Egyptian Journal of Physical Therapy (EJPT) **Egy. J. Phys. Ther. 2024** **Original article**

https://ejpt.journals.ekb.eg

Open versus closed kinetic chain exercise on quadriceps hamstring ratio and thickness in knee osteoarthritis

Fatma Sedeek Amin [1]. Amira Abdel Aziz Abdelstar [1.] Soheir Shehata Rezkallah[2.]Ayman El-Sayed Shafei [3.]

[1] Department of Basic Science, Faculty of Physical Therapy, Cairo University.

[2] Rheumatology Physical Medicine and Rehabilitation, Military Medical Academy.

[3] Department of Basic Science, Faculty of Physical Therapy, Cairo University.

***Correspondence to:**
Amira Abdelaziz Abdel star
Email:
Amiraaziz80@yahoo.com

Telephone:
00201090029351

Published online:
2024

Abstract:
Purpose: The objective of this research was to compare the impact of open kinetic chain exercise (OKCE) versus closed kinetic chain exercise (CKCE) on the quadriceps/hamstring ratio (Q/H ratio), the thickness of the quadriceps and hamstrings, and the functional ability of the knee in knee osteoarthritis. **Methods:** In a randomized controlled trial, a total of 60 patients with ages ranging from 40 to 60 years participated in the research. They have been split randomly into three equal groups: The OKCE group is represented by Group (A), the CKCE group by Group (B), and the control group by Group (C). Participants in all groups underwent a selected physical therapy program that involved ultrasound (US) and manual instrument-assisted soft-tissue Mobilization (IASTM) for 6 weeks, with 3 sessions per week. A dynamometer was used to assess the power of the quadriceps and hamstrings, and Ultrasonography was used to assess the thickness of both muscles. WOMAC questionnaire to assess the functional ability of the knee. **Results:** Mixed design MANOVA revealed overall significant differences regarding treatment, assessment time and interaction ($p<0.05$). The within-group comparison exhibited statistically significant differences between before and following treatment mean values for quadriceps thickness in groups A (OKCE) and B (CKCE) ($p = 0.001$), as well as the Q/H ratio in group B only and WOMAC scores in all three groups ($p<0.05$). A comparison of the Q/H ratio between groups showed a significant difference. A pairwise comparison showed a significant difference between groups A versus B and B versus C regarding the Q/H ratio**.** **Conclusion** CKCE yielded better improvement of quadriceps thickness and strength and Q/H ratio then OKCE. While OKCE was relatively superior to CKCE in improving hamstring thickness and strength. **Keywords:** Knee osteoarthritis, Quadriceps- hamstring ratio, Open versus closed chain exercise, Dynamometer.

1. Introduction

The weight-bearing joints, most frequently the knee, are affected by osteoarthritis (OA), the most prevalent disease of degenerative joints. Quadriceps weakness is one of the risk factors for knee osteoarthritis, along with age, inheritance, biochemical alterations in the

Pleas cite this article as follows: Fatma Sedeek Amin. Amira Abdel Aziz Abdelstar. Soheir Shehata Rezkallah. Ayman El-Sayed Shafei. Open versus closed kinetic chain exercise on quadriceps hamstring ratio and thickness in knee osteoarthritis. EJPT.2024, 17:34-42

cartilage of the articulation, obesity, and biomechanical compressive stresses, which cause destruction of the joint **(1)**

In the sagittal plane, the quadriceps muscle acts as the knee's main dynamic stabilizer. Thus, it's feasible that weakening in the quadriceps, whether it is absolute or relative to the hamstrings, could have a negative effect on the amount of compressive and shear stress placed on the joint of the knee **(2).**

The muscles surrounding the knee joint, the quadriceps and the hamstrings, are essential to preserving the knee's dynamic stability. For basic daily activities like rising out of a chair, walking, squatting, and climbing stairs, adequate quadriceps and hamstring strength are required. The knee joint is protected from stress by both muscle groups, which also stabilize it **(3).**

An ideal quadriceps-to-hamstring muscle torque ratio (Q/H ratio) balances the forces of the surrounding muscles on the joint of the knee that contribute to normal joint mechanics **(4).**

The concentric hamstring-quadriceps ratio (Hco/Qcon), as stated in earlier literature, has been the most commonly recorded strength ratio of the knee muscles. Steindler (1955) extended the generalization that the ratio of absolute knee extension muscular force to knee flexion muscular force ought to be 3:2, or Hcon/Qcon of 0.66.

