Closed Versus Open Chain Exercises in Management of Chondromalacia Patellae

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ABSTRACT

Background and purpose: *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 condition is more common in girls. The closed and open chain exercises are beneficial in strengthening of the quadriceps muscles and management of chondromalacia patellae. This study was conducted to compare between closed chain exercises and open chain exercises in management of chondromalacia Patellae patients.* ***Subjects and methods:*** *The study included fourty patients and divided randomly into two groups. The first group followed a physical therapy program of closed chain exercises, three sessions per week for three months (mean age = 18.25 ± 1.66 years). The second group submitted to a physical therapy program of open chain exercises, three sessions per week for three months (mean age, 17.75 ± 1.44 years). Outcome measures were rating score system of the japanese orthopaedic association for measuring daily living activities (up and down stairs), universal goniometer to detect range of motion of knee extension from 90º- 0º, and visual analogue scale to measure the pain severity.* ***Results:*** *There was a significant improvement in the first group (t. of pain = 0.004, t. of ROM = 0.005, t. of ADL = 0.006) than in the second group (t. of pain = 0.02, t. of ROM = 0.03, t. of ADL = 0.04).* ***Discussion and Conclusion:*** *This study provides that closed chain exercise is very effect more than open chain exercises in management of chondromalacia Patellae patients.*

Key words: *Anterior knee pain, Chondromalacia patella, Patellofemoral dysfunction, Patellofemoral pain syndrome, Closed chain exercises, Open chain exercises, Extensor knee mechanism.*

INTRODUCTION

The patella, the largest sesamoid bone in the body, possesses the thickest articular cartilage. The articular surface, which can have a variable contour, articulates with the trochlear groove of the femur[10]. Most patellae possess a median ridge that divides the proximal patella into a medial and lateral facet; the medial facet usually is the smaller of the two. The patellar tendon, occasionally termed the patellar ligament, originates at the inferior pole of the patella and inserts onto the tibial tuberosity[5,16,17].

The quadriceps muscle group functions 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[12]. 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.[4] 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[2,9].

Additional 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[14,15]. 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[7,34].

Tracking of the patella 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 hyperflexion increases patellofemoral stress, so does extreme extension[1,18,19,26,27].

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[7,27].

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[8,22,23,25].

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[20,21,30].

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 is necessary and a home exercise program is necessary[24,31]. 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[10,26,32,38].

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[24,33,36].

Many authers have advocated closed chain 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[29]. Also these exercises 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 particulary effective and the quadriceps effort is the highest in this range[13]. Open chain exercises are better tolerated and do not place supraphysiological stresses on the patellofemoral cartilage when the patients are unstable on their feet[3].

The aim of the current study is to compare between closed and open chain exercises in management of chondromalacia patellae.

MATERIALS AND METHODS

Subjects

All subjects were Chondromalacia Patellae patients. The study included 40 females volunteer patients and divided randomly into 2 groups, the first group (20 patients with mean age = 18.25 ± 1.66 years) followed a physical therapy program of closed chain exercises, three sessions per week for three months. The second group (20 patients with mean age = 17.75 ± 1.44 years) is submitted to a physical therapy program of open chain exercises in the form of active strengthening exercises, three sessions per week for three months. All the patients were listed at out clinic of orthopaedic departments at Cairo University Hospitals. All of them were suffering from pain, limitation of end extension and up and down stairs activity.

Instrumentations

1- Rating score system of Japanese Orthopaedic Association is to measure daily living activities, up and down stairs.
2- Universal goniometer is to detect range of motion (ROM) of knee extension from 90º -0º.
3- Visual analogue scale (VAS) is to measure the pain severity.

Procedures

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

Treatment procedures

The first group was submitted to closed chain exercises in form of Stationary bicycling without stressing the knee[24] (10 minutes at minimum resistance, adjust the seat high enough, range between 0º-90º) 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 90º). The program continued for 3 months, 3 sessions per week, performed and supervised by the same physical therapist.

