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Original Article

Effectiveness of core muscle strengthening for improving pain and dynamic balance among female patients with patellofemoral pain syndrome

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Abstract. [Purpose] Patellofemoral pain syndrome is a frequent musculoskeletal disorder, which can result from core muscles instability that can lead to pain and altered dynamic balance. The objective of this study is to assess the effect of core muscle strengthening on pain and dynamic balance in female patients with patellofemoral pain syndrome. [Subjects and Methods] Twenty female patients with age ranging from 16 to 40 years with patellofemoral pain syndrome were divided into study (N=10) and control (N=10) groups. Both groups were given 4 weeks of conventional physical therapy program and an additional core muscle strengthening for the study group. The tools used to assess the outcome were Visual Analogue Scale and Star Excursion Balance Test. [Results] The results of the study show that participants in the study group revealed a significantly greater improvement in the intensity of pain and dynamic balance as compared to the control group. [Conclusion] Adding a core muscle-strengthening program to the conventional physical therapy management improves pain and dynamic balance in female patients with patellofemoral pain syndrome.

Key words: Patellofemoral pain syndrome, Pain, Postural balance

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INTRODUCTION

Patellofemoral pain syndrome (PFPS) is one of the most common musculoskeletal conditions, which accounts for 20–40% of all knee problems in adolescents and active young adults[1, 2)]. PFPS is described as retropatellar or anterior knee aching pain without any other specific pathology and characterized by crepitation in the patellofemoral joint during and after weight bearing activities, such as squatting, walking up or down stairs and running. The other characteristic features of PFPS include pain while sitting with the knees flexed, instability, occasional weakness and locking sensations[2)]. The incidence of PFPS is 22/1,000 persons per year and is the most common cause of knee pain, with women affected more than men at a ratio of 2:1[3)]. Although, PFPS has many possible causative factors that are usually connected to maladies in biomechanics, the insufficient dynamic balance of the torso and lower extremity can also contribute to the development of PFPS. The dynamic balance is important, especially while performing movements that incorporate loading like climbing the stairs, performing squats and jumps[4, 5)]. The individuals having PFPS are found to have significant low- pressure pain threshold (local hyperalgesia) than healthy subjects[5)].

The first line of treatment for PFPS is conservative management, which includes non-operative interventions consisting of rest, ice, and drugs to manage inflammations, adjustment of activities, and physical therapy. The physical therapy manage-

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ment includes specific exercises targeting the knee, such as strengthening exercises for the quadriceps. Published studies show improvement in pain when subjects performed quadriceps exercises[6]. There are also hip strengthening exercises. Many studies stated that subjects who have enrolled in a program that targeted the abductors and external rotators of hip reported a moderate reduction in pain[7, 8]. The other treatment techniques like stretching exercises for the iliotibial band (IT), tensor fascia latae, hamstrings and the quadriceps, also showed greater benefits among the PFPS patients[9]. Patellar taping has gained widespread acceptance as a management option for PFPS[10]. Operative intervention could also be considered when conservative treatments are ineffective[11]. Nevertheless, many PFPS patients have a positive response when treated non-operatively. The utilization of exercises in the treatment program is supported by evidence[12]. The common goal of rehabilitation management in PFPS patients is to address the pain and thereby improve the physical function[13]. The physical therapists or clinicians use self- reported assessment of pain and function to check the effectiveness of various physical therapy interventions. The most common tool used to measure the intensity of pain in these patients is the Visual Analogue Scale (VAS), which is a reliable and valid measure to assess the intensity of pain[2, 14].

Dynamic balance refers to the capability of having suitable reactions regarding the motor system, in order to be able to cope up with the requirements needed for the quick alterations of position in the torso, while performing activities that add stress on the knee joint. Operationally, the dynamic stability may be defined as the ability of the body to maintain position or intended trajectory after external or internal disturbances[15, 16]. A stable erect body posture, or any specific joint, is controlled by the neuromuscular system in relation to the shift in the involved parts at the time of action including the core[4]. Pain may also affect dynamic balance in individuals with PFPS[17]. Deficiency in the control of the neuromuscular system of the body's trunk or "core" may affect the dynamic stability of the lower extremity, which can lead to injury in the tibiofemoral or patellofemoral joints[16].