The isometric quadriceps-to-hamstring strength ratio in cases of knee osteoarthritis is significantly lower than in healthy adults **(4).**

Exercise therapy is the most popular treatment among conservative physiotherapists for knee OA **(5).** All conservative therapies are thought to be built around exercise therapy. Various exercise treatment techniques are taught, including OKCE and CKCE **(6).**

Human movement is described by the kinetic chain, which can either be open (OKC) or closed (CKC). The part that is furthest from the body is free and not attached to anything throughout the OKC exercises. The CKC exercises fix the portion that is farthest from the body.

Studies on the treatment of knee osteoarthritis have focused on quadriceps strengthening, whereas the hamstring muscle has received little attention. The literature lacks sufficient studies of the ideal quadriceps-to-hamstring strength ratio needed for the joint of the knee to function effectively. **(1)**

This investigation has been conducted to provide an answer to the following: Is there a difference in the effect of OKCE versus CKCE on the Q/H ratio, muscle thickness of the quadriceps and hamstrings, and knee joint function in Osteoarthritis of the knee?

2. Patients and Methods

2.1. Study subjects and selection criteria:

Participants: 60 patients with OA ranging in age from 40 to 60 years were recruited and divided randomly into three equal groups: The OKCE group is represented by Group (A), the CKCE group by Group (B), and the control group by Group (C). Participants in all groups underwent a selected physical therapy program that involved ultrasound (US) and manual Instrument-assisted soft-tissue mobilization (IASTM).

Inclusion criteria:

In female patients, age group 40–60 years **(7)**, based on the radiological image and the criteria established by the American College of Rheumatology **(8)**, there was bilateral mild-to-moderate medial tibiofemoral OA. (Kellgren-Lawrence Grade II–III). The pretreatment exam involved a thorough review of medical history, physical exams with a special focus on the pain threshold, and radiographic results, which indicated the main symptoms of knee OA.

Excluded criteria:

A total knee replacement, a self-reported unstable heart condition, or a history of neurologic

dysfunction. Any limb length discrepancy or flatfoot. People who have engaged in sports/exercise for the past six months, the existence of inflammatory arthritis, a knee injection history, a knee surgery history, suspicion of additional diseases in the knee, and patients with any contraindications for the use of ultrasound.

2.2. Study Design:

Study design: The study has been conducted as a randomized control trial with pre- and post-testing. The dependent variables were the Q/H ratio, muscle thickness of the quadriceps and hamstrings, and WOMAC score. The independent variables were OKCE and CKCE.

2.3. Methods:

Patients were assessed before and after the therapy program. The assessment procedures included the following:

1-Dynamometer: utilized to assess the hamstring and quadriceps' strength.

2-Ultrsonography: used to evaluate the quadriceps and hamstrings' thickness.

3-WOMAC Osteoarthritis Index questionnaire: used to assess functional knee stability.

Treatment Procedure:

The total treatment duration was 6 weeks, with 3 sessions per week on alternate days. The therapy focused on the most painful and afflicted knee. Treatment was given to the dominant knee in patients who experienced equal pain in both knees.

A. Open kinetic chain exercise (OKCE):

Quadriceps setting: The patient contracted the quadriceps muscle isometrically in a supine position by raising his patella and keeping his knee extended. The patient managed to hold the contraction for 10 counts before relaxing. Ten repetitions of the exercise were performed. During all six weeks, the patients performed this exercise.