The second group was submitted to open chain exercises in the form of active strengthening exercises with minimum resistance (10 repetitions with 3 sets[25], from 90º to 0º sitting on chair, 6 seconds rest between each repetition, and 1 minute rest between the sets. The resistance is 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 90º). 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:

1- Rating score system of Japanese Orthopaedic Association is to measure daily living activities, up and down stairs, which are measured by 4 grades which are no restriction, mild restriction, moderate restriction and severe restriction.
2- Universal goniometer is to detect range of motion (ROM) of knee extension from 90º -0º. Patients was sitting on chair with knee flexed to 90º, ask the Patients to extend the knee. The fixed arm of the goniometer is 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.
3- Visual analogue scale (VAS) is to measure the pain which is represented from (0) position to (10) position. 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 were statistically treated and the following values were found minimum, maximum, mean, S.D., one sample paired T-test to compare between pre and post in the group and two sample unpaired T-test to compare between 2 groups, at a confidence level of (P = 0.05).

RESULTS

The results of the first group: There was a significant improvement of pain after physical therapy treatment from (5.81±0.93) to (1.77±0.73), ROM of knee extension increased from (2.72±0.44) to (1.27±34), ADL (up and down stairs) from (5.77±1.20) to (2.86±0.91), tab. (1) fig. (1).

Table (1): The mean difference of pain, ROM and ADL (up and down stairs), in first group.

	Pain		ROM		ADL (up & down stairs)	
	Pre	Post	Pre	Post	Pre	Post
Min	4	1	2	1	8	5
Max	7	3	3	2	4	2
Mean	5.81	1.77	2.72	1.27	5.77	2.86
SD	0.93	0.73	0.44	0.34	1.20	0.91
T-test	0.004*		0.005*		0.006*	

(*) significant, $P \leq 0.05$ (**) no significant, $P \geq 0.05$

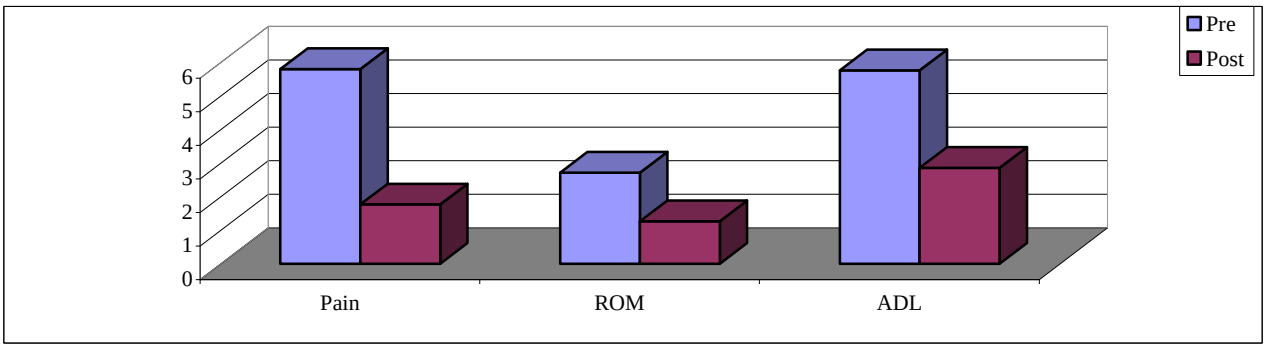

Fig. (1): The mean values of pain, ROM and ADL (up and down stairs) in first group.

The results of the second group: There was a significant improvement of pain after physical therapy treatment from (5.86±0.81) to (2.45±0.83), ROM of knee extension increased from (2.59±0.59) to (1.59±0.49), ADL (up and down stairs) from (5.86±1.17) to (4.59±1.46), tab. (2), fig. (2).

Table (2): The mean difference of pain, ROM and ADL(up and down stairs), in second group.

