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Eccentric versus Concentric Contraction of Quadriceps Muscles in Treatment of Chondromalacia Patellae

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Abstract: Chondromalacia patellae is a disorder often accompanied by patellofemoral instability. This can be simply a reflex inhibition of the quadriceps muscle secondary to pain. The eccentric and concentric contraction exercises are beneficial in strengthening of the quadriceps muscles and treatment of chondromalacia patellae. This study was conducted to compare between eccentric contraction and concentric contraction exercises in management of chondromalacia patellae patients. The study included forty patients divided randomly into two groups. The first group followed a physical therapy program of eccentric contraction exercises, stretching of hamstrings muscles and ultrasonic therapy, three sessions per week for three months (mean age = 17.25 ± 1.46 years). The second group submitted to a physical therapy program of concentric contraction exercises, stretching of hamstrings muscles and ultrasonic therapy, three sessions per week for three months (mean age, 18.75 ± 1.64 years). The measures were WOMAC (Western Ontario and McMaster University), universal goniometer to detect range of motion of knee extension from 90°-0° and VAS (visual analogue scale) to measure the pain severity. There was a significant improvement in pain, range of motion and WOMAC scores with eccentric contraction exercises. Eccentric contraction exercises were more effective than concentric contraction exercises in treatment of chondromalacia patellae patients.

Key words: Anterior Knee Pain · Patellofemoral Dysfunction · Patellofemoral Pain Syndrome · Eccentric and Concentric Contraction · Extensor Knee Mechanism

INTRODUCTION

Chondromalacia patellae is the "softening of the articular cartilage of the knee-cap." The articular cartilage refers to the cartilage lining under the knee-cap that joins with the knee joint. The articular cartilage is usually smooth and shiny so it is able to glide along the groove of the femur as the knee bends. However, softening of this cartilage can cause damage to the undersurface of the patella which results in Chondromalacia Patellae [1, 2].

Patella tracking begins with the lower patellar border lying in contact with the suprapatellar fat pad when the knee is fully extended. With knee flexion, the patella moves proximally with a lateral shift, which is limited in excursion by the lateral retinaculum. As the knee continues to flex, the tibia internally rotates and the patella moves upward. The amount of force placed on the patellofemoral joint increases with increasing knee flexion, whereas knee hyper flexion increases patellofemoral stress, so does extreme extension [2-6].

Soft tissue structures provide both dynamic and static stabilization of the patellofemoral joint. The vastus medialis obliquus (VMO) is an important dynamic medial stabilizer of the patellofemoral joint. The iliotibial band provides dynamic lateral stabilization of the patella through the iliopatellar band [7, 8]. Additional dynamic stabilization is provided by insertion of fibers from the vastus medialis and lateralis onto the patellar retinacula. Static stabilizers consist of the medial and lateral retinaculum and the joint capsule [1, 9].

Chondromalacia patellae (CMP) is evaluated in cases of patellofemoral pain syndrome. The term is used to describe pathological lesions of the patellar articular cartilage found at magnetic resonance imaging,

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arthroscopy or arthrotomy [10]. The patellofemoral joint is a complex articulation because of its dependence on both dynamic and static restraints for stability [11, 12].

Patellofemoral pain is typically activity induced and aggravated by actions that increase patellofemoral compressive forces, such as ascending and descending stairs, inclined walking, squatting and prolonged sitting. CMP and other patellofemoral disorders are often accompanied by patellofemoral instability. This can be simply a reflex inhibition of the quadriceps muscle secondary to pain [10, 13].

The quadriceps muscle group is functioning as a knee extensor when the leg is elevated. When the foot is on the ground, contraction of the quadriceps stabilizes the knee, functioning as a decelerator [14]. The patella provides a significant mechanical advantage to the knee extensor mechanism, allowing the knee to extend with a smaller contractile force of the quadriceps. In addition, the patella redirects the force exerted by the quadriceps, resulting in a large compressive stress on the patellofemoral joint. The magnitude of this stress usually is at a maximum with the knee flexed 90° and the foot planted, such as that occurring when one stands from a sitting position [15]. With the knee extended 0°, the patella rides laterally within the trochlear groove and is not in direct contact with the trochlear cartilage. With knee flexion, the patella moves medially and the degree of surface contact of the patellofemoral joint increases [16, 17].

The vastus medialis obliqus is the most important muscle in patellar mechanics. The imbalance between the vastus medialis and lateralis muscles is usually regarded as the main cause of patellofemoral pain syndrome. Therefore the main target of rehabilitation protocols for CMP is the vastus medialis muscle [10].