Straight Leg Raising (SLR): The patient contracted the quadriceps (quadriceps setting) isometrically in a supine position. The ipsilateral lower extremity was then raised to a hip flexion angle of around 45 degrees while the patient's knee remained extended. The exercise was repeated ten times, with the patient holding the position for ten counts before lowering the limb. The contralateral hip and knee have been flexed to around 45°and 90°, respectively, to reduce unnecessary low back stress. Beginning in the 3rd week, weight training started by attaching the sandbag to the ankle. Throughout the six weeks, the patient performs this exercise.

Full-arc extension: a sandbag strapped to the impacted lower extremity's leg just above the ankle while the patient was in a high sitting position. Using a towel roll, the popliteal space has been shielded. The patient slowly raised the weight through the 90-to 0-degree range of flexion of the knee (full extension) and held the posture for a count of five before lowering the load. The patient did three bouts of ten repetitions of this exercise each session; in between, he rested his foot on the stool. During the third week of the study until its conclusion, this exercise was done.

Air Cycling: the patient was lying supine on the mat, elevating his legs in the air with his knees and hip joints bent to roughly 90 degrees each. The patient cycled their lower limbs continuously in the air for two minutes while maintaining a slow and stable balance. The hands were situated beside the body and rested on the mat during the air cycling of the legs. This exercise continues for six weeks.

B. Closed kinetic chain exercise (CKCE):

Wall slides: The patient appeared to be getting ready to sit on a chair as he stood with his back to the wall and his knees and hips bent at a 60-degree angle. After sustaining the position for ten seconds, the patient stood up and relaxed for five seconds. Each exercise session consisted of a certain number of wall slide repetitions. In week 3, patients started performing wall slides while carrying dumbbells in both hands. All throughout the investigation, they continued to do this exercise.

Step-up and step-down: Using a steady stepper, the participant conducted step-ups and step-downs going forward and backward. The subject's trunk has been held erect to guarantee that the heel will be the last to depart before returning to the ground, emphasizing the quadriceps muscle's activities. Each exercise's component was done ten times by the participant. In the second week of the investigation, this exercise was started. Weighted exercises with a sandbag tied to the ankle started in the third week.

Each exercise was performed ten times throughout each session (with the exception of air cycling and full arc extension). One bout of exercise consisted of 2 minutes of continuous cycling in the air (OKCE). 10 full-arc extension repetitions (OKC) were completed three times. The weight that each participant began with was equal to their 10-repetition maximum (10RM), and they advanced by figuring out a new 10RM at the start of every week. Wall slides are performed with dumbbells**. (9)**

Table 1: summarizes the exercise training program.

week	Group A OKCE	Group B CKCE
Week1	(a)Quadriceps Setting(b)Air Cycling.	(a)Quadriceps setting. (b) Wall slides.
Week2	(a)Quadriceps Setting(b)Air Cycling. (c) Straight leg raising.	(a)Quadriceps setting(b) Wall slides
Week3	(a)Quadriceps Setting(b)Air Cycling. (c)Straight leg raising with weight.	a) Quadriceps setting (b) Wall slides with weight.
Week4	(a)Quadriceps Setting(b)Air Cycling (c) Straight leg raising (d) Full arc extension with weight.	(a)Quadriceps setting (b) Wall slides.
Week5	(a)Quadriceps Setting(b)Air Cycling (c) Straight leg raising (d) Full arc extension.	(a)Quadriceps setting (b) Wall slides (C) Step up and down.
Week6	(a)Quadriceps Setting(b)Air Cycling (c) Straight leg raising (d) Full arc extension.	(a)Quadriceps setting (b) Wall slides (c) Step up and down with weight.