	Pain		ROM		ADL (up & down stairs)	
	Pre	Post	Pre	Post	Pre	Post
Min	5	1	2	1	8	8
Max	7	4	3	2	4	3
Mean	5.86	2.45	2.59	1.59	5.86	4.59
SD	0.81	0.83	0.59	0.49	1.17	1.46
T-test	0.02*		0.03*		0.04*	

(*) significant, $P \leq 0.05$ (**) no significant, $P \geq 0.05$

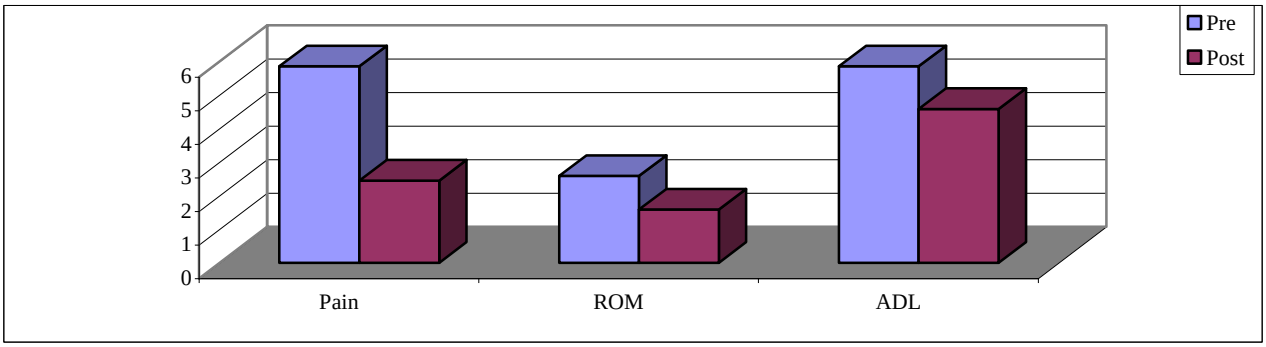

Fig. (2): The mean values of pain, ROM and ADL (up and down stairs) in second group.

There is no significant difference between pre measures of the first group and pre measures of the second group of pain, ROM of knee from 90º to 0º, and ADL (up and down stairs), where t. value of pain 0.08, t. value of ROM of knee 0.07, t. value of ADL 0.09 tab. (3), fig. (3).

Table (3): Pain, ROM of knee from 90º to 0º, and ADL (up and down stairs), pre of both groups.

	Pain		ROM		ADL (up & down stairs)	
	1st gr.	2nd gr.	1st gr.	2nd gr.	1st gr.	2nd gr.
Min	4	5	2	2	8	8
Max	7	7	3	3	4	4
Mean	5.81	5.86	2.72	2.59	5.77	5.86
SD	0.93	0.81	0.44	0.49	1.20	1.17
T-test	0.08**		0.07**		0.09**	

(*) significant, $P \leq 0.05$ (**) no significant, $P \geq 0.05$ gr. (group)

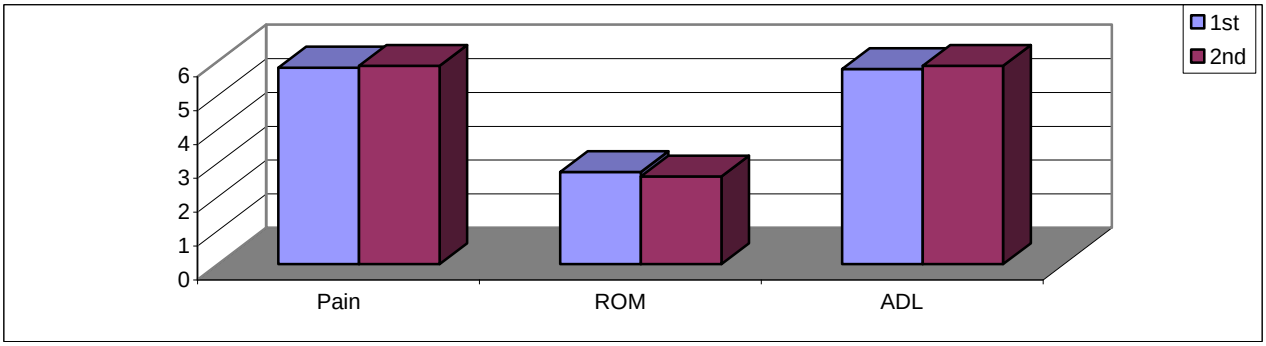

Fig. (3): Pain, ROM of knee from 90º to 0º, and ADL (up and down stairs), pre of both group.