Chondromalacia Patellae can occur frequently in teenagers (especially girls) when the articular cartilage "softens" in response to excessive and uneven pressure on the cartilage, due to structural changes in the legs with rapid growth and muscle imbalance around the knee. Any flexion of the knee increases the tendency of the patella to dislocate. Undue pressure is placed on the lateral (outer) facet of the patella. Moreover, in many of these teenagers, the vastus lateralis and vastus medialis components of the Quadriceps muscle are not well-balanced [15, 18-21].

Symptoms of chondromalacia patellae include pain, normally around the knee-cap. The pain may radiate to the back of the knee, or it may be intermittent and brought on by squatting, kneeling, going up or down stairs, especially down, or by repeated bending of the joint [13, 22, 23]. Pain with compression of the patella in full knee extension is not a clear evidence of articular pain. Pain in 70% of patients thought to have CP when the dynamic patellar compression test is performed at 10° of flexion [24].

Fortunately, most of the pain syndromes that result in pain around the front of the patella and the front of the knee usually resolve with non-surgical treatment. This treatment is directed at re-establishing the normal biomechanical relationship between the patella and the femur. Usually physical therapy and a home exercise program are necessary [25, 26]. The therapist will work at stretching the vastus lateralis, as well as strengthening the Quadriceps muscle and Hamstring muscles, using manual and electrical techniques. Occasionally the therapist may employ a technique called "patella taping" to keep the patella from tracking laterally [6, 27-29].

A knee brace is also often prescribed for patients who want to stay active in sports. The usual brace prescribed is what is known as a patella stabilizing brace. It consists of a knee sleeve with a patella cutout and a horse-shoe pad based laterally to keep the patella from tracking laterally. With conservative treatment, about 85% of patients improve enough that no further treatment is needed. In about 15% of patients, the pain stays severe, or becomes worse that surgical treatment is needed [25, 30, 31].

Eccentric contraction of the muscle is more effective than concentric contraction due to lengthening contraction is benefit than shortening contraction and also the residual fatigue of the muscle takes place after 6 seconds in eccentric contraction but it takes place 5 seconds in concentric contraction. So, the force exerted during the eccentric contraction is more than in concentric contraction. Many authors have advocated exercises as a recent category of exercises in rehabilitation of patellofemoral pain, because it can induce maximal VMO firing especially from 0 to 60 degrees of knee flexion [23]. Also these exercises are safer than open chain exercises and place minimal stress on patellofemoral joint, while others reported that open chain exercises at low flexion angles (from 0 to 20 degrees of flexion) are recommended because these exercises are particularly effective and the quadriceps effort is the highest in this range [32]. Exercises are better tolerated and do

not place supraphysiological stresses on the patellofemoral cartilage when the patients are unstable on their feet [33].

The aim of the current study was to compare between eccentric contraction and concentric contraction exercises in treatment of chondromalacia patellae.

MATERIALS AND METHODS

Subjects: All subjects were chondromalacia patellae patients. The study included 40 female volunteer patients divided randomly into 2 groups, the first group (20 patients with mean age = 17.25 ± 1.46 years) followed a physical therapy program of eccentric contraction exercises, stretching of hamstrings muscles and ultrasonic therapy, three sessions per week for three months. The second group (20 patients with mean age = 18.75 ± 1.64 years) was submitted to a physical therapy program of concentric contraction exercises, stretching of hamstrings muscles and ultrasonic therapy, three sessions per week for three months. All the patients were listed at out clinic of orthopedic departments at Cairo University Hospitals. All of them were suffering from pain, limitation of end extension activity.

Instrumentations

- WOMAC (Western Ontario and McMaster University), osteoarthritis index for assessing health status.
- Universal goniometer to detect range of motion (ROM) of knee extension from 90°-0°.
- Visual analogue scale (VAS) to measure the pain severity.

Treatment Procedure: The patients signed an informed consent form and were informed about the whole procedures before testing and training.

The first group was submitted to eccentric contraction exercises in form of active strengthening exercises with minimum resistance (10 repetitions with 3 sets) [23], starting from standing and asked the patient to sitting on chair slowly (90°), 6 seconds rest between each repetition and 1 minute rest between the sets. The resistance is progressed according to repetitions for the quadriceps muscles, with stretching hamstrings exercise (5 repetitions, 30 seconds in position of stretching, 30 seconds in position of relaxation) with postural instructions (avoid flexion more than 90°) and ultrasonic therapy (5 minutes, 2w/sec^2 in continuous form). The program continued for 3 months, 3 sessions per week, performed and supervised by the same physical therapist.