2. **DATA ANALYSIS:**

Calculation of sample size: The G*Power software (version 3.0.10) has been utilized to calculate the size of the sample prior to the study. The within- and between-interaction effects of the F-test MANOVA were chosen. With a power of 0.95, an α level of 0.05 (2-tailed), and an effect size of 0.405; three groups and three response factors; and a generating size of the sample of at least 20 participants per group, a total size of the sample of 60 participants was required.

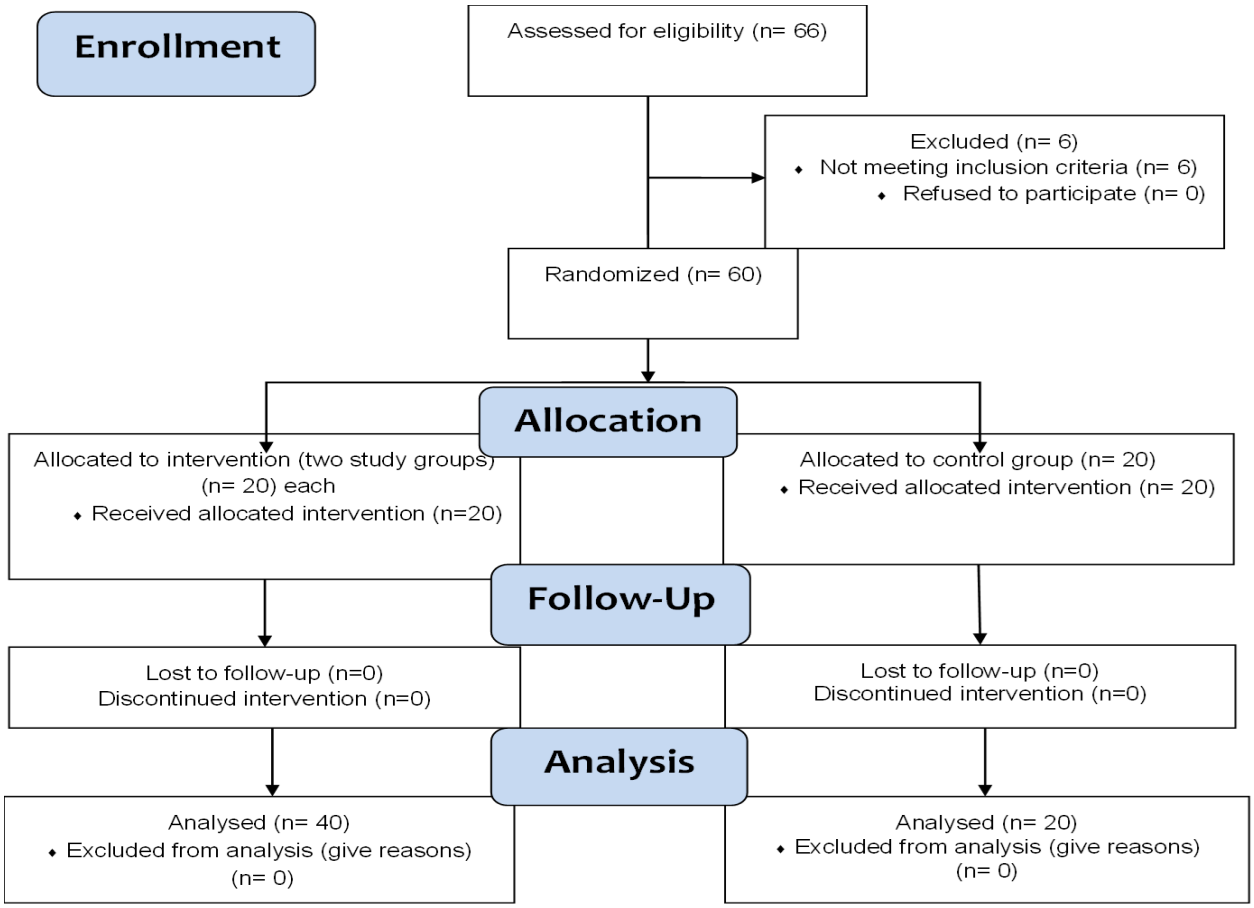

Figure (1): Study flow chart.

