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# Effects of closed and open kinetic chain exercises on pain, muscle strength, function, and quality of life in patients with knee osteoarthritis

Anıl Özüdoğru[1]*, Nihal Gelecek[2]

## SUMMARY

**OBJECTIVE:** Therapeutic exercises are well documented for the treatment of osteoarthritis; there is less evidence on what the effect of closed kinetic chain exercises is for knee osteoarthritis. The aim of this study was to investigate the effects of open kinetic chain exercises and closed kinetic chain exercises on pain, muscle strength, functional status, and quality of life in patients with knee osteoarthritis.

**METHODS:** The study included a total of 60 patients with primary unilateral knee osteoarthritis grade I and II. The patients were categorized into three groups as open kinetic chain exercises (n=20), closed kinetic chain exercises (n=20), and control group (n=20). The outcome measures, including pain, isokinetic muscle strength, functional status, and quality of life, were collected at baseline and at the end of 6 and 12 weeks.

**RESULTS:** Closed kinetic chain exercises and open kinetic chain exercises had significant improvement in pain, muscle strength, WOMAC, and SF-36 scores after the treatment and at their 6th and 12th week follow-ups compared to their baseline values and compared to the control group ($p<0.05$).

**CONCLUSION:** The changes in all outcome measures were similar between closed kinetic chain exercises and open kinetic chain exercises ($p>0.05$). Closed kinetic chain exercises and open kinetic chain exercises were similar for knee osteoarthritis grade I and II. Closed kinetic chain exercises could be safely added to the exercise programs of patients with low-grade knee osteoarthritis.

**KEYWORDS:** Knee osteoarthritis. Weight bearing exercise program. Joint pain. Muscle strength. Functional status.

## INTRODUCTION

Knee osteoarthritis (OA) is an important and painful health problem as it leads to functional disability and reduced quality of life (QoL)[1]. Furthermore, knee OA is a significant cause of disability and accounts for 3% of all disability causes[2]. As OA leads to disability and consequent labor and economic loss[2], its treatment is of great importance. Studies have shown that knee OA is characterized by inadequacy and pain associated with decreased quadriceps muscle strength. Strengthening training and has been shown to have positive effects on OA[3]. OA treatment is classified under three headings as follows: pharmacological methods, non-pharmacological methods, and surgical methods[4]. There are several studies showing the effectiveness of exercise training as a non-pharmacological method[5] as it is an easy and low-cost method that can be done for a long time. Exercise training is more effective than other treatment methods in terms of increasing the physical activity level of patients and enhancing physiological improvements such as increased muscle strength, flexibility of soft tissues, and ROM[6].

In spite of numerous studies reporting the importance of different types of exercise in the treatment of knee OA, the literature on exercise programs with optimal gains for knee OA has not yet been established[7]. The focus of knee and hip rehabilitation exercises for degenerative diseases has gradually shifted from open kinetic chain exercises (OKCE) to closed kinetic chain exercises (CKCE), which are more functional and could be applied safely and effectively. In addition to increasing muscle strength, CKCE could also facilitate joint position sense[8]. Nevertheless, it seems that researchers frequently prefer OKCE to decrease symptoms of hip or knee OA instead of CKCE[9].

It is well known that CKCE increase muscle strength and improve proprioceptive function by activating more muscle spindle and joint proprioceptors, consequently preparing the patient for daily living activities as they simulate some activities such as walking, climbing stairs, or standing up from a chair[10]. In addition, CKCE allow early weight bearing and mobilization and are usually performed after anterior or posterior cruciate ligament injuries or reconstruction surgeries[11]. Some researchers emphasize that CKCE cause axial loading and consequently increase compressive and destructive stress on the joint structures particularly on cartilage tissue. Therefore, the results of studies about the effects of CKCE on OA are

[1]Kırşehir Ahi Evran University, School of Physical Therapy and Rehabilitation– Kırşehir, Turkey.
[2]Dokuz Eylül University, School of Physical Therapy and Rehabilitation – İzmir, Turkey.
*Corresponding author: aozudogru@hotmail.com
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controversial because some predict that CKCE cannot be easily tolerated or may increase symptoms in patients with hip or knee OA. The aim of this study was to investigate the effects of CKCE on the severity of knee pain and stiffness, isokinetic muscle strength, WOMAC functional scores, and SF-36 QoL scores in patients with knee osteoarthritis and compare them with the effects of OKCE.

