

Effectiveness of Open Kinetic Chain Exercises Versus Closed Kinetic Chain Exercises in Individuals with Extension Lag Post-Total Knee Replacement

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Abstract:

➤ *Background:*

Total knee replacement (TKR) is one of the most popular surgical procedures performed on patients with severe knee arthritis, and knee extension lag is a common complication. Extension Lag is the inability to extend the knee to the final 15 degrees of extension.

The study's goal is to investigate and compare the effectiveness of a six-week open and closed kinetic chain exercise on pain and range of motion in people with knee extension lag after TKR.

➤ *Study Design:*

Comparative Study.

➤ *Methods:*

In a 6-week intervention study, 30 older individuals underwent total knee replacement. The subjects were divided into two groups: Group A received Open Kinetic Chain Exercises, and Group B received Close Kinetic Chain Exercises, with Conventional Exercise remaining the same for both groups for 6 weeks. The Universal Goniometer is used to quantify knee range of motion, while the Visual Analogue Scale is used to assess discomfort. Pre- and post-treatment data were gathered and analysed using SPSS 22.0. The Paired T-Test was used to determine the significance of the treatment.

➤ *Results:*

Close Kinetic Chain Exercise Can Be Used alongside a Conventional Exercise Program to effectively manage individuals with Extension Lag Post Total Knee Replacement in terms of pain reduction and correction. Group B showed greater pain reduction ($P < 0.05$) than Group A after treatment.

➤ *Conclusion:*

The study concluded that the treatment plan used by Group B, Close Kinetic Chain Exercise with Conservative Exercise, is more successful in minimising Extension lag in post-total knee replacement patients than Group A, Open Kinetic Chain Exercise with Conservative Exercise.

Keywords: Total Knee Arthroplasty, Extension Deficit, Closed kinetic Chain Exercise, Open Kinetic Chain Exercise.

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I. INTRODUCTION

Total knee replacement (TKR), often called total knee

arthroplasty (TKA), is one of the most popular surgical procedures used for managing advanced knee osteoarthritis. It is generally considered as the standard treatment for people

with severe and debilitating knee arthritis. (1) In 2010, around 650,000 TKR procedures were performed in the United States alone, with a projected increase to nearly 3.5 million by 2030. (2)

Despite the major goals of TKR (pain reduction and improved long-term function), many patients continue to experience postoperative deficits. Patients who have TKR typically experience chronic functional impairments when compared to healthy, age-matched individuals. Quadriceps weakness and delayed activation are two of the primary causes of postoperative activity limitations. Quadriceps strength may decline by up to 60% after surgery, underscoring the importance of targeted quadriceps activation during recovery. (3) Quadriceps weakness can be caused by various factors such as discomfort, disuse, and joint disease. Chronic knee pain frequently reduces muscle activation, which leads to functional weakness and extension lag. (4)

After TKA, extension lag is a common postoperative Complication. In addition, these individuals may have diminished quadriceps activation, decreased knee joint range of motion (ROM), and pain surrounding the knee joint, all of which make it more difficult to achieve complete knee extension. (5) From a physiological perspective, a muscle that contracts concentrically produces less peak tension as it gets shorter. In a similar vein, a muscle that contracts isometrically becomes weaker as it contracts at increasingly shorter lengths. This disorder, known as "active insufficiency," arises when shortened muscles are unable to produce appropriate actomyosin cross-bridges. One symptom of active insufficiency is thought to be muscle lag. (6) Disorders such as aberrant muscle lengthening, disuse atrophy, myopathy, neurological impairments, or pain-induced muscular inhibition can also cause pathological muscle lag. (6).

The inability to achieve the last 15 degrees of active knee extension while having complete passive extension is known as extension lag. The last 20 degrees of knee extension demand about 80% of quadriceps strength. One of the main objectives of physical therapy for patients after TKR is to manage extension lag. The term "extension lag" is favoured over "quadriceps lag" since the limitation may be caused by variables other than only quadriceps function, such as joint mechanics and discomfort. (7) Muscle strength declines when a muscle remains inactive for prolonged periods, but it improves gradually with constant resistance training. (8) Various rehabilitation approaches are shown to be beneficial in improving strength and function post TKR, including strengthening exercises, proprioceptive training, balance activities, and open and closed chain exercises. (9,10)

Resistance training following TKR frequently combines both open kinetic chain (OKC) and closed kinetic chain (CKC) exercises. (11) Closed kinetic chain workouts occur when the distal segment is fixed, resulting in synchronised action across numerous joints. For instance, squatting results in simultaneous bending of the hip, knee, and ankle. These exercises are useful for functional strengthening because they improve joint stability and encourage co-contraction of

adjacent muscles. (8) Open kinetic chain workouts, on the other hand, include free movement of the distal section while the proximal segment remains stationary. These exercises isolate muscles operating across a single joint and are especially effective for strengthening specific muscle groups, particularly the quadriceps. (12) CKCE increase co-activation and functional load-bearing, whereas OKCE focus on independent muscle strengthening. (13) OKCE is crucial in early-stage rehabilitation when ROM is restricted, even though CKCE is thought to be more useful. (14) While several studies have compared OKC and CKC workouts in terms of quadriceps strengthening, relatively few have specifically investigated their usefulness in treating postoperative extension lag. (14) This gap underscores the need for specific research to determine which exercise strategy is more helpful for minimising extension lag in persons undergoing TKR.