Statistical Analysis:
Using SPSS (IBM SPSS for Windows, v25, Chicago, IL, USA), a mixed-design multivariate analysis (2X3) has been performed to evaluate the difference in the amount of change in the scores of the participants on the measures of outcome among the three groups. Statistically Significant multivariate impacts have been discovered for the main impacts of groups (Wilk's A = 0.477, F = 4.75, p= 0.001, η2 = 0.310), time (Wilk's A = 0.051, F= 188.7, p = 0.001, η2 = 0.949), and the interaction of groups and time (Wilk's A= 0.198, F= 13.2, p = 0.001, η2 = 0.555). A one-way ANOVA has been employed to compare subject characteristics among groups. Prior to final analysis, the Shapiro-Wilk test was applied to ensure that the data was normally distributed. The homogeneity among groups has been confirmed using Levene's test for homogeneity of variances. The significance level for all statistical tests has been fixed at $p < 0.05$.

There was no statistically significant difference in mean age, weight, or height between the three groups (P > 0.05). **(Table 2)**

Table 2: Subjects' general characteristics.

General characteristics	Group A (n=20)	Group B (n=20)	Group C (n=20)	F-value	P-value
Age (years)	51.2 ± 6.7	54.3± 7	49.7 ± 8.1	2.05	0.137
Weight (kg)	96.9 ±17.1	88.6±17.3	89.6 ± 16.6	1.41	0.252
Height (cm)	165.9 ±3.4	163.7± 4.2	163.9± 3.3	2.08	0.134

Kg, kilogram; cm, centimeter; P, probability

4. Results

Multivariate analysis of the US assessment of quadriceps and hamstring muscles showed no statistically significant difference (F-value= 0.834, P-value= 0.440) (Table 3). Within-group comparison (pre vs. post) demonstrated significant enhancement in all three groups ($p<0.05$). Concerning the treatment effect on Q/H ratio, before treatment, there hadn't been statistically significant differences among the groups (P = 0.580), but after treatment, there have been statistically significant differences among the groups (P = 0.001). The post-hoc pairwise comparison test (Table 4) revealed no significant differences in terms of groups A and C (P = 0.999), significant differences among groups A and B (P = 0.001) in favor of group B, and significant differences among groups B and C (P = 0.001) in favor of group B. groups, comparison (before vs. after) revealed significant improvement in groups A and B but no difference in group C ($p<0.05$). Furthermore, as revealed in Table 3, there weren't statistically significant differences in WOMAC among groups before treatment (P = 0.0.059) or after treatment (P = 0.053). Within-group comparison (pre vs. post) showed significant improvement in the three groups ($p<0.05$).

Table (3): Comparison of the mean values of the measured variables between and within groups before and after the treatment

Variables	Group A OKCE	Group B CKCE	Group C (Control)	f-value	P value
US of Hamstring (cm)pre-treatment	3.7±0.6	3.6±0.5	3.4±0.9	0.834	0.440
Post-treatment	3.8±0.6	3.66±0.5	3.5±1	0.856	0.430
% of change	2.7%	1.7%	2.9%		
(P-value)	0.087	0.080	0.248		
US of Quadriceps (cm)pre-treatment	1.6±0.1	1.5±0.2	1.58±0.18	1.33	0.271
Post-treatment	1.67±0.1	1.6±0.2	1.6±0.18	0.764	0.471
% of change	4.3%	6.7%	1.3%		
(P-value)	0.001*	0.001*	0.033		
Q/H ratio					
Pre-treatment	0.73±0.28	0.76±0.12	0.67±0.27	0.551	0.580
Post-treatment	0.65±0.11	1±0.26	0.7±0.28	21.2	0.001*
% of change	11%	31.5%	4.5%		
(P-value)	0.077	0.001*	0.628		
WOMAC					
Pre-treatment	33.4±3.6	30.9±9.7	36.3±6.2	2.97	0.059
Post-treatment	70.5±7.3	62.7±14.7	64.3±7.4	3.1	0.053
% of change	111%	103%	77%		
(P-value)	0.001*	0.001*	0.001*		

kg, kilograms; p, probability; Data are mean± SD, Statistical significance is indicated by a p-value < 0.05.