There is a significant difference between post measures of the first group and post measures of the second group of pain, ROM of knee from 90º to 0º, and ADL (up and down stairs), where t. value of pain 0.02, t. value of ROM of knee 0.03, t. value of ADL 0.009, tab. (4) fig. (4).

Table (4): Pain, ROM of knee from 90º to 0º, and ADL (up and down stairs), post of the both group.

	Pain		ROM		ADL (up & down stairs)	
	1st gr.	2nd gr.	1st gr.	2nd gr.	1st gr.	2nd gr.
Min	1	1	1	1	5	8
Max	3	4	2	2	2	3
Mean	1.77	2.45	1.27	1.59	2.86	4.59
SD	0.73	0.83	0.44	0.49	0.91	1.46
t-test	0.02*		0.03*		0.009*	

(*) significant, $P \leq 0.05$ (**) no significant, $P \geq 0.05$ gr. (group)

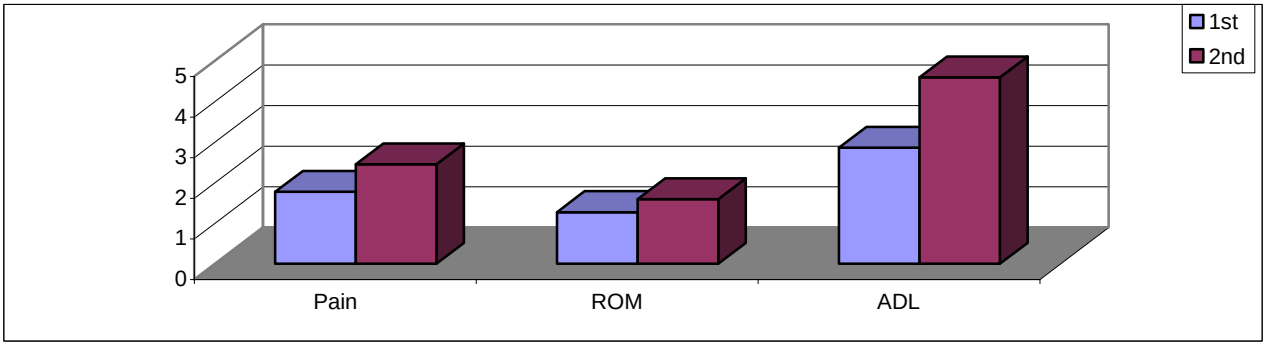

Fig. (4): Pain, ROM of knee from 90º to 0º,and ADL (up and down stairs), post of the first group and post in second group.

DISCUSSION

From the results above, we found that, there is a significant difference between pre and post measures of pain in the first group, because of there is increasing the power of the quadriceps muscles and stretching of hamstrings muscles leading to breaking down the circle of pain which is decreasing spasm of the muscles, increasing the muscle strengthening, and improving the circulation which decreases the concentration of metabolites. This power of the quadriceps muscles also is improving of ROM and ADL (up and down stairs). And also, there is a significant difference between pre and post measures of pain, ROM and ADL (up and down stairs) in the second group, for the same reasons above but less than of the first group.

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 japanese orthopaedic association for measuring daily living activities, up and down stairs, and universal goniometer to detect range of motion of knee extension from 90º -0º.

The results of this study come in agreement with many previous findings where they concluded that, the closed and open chain exercises are beneficial in strengthening of the quadriceps muscles, but the closed chain exercises is more effective than the open chain exercises[6,11,28,29,35].