## METHODS

### Participants

This study was carried out with a total of 60 patients with knee OA grade I and II according to the Kellgren-Lawrence classification. The participants, diagnosed with knee OA according to the radiographic assessment of their tibiofemoral joints by the same orthopedist, were randomly assigned to one of the three groups using an online random allocation software program.

The inclusion criteria were as follows: age between 45 and 75 years, diagnosed with unilateral knee OA grade I or II, and ongoing pain for at least 3 months. Patients with active synovitis, those who had participated in physiotherapy, conservative therapy, or regular exercise programs in the last 6 months, those who had undergone orthopedic surgeries in their knees, and those who were under medication (pain killers or NSAIDs) during the study were excluded from the study. Exclusion due to health problems at 6 and 12 weeks reveals other systemic health problems not related to exercise.

This study was approved by the Institutional Ethics Committee for Non-Invasive Human Research (ethical protocol number 05/2017), and in accordance with the policies and procedures of the Declaration of Helsinki, each participant provided verbal and written informed consent after being informed about the study.

### Interventions

The participants were randomly categorized into three groups: CKCE group (n=20), OKCE group (n=20), and control group (CG) (n=20). Patients in the CKCE and OKCE groups did exercises three times per week for a total of 12 weeks (the first 6 weeks under supervision and the second 6 weeks as progressive home exercise program). During the last 6 weeks, the patients in the CKCE and OKCE groups visited the physiotherapy department every 2 weeks for their exercise control and progression. Patients in the control group were asked to apply the home program three times per week for 12 weeks. Prepared by researchers, this program included standard OA exercises and was handed to the CG patients as printed brochures. As a home program, both the OKCE and CKCE groups were used together with the control group; ankle dorsiflexion/plantar flexion, active knee extension, hip adduction, heel slide, pelvic elevation, and hip adduction. Participants in the control group were checked for their participation in the exercise program via telephone.

*CKCE*: The patients in this group performed progressive "sit to stand, mini squat, anterior lunge and three-side step-up" exercises in a closed-chain position.

*OKCE*: The patients in this group performed "terminal knee extension, concentric quadriceps, and four-way straight leg rise" exercises as hip flexion, extension, abduction, and adduction. The exercise session lasted an average of 45 min including the warming and cooling phases.

### Outcome measures

*Pain severity*: Affected knee pain at rest was measured using visual analog scale (VAS)[12].

*Isokinetic muscle strength*: Although the isokinetic test is an open kinetic chain measurement, it is the gold standard in measuring muscle strength in patients with knee osteoarthritis[13]. For quadriceps and hamstring muscles, five repeated isokinetic muscle strength tests were performed at angular velocities of 90°/s, 120°/s, and 180°/s using an isokinetic testing device (Cybex System 4 Pro).

*Functional level*: As a valid and commonly used evaluation index in OA, the WOMAC index was used to evaluate the functional level of the patients[14].

*Joint stiffness*: The WOMAC index was used to evaluate the stiffness of the joints.

*Quality of life*: The Turkish version of the SF-36 was used to assess the QoL of the patients. This form includes 36 items and provides 8 dimensional measurements[15].

### Statistical analyses

Two-way ANOVA (mixed-model, 3 (time)×3 (group), repeated measures) was used to determine changes in dependent variables from baseline to posttreatment measurements.

## RESULTS

The study was completed with 60 patients. All groups had similar demographic and anthropometric characteristics ($p>0.05$) and baseline outcome measurements ($p>0.05$) (Table 1).

### Pain severity

For pain intensity, there was a significant effect of time observed in all groups according to statistical analysis ($p<0.05$). Post hoc

analyses revealed a significant difference in change for pain at rest between baseline values and after 6th and 12th week values for both intervention groups (p<0.05). But there was no significant difference between the OKCE and CKCE groups at 6 and 12 weeks (p>0.05) (Table 2).