The spine, abdominal region, pelvis, hips, and proximal lower extremities, are defined as the core of the body. This is sometimes defined as a muscular box, with the diaphragm as the roof, the pelvic floor and hip girdle musculature as the base, abdominals in the front, and the paraspinal and gluteal muscles in the back[18]. These muscles' strength allows the system to stabilize the spine mechanically and then distribute and deliver translational, compressive, and shear forces to and from the rest of the body[19]. The core or the compound of muscles consists of the static and dynamic anatomy at the zone that serves as the foundation in order to move the extremity[20]. The effects of core muscle strengthening have been proven as an effective method of management in various cases[18, 21, 22]. Previous studies states that the knee is the frequently injured joint in core instability with the decreased hip strength[23, 24]. Even though there are many studies on the management issues of PFPS, so far, there are no studies about the effectiveness of the core muscle stability program for the improvement of pain and balance in PFPS patients. The objective of this study is to define the effectiveness of core muscle strengthening program in improving pain and dynamic balance in females with PFPS.

SUBJECTS AND METHODS

This was a Quasi experimental study that included 20 females diagnosed with PFPS, with the age between 16 and 40 years, who were referred from the Orthopedic department. Subjects were randomly assigned to either core muscle strengthening exercise group (Exp; N=10) or control (Con; N=10) group. This age interval has been chosen because the majority of the women are beyond puberty by 16 years of age, and after 40 years of age, there is an increased prevalence of hormonal changes and arthritis development[25]. The randomization was made by an investigator who was not involved in the assessment or management of patients. The randomization was done with Microsoft Excel for Windows. Codes were enclosed in sealed, sequentially numbered envelopes. The baseline characteristics of the participants are presented in Table 1 and it does not show any significant difference between the characteristics of both groups.

The inclusion criteria were as follows: female patients aged between 16–40 years, with anterior knee pain for at least 4 weeks that was aggravated by at least 2 of the following activities: jumping, running, prolonged sitting, stair climbing, kneeling, and squatting; positive patellar grinding test; must be active for at least 30 min a day almost all days of the week. In addition, they should have an average pain intensity level of 30 mm on a 100 mm visual analogue scale and must have an insidious onset of symptoms, unrelated to a traumatic damage. The exclusion criteria were: cruciate, meniscal, collateral ligament injuries or tenderness, any intra-articular injury, tenderness over the illiotibial band, patellar tendon, or pes anserine tendons, patellar apprehension sign if positive, Sinding-Larsen-Johanssen syndromes or Osgood-Schlatter disease, evidence of joint effusion, referred pain from the hip or lumbar region, known case of articular cartilage damage (from previously

Table 1. Baseline characteristics of the participants

	Group	
	Conventional	Experimental
Age (years)	22.2 ± 1.3	21.4 ± 1.8
Height (cm)	158.7 ± 5.1	160.3 ± 4.6
Body weight (kg)	64.8 ± 8.4	68.3 ± 7.7

obtained imaging), any previous surgery around the knee, any spinal or lower extremity deformities, nonsteroidal anti-inflammatory drug or corticosteroid long use, pregnancy, athlete type training (a person who participates in a specific sport at least 2 h /day and 3 times a week regularly)[20, 25–27].

The experimental group was given core muscle strengthening exercises thrice weekly for 4 weeks, in addition to the conventional physical therapy program. The control group was given only the conventional intervention program during the same time period. All the subjects were recruited from King Abdul Aziz University Hospital, in Jeddah, Saudi Arabia. Information was given to all subjects about the study procedures and a written, signed consent form has been obtained from each subject. The study has been approved by the Institutional Ethical Review Committee.

The outcome measures used in the current study were: Visual Analog Scale (VAS) and Star Excursion Balance Test (SEBT). Both these measures were assessed at the start of the study and at the end of the 4 weeks of intervention. The VAS is a reliable tool used to assess the level of pain intensity from 0 to 10, where 0 indicates no pain and 10 indicates maximum unbearable pain[24, 28]. Clinically meaningful improvement in the VAS pain score is 20 mm. Any patient who achieves this score is considered to have a successful outcome[29].