Table (4): post hoc test between three groups for post-treatment for Hamstring and Quadriceps strength

Q/H ratio	Group A vs. B	Group A vs. C	Group B vs. C
Mean difference	-0.44	-0.058	0.387
P-value	0.001*	0.999	0.001*

5. Discussion

This study's objective has been to compare the impacts of OKCE and CKCE on the Q/H ratio, muscle thickness of the quadriceps and hamstrings, and functional ability of the knee joint in knee OA. There have been statistically significant differences among the prior to and following treatment mean values of the US of the Quadriceps in the three groups ($p<0.05$). The pre- and post-therapy mean values of hamstring strength in groups A and B ($p< 0.05$) differed statistically significantly. There have been statistically significant differences between the before and after therapy mean values of the Q/H ratio in group B ($p=0.001$). There have been statistically significant differences among the before- and after-therapy mean values of WOMAC in the three groups ($p< 0.05$).

Our results concur with a study that **(9)** found a significant enhancement in outcomes after combined chain exercises. They attributed this improvement to increased quadriceps muscular strength, which improves knee joint stability. Data from the literature indicates that strengthening exercises can stimulate the β-endorphin system, which suppresses pain by reducing the binding and availability of μ-opioid receptors in the main brain areas involved in processing pain and rewards **(1o).** positively modifying the central nervous system's sensory input and the gate control mechanism (controlling the perception of pain) **(11)** and enhancing the flow of blood and nutrition for cartilage **(12)**.

According to another study, OKCE, CKCE, and CCE are all successful in enhancing muscle strength as well as muscle thickness in knee OA patients. As a result, the findings indicate that all three exercise regimens may be utilized independently to improve quadriceps muscle performance and function in this patient group. Nevertheless, given the proportion of trial dropouts, the findings ought to be interpreted with caution**. (13)**

There was a study that discovered that CKCE produced significantly greater quadriceps muscle strength in comparison to OKCE **(14)**

OKCE is superior for strengthening isolated quadriceps muscles, whereas CKCE facilitates co-contraction of other groups of muscles with bodyweight, offering extra resistance **(15)**.

The OKCE and CKCE used in this research are progressive resistance exercises that were recognized as a viable approach to increasing the muscles' capacity for generating force **(7),** explaining the significant gain in quadriceps muscle strength observed **(11).**

At weeks eight and twelve of the trial, OKCE, CKCE, and CCE group participants in Sale's 2003 study displayed significant enhancements in thigh girth. It was revealed that the first quick increase in skeletal muscle tension-generating ability during resistance exercise was mostly attributed to neural responses rather than adaptive muscular changes**. (16)**

In one research group **(17)**, it was found that adding isokinetic OKCE to CKCE in the 6th week following the start of the exercise in both groups generated significantly greater isokinetic quadriceps strength in comparison to the group that just possessed CKCE. Isokinetic strength training and evaluation, however, weren’t taken into account in the current research.

The fact that this study was a randomized control trial limits our ability to conclude causality. Second, we did not take into consideration other individual features, including knee alignment and inflammation, that may affect knee pain. The last limitation is the duration of the study, so there is a requirement for long-term and follow-up research for the comparison of the impacts of OKCE and CKCE on Q/H ratio, muscle

thickness of the quadriceps and hamstrings, and functional ability of the knee joint in knee OA.

Conclusion

CKCE in the treatment of KOA was found to be superior to OKCE in improving quadriceps ms. thickness, strength, and Q/H ratio. While OKCE was relatively superior to CKCE in improving hamstring thickness, strength, and function.