### Isokinetic knee extension and flexion muscle strength

Knee extension and flexion muscle strength increased at the 6th and 12th week evaluations in both kinetic-chain groups. Yet, there was no change in the control group (p>0.05). For knee flexion and extension muscles isokinetic strength, there was a significant effect of time, with all groups showing an increase. There was also a significant time-group interaction. There was a significant difference between groups when groups were compared across various time points (p<0.05) (Table 3).

### Functional level

For WOMAC scores (pain, stiffness, and physical function), there was a significant effect of time, with all groups showing a decrease (lower values indicate improvement). There was also a significant time-group interaction. There was a significant difference between groups when the groups were compared across various time points (p<0.05) (Table 3).

### Quality of life

Post-intervention at the 6th and 12th week evaluations, no difference was found between OKCE and CKCE for pain severity, muscle strength, WOMAC scores, and SF-36 score (p>0.05). But there were significant differences between the control group and intervention groups after the 6th and 12th week values (p<0.05) (Tables 2 and 3).

## DISCUSSION

To conduct this study, 12-week-long CKCE and OKCE protocols were prepared for the patients with knee osteoarthritis. These two exercise protocols were investigated in terms of their effects on pain, isokinetic muscle strength, WOMAC functional scale, and QoL. The results of this study demonstrated that both protocols reduced pain and joint stiffness and improved isokinetic knee muscle strength as well as WOMAC and SF-36 scores after 6 and 12 weeks. In addition, these two types of kinetic-chain exercises were found to have similar effects on all outcome measures.

### Pain

Patients in the CKCE and OKCE groups, but not those in the control group, had a significant decrease in their knee pain by the end of the 6 and 12 weeks. In this study, the exercises in the closed kinetic chain position, which were performed with body weight from the first day, were carried out under a certain plan for 12 weeks and performed under supervision. Pain intensity in our patients in the CKCE group decreased in the third month at a similar rate to the OKCE group patients. The fact that the results of the CKCE program and the OKCE group were close suggested that the exercises given were aimed at the lower extremity, especially the muscles around the knee, and that the improvements in muscle strength and joint stability were similar.

**Table 1.** Comparison of groups' descriptive and demographic characteristics.

| | OKCE (n=20) X±SD | CKCE (n=20) X±SD | Control (n=20) X±SD | p-value |
|---|---|---|---|---|
| Age (years) | 53.05±10.88 | 54.40±7.92 | 56.10±12.73 | 0.667** |
| Height (cm) | 163.00±9.85 | 162.55±7.04 | 160.25±12.03 | 0.641** |
| Body weight (kg) | 79.40±13.35 | 75.85±13.49 | 76.40±12.98 | 0.410** |
| BMI (kg/m$^2$) | 30.05±5.55 | 28.93±6.27 | 29.45±6.28 | 0.854** |
| | | n (%) | n (%) | n (%) | p-value |
| Gender | Female | 11 (55) | 10 (50) | 9 (45) | 0.819* |
| | Male | 9 (45) | 10 (50) | 11 (55) | |
| Affected leg | Left | 10 (50) | 10 (50) | 9 (45) | 0.935* |
| | Right | 10 (50) | 10 (50) | 11 (55) | |
| Radiological assessment | Grade I | 3 (15) | 10 (50) | 8 (40) | 0.057* |
| | Grade II | 17 (85) | 10 (50) | 12 (60) | |

OKCE: open kinetic chain exercise group; CKCE: closed kinetic chain exercise group; BMI: body mass index; *Chi-square test; **Kruskal-Wallis test; X: mean; SD: standard deviation.