The second group was submitted to concentric contraction exercises in the form of active strengthening exercises with minimum resistance (10 repetitions with 3 sets), from 90° to 0° sitting on chair, asked the patients to extend his knee to zero position, 6 seconds rest between each repetition and 1 minute rest between the sets. The resistance was progressed according to repetitions for the quadriceps muscles and stretching hamstrings exercise (three repetitions, 30 seconds in position of stretching, 30 seconds in position of relaxation) and postural instruction (avoid flexion more than 90°) and ultrasonic therapy (5 minutes, 2 w/sec^2 in continuous form). The program continued for 3 months, 3 sessions per week, performed and supervised by the same physical therapist.

All the patients were assessed before treatment and reassessed after 12 weeks by:

- WOMAC (Western Ontario and McMaster University), the WOMAC consists of three subscales [41]. The pain subscale (P subscale) includes five questions, the stiffness subscale (S subscale) includes two questions and the physical function subscale (PF subscale) includes 17 questions.
- Universal goniometer is to detect range of motion (ROM) of knee extension from 90°-0°[43]. Patients were sitting on chair with knee flexed to 90°, asked to extend the knee. The fixed arm of the goniometer was placed in parallel to the femur and the movable arm in parallel to the leg then the subjects were asked to extend the leg and record the angle of extension.
- Visual analogue scale (VAS) is to measure the pain which is represented from (0) position to (10) position [42]. Zero position means no pain, (10) position means unbearable pain, from 1 to 10 means graduation intensities of pain. The subjects were asked to indicate the level of pain by placing a dash at the appropriate level on the 10 cm horizontal line.

Data Analysis: The collected data was statistically analyzed using one sample paired T-test to compare pre and post test within the group and two sample unpaired T-test to compare between the 2 groups, at a confidence level of $P > 0.05$.

Table 1: The pre and post test measures of pain, ROM and WOMAC scores in eccentric group [Group 1]

			ROM(degrees)				WOMAC							
	PAIN(VAS)		FLEX		EXTEND		PAIN		STIFFNESS		FUNCTION		TOTAL	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Mean	6.5	2.3	88.5	98.45	-13.05	-7.25	11.1	5.9	4.45	1.95	30.4	18.35	46	26.2
SD	1.1	0.73	9.61	7.72	3.605	2.69	1.77	0.91	1.19	0.88	8.32	8.13	8.44	7.91
T-test	21	-14.03	-20.24	18..14	10.16	18.63	29.85							
p-value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001							

Significant P ≤ 0.05; There was significant improvement in pain (6.5±1.1 to 2.3±0.73), ROM Flex-(88.5±9.61 to 98.45±7.72), Exten-(-13.05±3.605 to-7.25±2.69), WOMAC scores pain (11.1±1.77 to 5.9±0.91), stiffness (4.45±1.19 to 1.95±0.88), function (30.4±.32 to 18.35±8.13) and total scores (46±8.44 to 26.2±7.91)

Table 2: The pre and post test measures of pain, ROM and WOMAC scores in concentric group [Group 2]

			ROM(degrees)				WOMAC							
	PAIN(VAS)		FLEX		EXTEND		PAIN		STIFFNESS		FUNCTION		TOTAL	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Mean	6.45	3.6	87.25	92.25	-12.3	-9.3	11.1	8.6	4.45	2.95	30.1	26.3	45.1	37.85
SD	1.19	1.35	10.44	9.32	3.465	3.54	2.07	2.08	1.39	1.19	11.66	10.85	13.12	12.54
T-test	13.65	-11.65	-13.78	11.18	8.9	10.15	20.45							
p-value	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001							

Significant P ≤ 0.05;There was significant improvement in pain (6.45±1.19 to 3.6±1.35), ROM Flex-(87.25.±10.44 to 92.25±9.32), Exten-(-12.3±3.465 to-9.3±3.54), WOMAC scores pain (11.1±2.07 to 8.6±2.08), stiffness (4.45±1.39 to 2.95±1.19), function (30.1±11.66 to 26.3±10.85) and total scores (45.1±13.12 to 37.85±12.54)

Table 3: Comparison of post scores of group 1(eccentric) and group 2(concentric)

			ROM				WOMAC							
	Pain By VAS		FLEX		EXTEND		Pain		Stiffness		Function		Total	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Mean	2.3	3.6	98.45	92.25	-7.25	-9.3	5.9	8.6	1.95	2.95	18.35	26.3	45.1	37.85
SD	0.73	1.35	7.72	9.32	2.69	3.54	0.91	2.08	0.88	1.19	8.13	10.85	13.12	12.54
T-test	-4.33	6.76	5.205	-6.28	-4.15	-3.5	20.45							
p-value	0.0001	0.0001	0.0001	0.0001	0.001	0.002	0.0001							

Significant P ≤ 0.05; There was significant improvement in group 1(eccentric) when compared to group 2(concentric) in pain, ROM and WOMAC scores

RESULTS

The results were illustrated in Tables (1-3) and there was significant improvement in group 1(eccentric) when compared to group 2 (concentric) regarding pain, ROM and WOMAC scores (Tables 3).