Reference:

1- Radha MS, Gangadhar MR. Prevalence of knee osteoarthritis in Mysore city, Karnataka. International Journal of Recent Scientific Research. 2015;6(4): (3316-3320).

2- Segal NA, Glass NA, Torner J, Yang M, Felson DT, Sharma L, Nevitt M, Lewis CE. Quadriceps weakness predicts risk for knee joint space narrowing in women in the MOST cohort. Osteoarthritis Cartilage. 2010;18(6): (769-75).

3- Cho,H.Y.,Kim,E.H.,Kim,J.,and Yoon, Y.W. Kinesio taping improves pain, range of motion, and proprioception in older patients with knee osteoarthritis: a randomized controlled trial. A Journal of physical medicine and Rehabilitation.2015;94(3) :(192-200).

4- Asgaonkar B, Bane J. Comparison of quadriceps to hamstring strength ratio in patients with osteoarthritis of the knee and healthy adults. Indian Journal of Physiotherapy and Occupational therapy.2019;13:(3).

5- McCarthy CJ, Oldham JA. The effectiveness of exercise in the treatment of osteoarthritic knees: a critical review. Physical Therapy Reviews. 2013;4(4): (241-250).

6- Bennell KL, Hinman RS. A review of the clinical evidence for exercise in osteoarthritis of the hip and knee. Journal of Sciences and Medicine in Sport. 2011;14:(4-9)

7- Van Dijk GM, Dekker J, Vennhof C, van den Ende CH. The course of functional status and pain in osteoarthritis of the hip or knee: a systematic review of the literature. *Arthritis & Rheumatology* 2006;55: (779-85).

8- Altman R, Hochberg M, Moskowitz R, Schnitzer T, American College of Rheumatology: recommendations for the medical management of osteoarthritis of the hip and knee. 2000 update. *Arthritis Rheum* 2000;43:(1905– 15.)

9- Olagbegi OM, Adegoke BOA, Odole AC. Effectiveness of combined chain exercises on pain and function in patients with knee osteoarthritis. Bangladesh Journal of Medical Science. 2016;15(2): (178-88).

10- Saanijoki T, Tuominen L, Tuulari JJ, et al: Opioid release after high-intensity interval training in healthy human subjects. Neuropsychopharmacology 2018; 43:246–54.

11- Marks R: Peripheral articular mechanisms of pain production in osteoarthritis. Aust J Physiotherapy 1992; 38:289–98.

12- Simkin PA, Hang A, Benedict RS: Effects of exercise on blood flow to canine articular tissues. J Orthop Res. 1990; 8:297–303.

13- Oladapo Michael Olagbegi, Babatunde Olusola Adegoke and Adesola Christiana Odole**.** Effectiveness of three modes of kinetic chain exercises on quadriceps muscle strength and thigh girth among individuals with knee osteoarthritis. Olagbegi et al. Archives of Physiotherapy, 2017. 7:9.

14- Daskapan A, Anaforoglu B, Pekyavas NO, Tuzun EH, Cosar SN, Karata M. Comparison of mini-squats and straight leg raises in patients with knee osteoarthritis: a randomized controlled

clinical trial. Turk J Rheumatol. 2013;28(1): (16–26)

15- Kisner C, Colby LA. Therapeutic exercises: foundations and techniques. Philadelphia: F.A. Davis Company; 2007.

16- Sale DG. Neural adaptation to strength training. In: Komi PV, editor. Strength and power in Sport. 2nd ed. Oxford: Blackwell Science; 2003.

17- Mikkelsen C, Werner S, Erikson E. Closed kinetic chain alone compared to combined open and closed kinetic chain exercises for quadriceps strengthening after anterior cruciate ligament reconstruction concerning return to sports: a prospective matched follow-up study. Knee Surg Sports Traumatol Arthrosc. 2000;8(6):337–42.