**Table 2.** Two-way mixed model ANOVA post hoc multiple comparison of participants' pain and muscle strength.

| Variable | Time frame | OKCE (n=20) Mean±SD | CKCE (n=20) Mean±SD | Control (n=20) Mean±SD | Time | | Group × time | |
|---|---|---|---|---|---|---|---|---|
| | | | | | F | p-value | F | p-value |
| Pain (VAS) 0–10 | Baseline | 5.31±0.86 | 4.87±1.24 | 5.26±1.13 | 81.075 | <0.001* | 18.248 | <0.001*# |
| | 6th week | 2.07±1.22 | 2.55±1.61 | 5.10±1.75 | | | | |
| | 12th week | 2.01±1.14 | 1.76±1.07 | 5.08±1.37 | | | | |
| 90°/s Extension (Nm) | Baseline | 62.02±14.31 | 57.59±14.83 | 63.46±10.94 | 189.817 | <0.001* | 597.661 | <0.001* |
| | 6th week | 76.57±15.59 | 69.67±16.56 | 64.06±11.03 | | | | |
| | 12th week | 76.79±15.24 | 70.17±16.39 | 64.48±11.72 | | | | |
| 120°/s Extension (Nm) | Baseline | 51.19±8.31 | 54.65±10.13 | 51.52±7.95 | 70.693 | <0.001* | 21.546 | <0.001*x |
| | 6th week | 59.08±9.99 | 61.14±11.19 | 51.21±8.25 | | | | |
| | 12th week | 58.34±10.76 | 60.72±11.75 | 50.98±8.56 | | | | |
| 180°/s Extension (Nm) | Baseline | 36.08±16.02 | 37.08±13.04 | 36.83±12.02 | 120.811 | <0.001* | 28.964 | <0.001* |
| | 6th week | 48.24±16.42 | 46.73±13.95 | 36.90±11.75 | | | | |
| | 12th week | 48.47±17.12 | 47.23±13.86 | 37.32±12.64 | | | | |
| 90°/s Flexion (Nm) | Baseline | 46.47±10.60 | 43.35±12.13 | 43.64±11.21 | 28.105 | <0.001* | 13.522 | <0.001* |
| | 6th week | 52.78±11.54 | 47.87±12.40 | 42.49±11.37 | | | | |
| | 12th week | 51.98±11.40 | 47.79±12.64 | 42.58±11.52 | | | | |
| 120°/s Flexion (Nm) | Baseline | 56.67±11.40 | 53.50±9.39 | 53.86±8.89 | 33.361 | <0.001* | 17.209 | <0.001*x |
| | 6th week | 64.61±12.90 | 57.83±10.06 | 53.26±9.16 | | | | |
| | 12th week | 63.92±11.54 | 56.72±10.58 | 57.62±11.44 | | | | |
| 180°/s Flexion (Nm) | Baseline | 61.44±13.68 | 58.82±15.26 | 57.57±12.66 | 2.080 | N.S. | 5.416 | <0.001* |
| | 6th week | 64.24±17.16 | 60.59±16.86 | 56.18±13.05 | | | | |
| | 12th week | 64.74±18.00 | 59.89±17.24 | 55.21±14.63 | | | | |

*Significant difference; CG: control group; N.S.: not significant; #significant difference with the control group; xSignificant difference between OKCE and CKCE.

## Muscle strength

There are several studies in the literature about progressive resistive exercises and muscle strength in knee OA, due to the fact that knee extensor and flexor muscle weakness increases the risk of knee osteoarthritis[16]. Although it is well known that CKCE and OKCE are both effective in improving quadriceps muscle strength in knee OA, there is no consensus regarding the comparative effectiveness of these two types of kinetic-chain exercises[17]. The effects on muscle strength can differ among studies depending on the duration, intensity, or number of sets of the exercises. In some studies, it has been shown that both types of exercises have similar efficacy; the others, however, report that CKCE has superior effects on muscle strength as it improves electromyographic activities on muscle fibers, particularly type IIB, and it also has large neural adaptive responses[18,19]. In contrast, there are a small number of studies about CKCE and knee or hip OA and research focusing on the effectiveness of CKCE in ligamentous injuries of the knee, particularly in young patients with ACL injuries or after reconstruction and patellofemoral pain syndromes[20-22]. Additionally, unlike CKCE, OKCE and combined exercises (OKCE and CKCE) have been well documented to improve quadriceps muscle strength in knee OA[19]. Similar to the results of our study, Olagbegi et al. reported that OKCE, CKCE, and combined exercises are similarly effective in improving quadriceps muscle strength in grade II knee OA.