The SEBT for the lower quarter is a functional screening tool, commonly used to examine the balance of the lower extremity. For this test, subjects were asked to adopt a single-leg stance and it was requested of them to perform a maximal reach with the opposite leg, along the marked lines, while keeping the weight bearing leg placed at the center, with good stability, followed by return to the initial upright posture, without losing the balance. This test was performed in three reach directions: anterior (ANT), posterolateral (PL) and posteromedial (PM). All participants performed pre-test trials with demonstration and verbal instructions. Subjects were permitted 3 trials of practice in each direction before the actual test performance[30]. All participants performed the test on the unaffected leg first and then on the affected leg. Participants had 15-seconds rest intervals between each test with the same leg and on the same direction. One minute of rest was given between reaches in the different directions and when changing feet. A trial was repeated if: (a) the subject was not able to maintain single leg stance, (b) the heel of the stance foot did not remain in contact with the floor, (c) weight was shifted onto reach foot, or (d) the subject did not maintain start and return positions for one full second. Three trials of reach distances for each direction were averaged and normalized to limb length (% LL, cm). The limb length was measured from the anterior superior iliac spine to the medial malleolus bilaterally. Overall, 6 different SEBT scores were calculated: 3 directional scores on the affected (A) leg (SEBTANT-A, SEBTPL-A, and SEBTPM-A) and 3 directional scores on the unaffected (U) leg (SEBTANT-U, SEBTPL-U, and SEBTPM-U). Finally, the 6 SEBT was averaged in a single composite SEBT score per participant (SEBTCOM)[30].

The core muscle strength training program lasted for 4 weeks and comprised of 3 training sessions per week, with a total of 12 sessions for the study group. Each session lasted for 30 to 45 minutes, starting with a brief warm-up exercise program consisting of low-intensity core strength exercises to prepare the neuromuscular system for the training loads and ending with a cool-down program (i.e., dynamic stretching)[31]. During the main part of the training, the "big 3" exercises as described byMcGill[32] were conducted. These include the curl-up, side bridge, and quadruped position.

Cross curl-ups: Subjects were made to lie in supine position, hands folded behind the neck, elbows pointed to the sides, knees in a flexed position, feet rested on a mat; subjects curled-up until the scapulae left the mat, and rotated to the left and right at a moderate velocity.

Side bridge (both sides): Subjects were told to assume a side lying position with knees flexed, the supporting shoulder superior to the respective elbow, the uninvolved arm held in akimbo, and the supporting forearm flat on the mat; subjects raised their hips until a straight line is reached from the knees up to the shoulders and they continuously raised and lowered their hips at a moderate velocity.

Quadrupedal stance (Birddog exercise): Subjects were made to stay in a quadrupedal stance, with both hands and knees flat on the surface; they lifted a leg and the contralateral arm in horizontal position at moderate velocity.

Training intensity was progressively increased over the 4-weeks training program by modulating lever lengths and repetitions. During training weeks 1–2, participants performed the "big 3" with 20 repetitions and in the weeks 3–4, repetitions were increased to 23. Rest for 2–3 min was taken between the exercises[32].

The Conventional physical therapy program was designed based on the preliminary studies, which suggest that eccentric exercises are more effective than concentric exercises, because the primary function of the knee joint is eccentric[33]. According to that, the quadriceps strengthening was given in the form of eccentric contraction. The conventional program also included hip abductors and external rotators strengthening exercises[8]. Isometric exercises for the quadriceps and hip abductors, like illiotibial band and hamstring stretching exercises were also given as home programs[34]. The common targeted impairments during the physical therapy management are: weakness of muscles, tightness of muscle and soft tissues, and poor movement quality. Among all these, the quadriceps muscle weakness is the most commonly addressed issue during physical therapy, because studies show that there is decreased pain and increased function in patients who received a strengthening program for quadriceps muscle. However, the weakness of the hip abductors and external rotators muscle was also addressed by physical therapy, because there are studies to prove that subjects with PFPS have weakness of these muscles and strengthening of these hip muscles may be helpful to decrease pain in this population[26].

RESULTS

The data were statistically analyzed by using the statistical package SPSS for Windows (version 19.0; SPSS Inc., Chicago, IL, USA). Descriptive statistics including mean, standard deviation, and 95% confidence interval values were performed. Paired *t* test was used to compare the dependent variables for balance variables between pre rehabilitation and post rehabilitation testing. The subjective outcome variable VAS was compared by using the non-parametric Mann- Whitney U test.

Since the results of the intergroup comparison for VAS show that there is a significant difference between the groups in terms of the intensity of pain (p=0.032 [p> 0.05]), which indicated that the study group had better improvement (Table 2). The results for the SEBT show that there is a significant difference between the groups in terms of the dynamic balance (p= 0. 01 [p>0.05]) and that the study group had a better improvement in the dynamic balance (Table 3).