In comparison of the pre treatment measures of pain, ROM and ADL (up and down stairs) for both groups, there is no significant difference. But In comparison of the post treatment measures of pain, ROM and ADL (up and down stairs) for both groups, there is highly significant results of the first group than the second group because of strengthening of quadriceps muscles by closed chain exercise is more effective than open chain. This is explained by, there is no load on the patellofemoral joint due to concentric contraction of quadriceps and eccentric contraction of hamstrings muscles at the same time during extension, and eccentric contraction of quadriceps and concentric contraction of hamstrings muscles during flexion, leading 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 decreasing, and also the inflammation process

and pain subsiding. Stretching of hamstrings muscles is increasing the ROM of end extension of the knee which giving more power and stability of the joint during up and down stairs. So, decreasing the pain, and increasing ROM will improve active daily living (up and down stairs). All of these results was done from closed chain exercises between range of motion of 0º to 90º only, not more than 90º because the stability of the patella decrease after 90º, and also joint reaction force and degeneration is increasing[3,13,29,37].

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 the effect of closed chain exercises. We found that the improvement in the first group was more significant more than in the second group for pain, ROM of knee end extension, and ADL (up and down stairs).

This is explained by the assumption that the imbalance, and the mechanical defect of lost end extension was decreased, due to decreased spasm of hamstrings muscles, and increased power of quadriceps muscles. This is leading to balance of muscles of anterior and posterior component of the knee joint, with decreasing the load, joint reaction force and degeneration of the joint.

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

At the end, it was suggested that pateints who have a chondromalacia patellae can live without any hindering problems if they follow the closed chain exercises and stretching of tight hamstrings muscles.

Conclusion

This study showed that closed chain exercises and stretching of tight muscles (hamstrings muscles) is very important to be included in the program of management of chondromalacia patellae patients and its sharing in the correction of pathomechanics in the knee joint.

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الملخص العربي

مقارنة بين تمرينات السلسلة المغلقة والسلسلة المفتوحة في معالجة خشونة عظمة الرضفة بالركبة

تعتبر الخشونة بعظمة الرضفة بمفصل الركبة من أهم أسباب الألم الأمامي بمفصل الركبة وأيضا إعاقة المدى الحركي لمفصل الركبة مما يؤدى إلى إعاقة الحركة أثناء صعود وهبوط السلم والذي يعتبر من الأنشطة اليومية . ولذلك تمت دراسة مقارنة بين تأثير برنامج العلاج الطبيعي المتمثل في بعض التمرينات لتقوية العضلة الأمامية للفخذ بطريقة السلسلة المغلقة مع شد العضلة الخلفية للفخذ و تأثير برنامج العلاج الطبيعي المتمثل في بعض التمرينات لتقوية العضلة الأمامية للفخذ بطريقة السلسلة المفتوحة مع شد العضلة الخلفية للفخذ . وفى هذه الدراسة تم استخدام تمرينات لتقوية العضلة الأمامية للفخذ بطريقة السلسلة المغلقة مع شد العضلة الخلفية للفخذ لعمل توازن عضلي حول مفصل الركبة وقد أجرى البرنامج لمجموعة واحدة 3 جلسات أسبوعيا لمدة 3 شهور لمجموعة واحدة مكونة من 20 مريضاً، نفس البرنامج بنفس الأخصائي لكل مريض ويتضمن البرنامج أيضا التعليمات الصحيحة للأنشطة اليومية. ومجموعة أخرى تم استخدام تمرينات لتقوية العضلة الأمامية للفخذ بطريقة السلسلة المفتوحة مع شد العضلة الخلفية للفخذ لعمل توازن عضلي حول مفصل الركبة وقد أجرى البرنامج لمجموعة واحدة 3 جلسات أسبوعيا لمدة 3 شهور لمجموعة واحدة مكونة من 20 مريضاً، نفس البرنامج بنفس الأخصائي لكل مريض ويتضمن البرنامج أيضا التعليمات الصحيحة للأنشطة اليومية . وقد ظهر من الدراسة أن برنامج العلاج الطبيعي الأول أكثر تأثيرا لعلاج مرضى الخشونة بعظمة الرضفة مع شد العضلة الخلفية للفخذ من برنامج العلاج الطبيعي الثاني . وفى هذه الدراسة أثبتت النتائج أهمية التمرينات لتقوية العضلة الأمامية للفخذ بطريقة السلسلة المغلقة ومدى تأثير ذلك على النتائج .