In this study, 12-week-long OKCE and CKCE progressive exercise programs were planned for each patient with OA. Particular attention was paid to activate same muscle groups to keep the two exercise programs homogenous. As a result of the study, in the OKCE and CKCE groups, significant increases in muscle strength were observed in both knee flexors (hamstring muscles) and knee extensors (quadriceps muscles) compared to the control group. However, comparing the effects of OKCE and CKCE showed that the increase in muscle strength was similar at all angular velocities. Our patients with knee OA grade I and II could benefit from participation in exercise programs because their pain severity was moderate and not too high. These 12-week-long regular and supervised

**Table 3.** Two-way mixed model ANOVA post hoc multiple comparison of participants' physical function and quality of life scores.

| Variable | Time frame | OKCE (n=20) Mean±SD | CKCE (n=20) Mean±SD | Control (n=20) Mean±SD | Time | | Group × time | |
|---|---|---|---|---|---|---|---|---|
| | | | | | F | p-value | F | p-value |
| WOMAC Pain | Baseline | 9.70±4.15 | 8.90±4.27 | 10.15±3.66 | 27.984 | <0.001* | 10.519 | <0.001*# |
| | 6th week | 6.65±3.66 | 5.80±5.27 | 10.80±4.26 | | | | |
| | 12th week | 6.65±4.35 | 6.00±5.43 | 10.30±4.49 | | | | |
| WOMAC Stiffness | Baseline | 3.95±1.35 | 4.15±1.08 | 3.90±1.11 | 51.510 | <0.001* | 12.275 | <0.001*# |
| | 6th week | 2.30±1.08 | 2.50±1.31 | 3.85±1.42 | | | | |
| | 12th week | 2.35±1.38 | 2.55±1.27 | 3.90±1.88 | | | | |
| WOMAC Physical function | Baseline | 33.20±9.32 | 33.55±10.31 | 32.90±8.76 | 115.030 | <0.001* | 24.471 | <0.001* |
| | 6th week | 23.65±9.61 | 24.05±9.94 | 32.60±8.42 | | | | |
| | 12th week | 23.00±9.59 | 24.15±10.58 | 32.65±8.59 | | | | |
| SF-36 Physical Functioning | Baseline | 44.00±4.75 | 44.30±4.56 | 45.25±5.25 | 13.639 | <0.001* | 5.377 | <0.001*# |
| | 6th week | 52.75±11.41 | 54.80±12.57 | 44.50±9.58 | | | | |
| | 12th week | 52.00±14.81 | 55.05±15.71 | 43.25±11.72 | | | | |
| SF-36 Role Limitations (Physical) | Baseline | 11.50±11.36 | 16.00±11.42 | 13.00±9.23 | 56.00 | <0.001* | 114.00 | <0.033*# |
| | 6th week | 26.00±9.94 | 22.50±11.18 | 14.00±10.46 | | | | |
| | 12th week | 28.00±10.05 | 24.00±12.73 | 13.50±12.25 | | | | |
| SF-36 Pain | Baseline | 30.75±16.74 | 30.25±13.76 | 31.12±17.61 | 14.057 | <0.001* | 4.313 | <0.003*# |
| | 6th week | 49.50±25.75 | 49.00±19.62 | 30.05±20.04 | | | | |
| | 12th week | 48.25±23.84 | 49.62±27.91 | 29.25±21.38 | | | | |
| SF-36 General Health Perception | Baseline | 53.50±22.48 | 51.75±22.95 | 51.75±19.68 | 54.891 | <0.001* | 14.932 | <0.001* |
| | 6th week | 71.25±20.25 | 69.25±21.23 | 51.00±20.65 | | | | |
| | 12th week | 70.75±20.14 | 68.75±22.64 | 51.00±22.10 | | | | |
| SF-36 Mental Health | Baseline | 56.40±13.35 | 58.80±13.11 | 59.00±15.94 | 10.211 | <0.001* | 3.310 | <0.001*# |
| | 6th week | 73.20±9.97 | 69.40±9.20 | 59.20±6.43 | | | | |
| | 12th week | 68.80±11.50 | 62.20±14.76 | 58.80±7.00 | | | | |

*Significant difference; CG: control group; #significant difference with the control group.

exercise programs led to favorable physiological responses[23,24] and created positive changes on both neural, cellular, and hormonal elements, causing a similar increase in muscle strength.