DISCUSSION

From the results above, we found that, there is a significant difference between pre and post measures of pain, ROM, WOMAC index in the first group, as there was an increase in the power of the quadriceps muscles

and stretching of hamstrings muscles leading to break in the circle of pain decreasing spasm of the muscles and increasing the muscle strength. These increases in power of the quadriceps muscles would in turn lead to improvement in ROM and health status. And also, there was a significant difference between pre and post measures of pain, ROM, WOMAC index in the second group, for the same reasons above but less significant than of the first group.

The knee with chondromalacia patellae has reduced muscular strength and functional capacity. The exercise programme used in this study had a positive effect on the functional ability of the knee and muscle strength.

Eccentric contraction of the muscle is more effective than concentric contraction due to that lengthening contraction is more beneficial than shortening contraction and also the residual fatigue of the muscle takes place after 6 seconds in eccentric contraction but it takes place 5 seconds in concentric contraction. So, the force exerted during the eccentric contraction is more than in concentric contraction. The improvement in the strength of this muscle group also led to improvement in the clinical status of the health.

The improvement of ROM of knee extension occurs consequently to pain reduction which is responsible for improvement in muscle function. In the current study the pain intensity was determined by VAS which is valid, reliable and commonly used assessment tool of pain. The function was measured by WOMAC (Western Ontario and McMaster University), osteoarthritis index for assessing health status and universal goniometer to detect range of motion of knee extension from 90°-0°.

Also ultrasonic therapy is responsible for softening of the hard tissues around the muscles through its micro massage effect. The therapeutic efficacy of low intensity ultrasound thermotherapy was satisfied and more effective for mild to moderate chondromalacia patellae.

The results of this study come in agreement with many previous findings where they concluded that, the eccentric and concentric contraction exercises are beneficial in strengthening of the quadriceps muscles, but the eccentric contraction exercises is more effective than the concentric contraction exercise [23, 34-38].

Patients with patellofemoral pain trained in eccentric exercises of the quadriceps has the following advantages; pain decreases, the physical and mental components of the SF-36 form show an improvement and the percentage time that the patient is able to control the target also increases. Thus isotonic eccentric quadriceps exercises should form a part of treatment in the rehabilitation protocol for the patients with patellofemoral pain syndrome [39].

However when eccentric exercises are done muscles are less active as indicated by EMG records. Thus the central nervous system can exploit the ability of muscles to generate higher tensions during negative work and thereby reduce the energy cost by reducing the number of active motor units [39].

In comparison of the post treatment measures of pain, ROM and WOMAC index for both groups, there were highly significant results of the first group than the second group because of significant improvement in quadriceps muscle strength. These results in reduction of load on the patellofemoral joint due to eccentric contraction of quadriceps and balance with hamstrings muscles at the same time during extension and flexion, led to balance between anterior and posterior power of the muscles of the knee joint with decreasing the load on the patella. So, the joint reaction force and degeneration decreases and also the inflammation process and pain subside. Stretching of hamstrings muscles increases the ROM of end extension of the knee which gives more power and stability of the joint during stair climbing. So improvement in pain and ROM will improve activities daily living. All of these results were reported from eccentric and concentric exercises between range of motion of 0° to 90° only, not more than 90° because the stability of the patella decrease after 90° and also joint reaction force and degeneration increases [23, 32, 33, 40].

In the second group, balance between the power of anterior and posterior muscles of the knee joint increased and the load on the patella decreased, but less than the first group. The improvement of pain was due to decreasing the hypertonicity and hyperactivity of the hamstrings muscles and strengthening of the weak quadriceps muscles.

The results of this study showed that, the improvement in the first group was more significant than in the second group for pain, ROM of knee end extension and WOMAC (Western Ontario and McMaster University) for assessing health status.

From all of the above, we found that the eccentric contraction exercises program and stretching of tight hamstrings muscles, are more effective for chondromalacia patellae patients than concentric contraction exercises.

This study showed that eccentric and concentric contraction exercises and stretching of tight muscles (hamstrings muscles) are very important to be included in the program of treatment of chondromalacia patellae patients.

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