. Incidence and prevalence of patellofemoral pain: A systematic review and meta-analysis. Screen HR, ed. PLoS One. 2018;13(1):e0190892. doi: 10.1371/journal.pone.0190892.
3. Boling M, Padua D, Marshall S, Guskiewicz K, Pyne S, Beutler A. Gender differences in the incidence and prevalence of patellofemoral pain syndrome. Scand J Med Sci Sports. 2010;20(5):725-30. doi: 10.1111/j.1600-0838.2009.00996.x.
4. Harbaugh CM, Wilson NA, Sheehan FT. Correlating femoral shape with patellar kinematics in patients with patellofemoral pain. J Orthop Res. 2010;28(7):865-72. doi: 10.1002/jor.21101.
5. Lin F, Wilson NA, Makhsous M, et al. In vivo patellar tracking induced by individual quadriceps components in individuals with patellofemoral pain. J Biomech. 2010;43(2):235-41. doi: 10.1016/j.jbiomech.2009.08.043.
6. Earl JE, Vetter CS. Patellofemoral Pain. Phys Med Rehabil Clin N Am. 2007;18(3):439-58. doi: 10.1016/j.pmr.2007.05.004.
7. Ng GYF, Zhang AQ, Li CK. Biofeedback exercise improved the EMG activity ratio of the medial and lateral vasti muscles in subjects with patellofemoral pain syndrome. J Electromyogr Kinesiol. 2008;18(1):128-33. doi: 10.1016/j.jelekin.2006.08.010.
8. Utting MR, Davies G, Newman JH. Is anterior knee pain a predisposing factor to patellofemoral osteoarthritis? Knee. 2005;12(5):362-5. doi: 10.1016/j.knee.2004.12.006.
9. Metsavaht L, Leporace G, de Mello Sposito MM, Riberto M, Batista LA. What Is the Best Questionnaire For Monitoring The Physical Characteristics Of Patients With Knee Osteoarthritis In The Brazilian Population? Rev Bras Ortop. 2011;46(3):256-61. doi: 10.1016/S2255-4971(15)30191-9.
10. Kaya D, Citaker S, Kerimoglu U, et al. Women with patellofemoral pain syndrome have quadriceps femoris volume and strength deficiency. Knee Surg Sport Traumatol Arthrosc. 2011;19(2):242-7. doi: 10.1007/s00167-010-1290-2.
11. Fukuda TY, Melo WP, Zaffalon BM, et al. Hip Posterolateral Musculature Strengthening in Sedentary Women With Patellofemoral Pain Syndrome: A Randomized Controlled Clinical Trial With 1-Year Follow-up. J Orthop Sport Phys Ther. 2012;42(10):823-30. doi: 10.2519/jospt.2012.4184.
12. Powers CM. The Influence of Altered Lower-Extremity Kinematics on Patellofemoral Joint Dysfunction: A Theoretical Perspective. J Orthop Sport Phys Ther. 2003;33(11):639-46. doi: 10.2519/jospt.2003.33.11.639.
13. Powers CM, Bolgla LA, Callaghan MJ, Collins N, Sheehan FT. Patellofemoral pain: proximal, distal, and local factors, 2nd International Research Retreat. J Orthop Sports Phys Ther. 2012;42(6):A1-54. doi: 10.2519/jospt.2012.0301.
14. Akuthota V, Nadler SF. Core strengthening11No commercial party having a direct financial interest in the results of the research supporting this article has or will confer a benefit upon the author(s) or upon any organization with which the authors is/are associated. Arch Phys Med Rehabil. 2004;85:86-92. doi: 10.1053/j.apmr.2003.12.005.
15. Kibler W Ben, Press J, Sciascia A. The Role of Core Stability in Athletic Function. Sport Med. 2006;36(3):189-98. doi: 10.2165/00007256-200636030-00001.
16. Hodges PW, Richardson CA. Contraction of the Abdominal Muscles Associated With Movement of the Lower Limb. Phys Ther. 1997;77(2):132-42. doi: 10.1093/ptj/77.2.132.