## Functional level

Studies investigating the effects of OKCE and CKCE programs on functional levels, evaluated using the WOMAC index, have reported inconsistent results; while the effects of these two exercise types tend to be similar in some studies, others report benefits in favor of either of the programs.

Several studies in the literature report that exercise programs increase functional level in patients with knee OA[7,25]. According to the results of some studies, CKCE might be slightly more effective than the other therapeutic exercises and practices, since the CKCE exercises include weight transfer and are similar to functional daily activities such as sitting and stair climbing[9,26,27].

In this study, OKCE and CKCE had similar effects on the patients' functional levels. This may be because one of these programs was composed of resistive exercises, which—if performed regularly—can lead to improvements in neuromuscular system and proprioceptive structures by stimulating mechanoreceptors. The other reason can be the fact that OKCE and CKCE programs can reduce knee extensor limitation and increase quadriceps muscle strength, which decrease joint stiffness, knee flexion contracture, or imbalance of the knee muscle strength.

## Quality of life

OA plays a dramatic role in decreasing the quality of the patients' lives as it causes physical, psychological, and social impairments associated with inactivity and pain. Although exercise programs for knee OA have been reported to improve QoL by improving variables such as pain, stiffness, joint stability, or

the functional status of patients, many studies have not evaluated QoL. The other power of this study was that we did assess QoL using SF-36 scale, and we wanted to determine whether CKCE or OKCE could change physical, mental, and social health parameters or not.

There is no consensus regarding the exercise type that could improve all parameters of QoL in patients with knee OA.

Each subparameter of the SF-36 questionnaire was assessed separately within and between groups. Regular and supervised OKCE and CKCE programs increased the QoL in patients with knee OA. Both exercise groups improved in the subparameters of "physical function," "pain," "general health perception," and "mental health," but not in the subparameter of "role limitations." Changes in the musculoskeletal and neuromuscular system and a decrease in pain intensity increased the physical capabilities of the patient, and this may have been reflected in some subparameters of QoL.

### Clinical implication of this study

The results of the present study indicated that, similar to OKCE or combined exercise programs, progressive resistive CKCE can be safely applied in patients with grade I and II knee OA. This study also suggests that, similar to OKCE programs, CKCE programs can also be easily tolerated by the patients. Both types of kinetic-chain exercise regimes decrease knee pain and stiffness and improve muscle strength, functional status, and QoL of the patients. A key strength of the current study was including a control group that was also evaluated at baseline, 6th week, and 12th week. It helped to clearly demonstrate the pure effects of the CKCE and OKCE programs by eliminating control group effects.

### Limitations and strengths of the study

Patients with knee OA tend to discontinue their exercise programs particularly when their pain decreases or their daily living activities improve. Similarly, this study was limited by the absence of long-term follow-ups such as 6 months or 1 year. Another limitation of the present study was that the physiotherapists—as the evaluators—were not blind to the groups, although the researchers are academic staff and did their best to minimize assessment-related bias.

On the contrary, the strongest aspect of our study is that both middle-aged and older patients with knee OA in our CSCE and CSCE program groups complete regular, supervised programs for the first 6 weeks, frequent control for the last 6 weeks, and exercise progression, with a daily appointment system. In addition, exercise programs were created homogeneously for all groups.

## CONCLUSION

This study demonstrates that in patients with knee OA, both OKCE and CKCE are effective in reducing knee pain and stiffness and in improving isokinetic muscle strength, WOMAC, and SF-36 scores. It also indicates that the beneficial effects of regular and supervised CKCE or OKCE programs outweigh those of unsupervised home exercise programs. It is recommended that future studies investigate the effects of the CKCE and OKCE programs over a longer period of time.

## AUTHORS' CONTRIBUTIONS

**AÖ:** Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Resources, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. **NG:** Conceptualization, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing.

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