DISCUSSION

This study was conducted to assess the effectiveness of core muscle strengthening on reducing pain and improving dynamic balance in female patients with PFPS. Even though the effectiveness of core muscle strengthening has been proved by many previous studies in various other preconditions, there is no published study to analyze the effectiveness of core muscle strengthening for improving the pain and balance among the PFPS patients[18, 21, 22, 35]. The results of this study indicate that female patients with PFPS in the study group showed a significant difference in terms of reduction in the intensity of pain. This improvement could be achieved as an immediate effect, because strengthening of the core muscles must have rectified the improper recruitment of the muscles, in order to provide proximal stability, since patients with PFPS present a different recruitment pattern. Rojhani Shirazi Z et al.[20] reported that improvement in core muscles could be an effective strategy in the rehabilitation of patients with PFPS. Having a sufficient proximal stability would reduce the stress load over the patellofemoral joint, which could be the other reason for the significant pain reduction in the study group. Combining core strengthening with the traditional physical therapy program also could be an effective factor for reduction in the pain intensity. Earl JE & Hoch AZ[25] showed in their study a significant improvement in terms of pain and function in women with PFPS who received a proximal strengthening program, which is similar to our findings regarding the improvement in pain. Another factor that must have contributed to the reduction of pain might be the change in fear and avoidance beliefs about physical activity, as this is the strongest predictor of function and pain outcomes[26].

The other main focus of this study was to test the change in dynamic balance among the PFPS patients following a core muscle strengthening program and to the best of our knowledge; this was the first study that has been conducted to analyze the effect of core muscle strengthening on improving the balance among the PFPS patients. The study findings showed that there was a significant improvement in the dynamic balance in the study group. The decrease in pain intensity must have influenced the increased distances in SEBT. The significant increase in dynamic balance is a confirmation of the proposed hypothesis, which suggested that strengthening in the core muscles provides a better stability for the lower limb movements allowing the occurrence of a smooth and stable movement. Strengthening the core could have resulted in a smaller displacement in the mediolateral center of pressure and also, in the center of mass. This means that, the motion at the level of the trunk and hip is properly controlled, resulting in the significant dynamic balance improvement that has been recorded in the study group. This outcome signifies that amelioration in the control of body balance may be related to an improved neuromuscular control, which occurs due to increased postural stability. Therefore, trunk strength and stability programs of the hip-lumbopelvic complex should be considered as a major treatment strategy in the improvement of the whole body balance[36].

Table 2. Comparison of VAS between the control and study groups

		Mean VAS			
Group	N	Pre	Post	SD	Difference
Control	10	6.5	2.3	3.26	4.2
Experimental	10	6.3	1.2*	4.17	5.1

*p<0.05

Table 3. Comparison of SEBT between the control and study groups

		Mean SEBT			
Group	N	Pre	Post	SD	Difference
Control	10	56.3	68.7	4.64	12.4
Experimental	10	58.1	78.1*	7.35	20.0

*p<0.05

Core muscle strengthening must have altered the sensory or motor pathways (or both), which in turn influenced the ability of the patient to maintain the postural control. Moreover, the reduced pain must have enhanced the magnitude of Vastus Medialis Oblique (VMO) activation for the stabilization of the knee while performing the SEBT, which may allow the subjects to maintain their balance in a better way, while attempting to reach far distances[37]. According to Earl &Hertel[38], in normal healthy subjects, the activity of VMO was at peak level while doing the anterior reach of the SEBT. Another explanation for increase in SEBT performance could be the biomechanical corrections of the other joints in the lower extremity following the core strengthening.

Even though core muscle strengthening has been included as an intervention method, the strength of the core muscles was not documented in the present study, as this was not an objective of this study, but could be considered in the future studies. Some of the limitations of our study include the relatively small sample size, although appropriate statistical power was obtained. Studies with larger number of subjects should be performed. The study has been conducted only in the female population, as it was clear from the literature that PFPS is more common among the female subjects, as compared to their male counterparts[39]. However, the results of this study could be considered as a mode of treatment, even in the male population. In conclusion, the study findings revealed that adding a core muscle strengthening program along with the conventional physical therapy program can be beneficial for reducing the pain intensity and improving the dynamic balance in females with PFPS.

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