17. Uliam Kuriki H, Mícolis de Azevedo F, de Faria Negrão Filho R, Alves N. Comparison of different analysis techniques for the determination of muscle onset in individuals with patellofemoral pain syndrome. J Electromyogr Kinesiol. 2011;21(6):982-7. doi: 10.1016/j.jelekin.2011.08.002.
18. Lima KMM e, Flôr J da S, Barbosa RI, et al. Effects of a 12-week hip abduction exercise program on the electromyographic activity of hip and knee muscles of women with patellofemoral pain: A pilot study. Mot Rev Educ Física. 2020;26(1). doi: 10.1590/s1980-6574201900040103.
19. Briani R V., Pazzinatto MF, De Oliveira Silva D, Azevedo FM. Different pain responses to distinct levels of physical activity in women with patellofemoral pain. Brazilian J Phys Ther. 2017;21(2):138-43. doi: 10.1016/j.bjpt.2017.03.009.

20. Briani RV, de Oliveira Silva D, Pazzinatto MF, et al. Comparison of frequency and time domain electromyography parameters in women with patellofemoral pain. Clin Biomech. 2015;30(3):302-7. doi: 10.1016/j.clinbiomech.2014.12.014.
21. Da Cunha RA, Costa LOP, Hespanhol LC, Pires RS, Kujala UM, Lopes AD. Translation, Cross-cultural Adaptation, and Clinimetric Testing of Instruments Used to Assess Patients With Patellofemoral Pain Syndrome in the Brazilian Population. J Orthop Sport Phys Ther. 2013;43(5):332-9. doi: 10.2519/jospt.2013.4228.
22. Stegeman D, Hermens H. Standards for Surface Electromyography: the European Project "Surface EMG for Non-invasive Assessment of Muscles (SENIAM)". Enschede Roessingh Res Dev. 2007;10:8-12.
23. Cowan SM, Hodges PW, Bennell KL, Crossley KM. Altered vastii recruitment when people with patellofemoral pain syndrome complete a postural task. Arch Phys Med Rehabil. 2002;83(7):989-95. doi: 10.1053/apmr.2002.33234.
24. Cohen J. Statistical Power Analysis for the Behavioral Sciences. Routledge. 2013. doi: 10.4324/9780203771587.
25. Bolgla LA, Earl-Boehm J, Emery C, Hamstra-Wright K, Ferber R. Pain, function, and strength outcomes for males and females with patellofemoral pain who participate in either a hip/core- or knee-based rehabilitation program. Int J Sports Phys Ther. 2016;11(6):926-35.
26. Chevidikunnan MF, Al Saif A, Gaowgzeh RA, Mamdouh KA. Effectiveness of core muscle strengthening for improving pain and dynamic balance among female patients with patellofemoral pain syndrome. J Phys Ther Sci. 2016;28(5):1518-23. doi: 10.1589/jpts.28.1518.
27. Earl JE, Hoch AZ. A Proximal Strengthening Program Improves Pain, Function, and Biomechanics in Women With Patellofemoral Pain Syndrome. Am J Sports Med. 2011;39(1):154-63. doi: 10.1177/0363546510379967.
28. Coppack RJ, Etherington J, Wills AK. The Effects of Exercise for the Prevention of Overuse Anterior Knee Pain. Am J Sports Med. 2011;39(5):940-8. doi: 10.1177/0363546510393269.
29. Østerås B, Østerås H, Torsensen TA. Long-term effects of medical exercise therapy in patients with patellofemoral pain syndrome: Results from a single-blinded randomized controlled trial with 12 months follow-up. Physiotherapy. 2013;99(4):311-6. doi: 10.1016/j.physio.2013.04.001.
30. Araujo EHD, Mendonça LM, Ramalho N, Cordeiro TTP, Souza MC, Silva RS. Intervention treating kinetic chain versus heavy-slow resistance training in athletes with patellar tendinopathy: protocol for a randomized blind clinical trial. Muscles Ligaments Tendons J. 2022;12(3):386-95. doi: 10.32098/mltj.03.2022.14.
31. Biabanimoghadam M, Motealleh A, Cowan SM. Core muscle recruitment pattern during voluntary heel raises is different between patients with patellofemoral pain and healthy individuals. Knee. 2016;23(3):382-6. doi: 10.1016/j.knee.2016.01.008.
32. Peters JSJ, Tyson NL. Proximal exercises are effective in treating patellofemoral pain syndrome: a systematic review. Int J Sports Phys Ther. 2013;8(5):689-700.
33. Crossley KM, Stefanik JJ, Selfe J, et al. 2016 Patellofemoral pain consensus statement from the 4th International Patellofemoral Pain Research Retreat, Manchester. Part 1: Terminology, definitions, clinical examination, natural history, patellofemoral osteoarthritis and patient-reported outcome measures. Br J Sports Med. 2016;50(14):839-43. doi: 10.1136/bjsports-2016-096384.
34. Şahi̇n M, Ayhan Ff, Borman P, Atasoy H. The effect of hip and knee exercises on pain, function, and strength in patientswith patellofemoral pain syndrome: a randomized controlled trial. TURKISH J Med Sci. 2016;46:265-77. doi: 10.3906/sag-1409-66.
35. Collins NJ, Barton CJ, van Middelkoop M, et al. 2018 Consensus statement on exercise therapy and physical interventions (orthoses, taping and manual therapy) to treat patellofemoral pain: recommendations from the 5th International Patellofemoral Pain Research Retreat, Gold Coast, Australia, 2017. Br J Sports Med. 2018;52(18):1170-8. doi: 10.1136/bjsports-2018-099397.
36. Ferber R, Bolgla L, Earl-Boehm JE, Emery C, Hamstra-Wright K. Strengthening of the Hip and Core Versus Knee Muscles for the Treatment of Patellofemoral Pain: A Multicenter Randomized Controlled Trial. J Athl Train. 2015;50(4):366-77. doi: 10.4085/1062-6050-49.3.70.
37. Van der Heijden RA, Lankhorst NE, van Linschoten R, Bierma-Zeinstra SM, van Middelkoop M. Exercise for treating patellofemoral pain syndrome. In: van Middelkoop M, ed. Cochrane Database of Systematic Reviews. John Wiley & Sons, Ltd; 2013. doi: 10.1002/14651858.CD010387.
38. Cabral CMN, Melim ÂM de O, Sacco I de CN, Marques AP. Fisioterapia em pacientes com síndrome fêmoro-patelar: comparação de exercícios em cadeia cinética aberta e fechada. Acta Ortopédica Bras. 2008;16(3):180-5. doi: 10.1590/S1413-78522008000300012.
39. Nakagawa TH, Maciel CD, Serrão FV. Trunk biomechanics and its association with hip and knee kinematics in patients with and without patellofemoral pain. Man Ther. 2015;20(1):189-93. doi: 10.1016/j.math.2014.08.013.
40. Leetun DT, Ireland ML, Willson JD, Ballantyne Bt, Davis IM. Core Stability Measures as Risk Factors for Lower Extremity Injury in Athletes. Med Sci Sport Exerc. 2004;36(6):926-34. doi: 10.1249/01.MSS.0000128145.75199.C3.
41. Cowan SM, Bennell KL, Hodges PW, Crossley KM, McConnell J. Delayed onset of electromyographic activity of vastus medialis obliquus relative to vastus lateralis in subjects with patellofemoral pain syndrome. Arch Phys Med Rehabil. 2001;82(2):183-9. doi: 10.1053/apmr.2001.19022.
42. Pal S, Draper CE, Fredericson M, et al. Patellar Maltracking Correlates With Vastus Medialis Activation Delay in Patellofemoral Pain Patients. Am J Sports Med. 2011;39(3):590-8. doi: 10.1177/0363546510384233.
43. Vetrano M, Oliva F, Bisicchia S, et al. I.S.Mu.L.T. First-time patellar dislocation guidelines. Muscles Ligaments Tendons J. 2017;7(1):1-10. doi: 10.11138/mltj/2017.7.1.001.