II. MATERIALS AND METHODS

The research design used for this investigation was an interventional study. Convenience sampling was applied to identify the study population, which consisted of patients with knee extension lag following total knee replacement (post-TKR). A total of 30 people were enrolled in the investigation. Group A included 15 participants who did open kinetic chain exercises, while Group B had 15 people who did closed kinetic chain activities. The study was conducted at Nootan College of Physiotherapy, Ortho OPD 1, Visnagar, Gujarat (384315). The trial lasted 6 months, with each participant receiving therapy for 6 weeks.

➤ Inclusion Criteria:

- Both male and female participants
- Age between 50–75 years
- Individuals presenting with knee extension lag after undergoing TKR
- Individuals who were 11±2 days to 1-month post-TKR (15)
- Positive active and passive lag test

➤ Exclusion Criteria:

- Individuals with an extension lack
- Presence of any healing fractures
- Individuals with severe cardiopulmonary disease (7)
- Surgical complications following TKA (7)
- Hip pathology (7)
- Individuals diagnosed with neoplasms or neurological disorders affecting the lower limb (16)

After receiving ethical approval from the institutional ethics committee, all subjects had a comprehensive orthopaedic evaluation. The assessment included demographic information, a medical history, pain evaluation using the visual analogue scale (VAS), knee range of motion (ROM), special tests such as active and passive lag tests, investigation reports, and an assessment of functional activities. After being instructed on the study's objectives and

methodology, participants who met the inclusion criteria were asked to sign a written consent form. Following that, the participants were separated into two groups. Group A received five closed kinetic chain workouts per week, while

group B received five open kinetic chain activities per week.

➤ *Intervention Design [For 6 Weeks (4 Sessions/Week)*

Table 1 Group A (OKCE)

WEEK	EXERCISE	REPETITION
Week 1	<ul style="list-style-type: none"> • Knee extension in high sitting • Last-degree knee extension on the bolster <ul style="list-style-type: none"> • Straight leg raising • Hamstring curls 	(10 repetitions, 4 sets)
Week 2	<ul style="list-style-type: none"> • Knee extension in high sitting • Last-degree knee extension on the bolster <ul style="list-style-type: none"> • Straight leg raising • Hamstring curls 	With Minimal Resistance (10 repetitions, 4 sets)
Week 3	<ul style="list-style-type: none"> • Knee extension in high sitting • Last-degree knee extension on the bolster <ul style="list-style-type: none"> • Straight leg raising • Hamstring curls 	With Maximal Resistance (10 repetitions, 4 sets)
Week 4-6	<ul style="list-style-type: none"> • Knee extension in high sitting • Last-degree knee extension on the bolster <ul style="list-style-type: none"> • Straight leg raising • Hamstring curls 	With Maximal Resistance (10 repetitions, 4 sets)



Fig 1 Knee Extension in High Sitting



Fig 3 Straight Leg Raising



Fig 4 Quadriceps Isometric

Table 2 Group B (Close Kinetic Chain Exercise)

WEEK	EXERCISES	REPETITIONS
Week 1	<ul style="list-style-type: none"> • Half Squats • Step-up and step-down (Low step with 2-3 inches in height) • Forward lunges 	(10 repetitions, 4 sets)
Week 2	<ul style="list-style-type: none"> • Half squats • Forward lunges • Step up and step down (weight added in both hands with dumbbells) • Wall slides 	With Minimal Resistance (10 repetitions, 4 sets)
Week 3	<ul style="list-style-type: none"> • Half squats with weight • Forward lunges • Wall slides (Knee flexion up to 60 degrees) • Step-up and step-down 	With Maximal Resistance (10 repetitions, 4 sets)
Week 4-6	<ul style="list-style-type: none"> • Mini-squats with weight • Step-up and step-down, forward and backward step-ups and step downs • Wall slides (up to 60 degrees of knee flexion) • Forward lunges 	With Maximal Resistance (10 repetitions, 4 sets)



Fig 5 Half Squats



Fig 7 Forward Lunges



Fig 6 Step Up and Down



Fig 8 Wall Slides

Table 3 Conservative Exercise for Both Group

WEEK	EXERCISE	REPETITION
Week 1-6	<ul style="list-style-type: none"> • Ice pack • Calf and hamstring stretching • Quadriceps Isometric 	(Every 4 hours) (15-sec hold, 5 reps) (10 repetitions, 4 sets)

➤ *Data Collection Procedure:*

Data will be collected during the session and at the end of the six-week training period. A follow-up will be conducted in 6 months. The participants had a thorough pre-evaluation to acquire information about demographics, examination, and functional outcomes.

➤ *Outcome Measure:*

Range of Motion Visual Analogue Scale.

➤ *Statistical Analysis:*

Data were tabulated and analysed using SPSS 22.0 software for Windows, including paired and unpaired t tests. Treatment resulted in considerable improvement ($p < 0.05$) in terms of increased range of motion and reduced pain.

➤ *Results:*

The study comprised thirty individuals in all, who were split equally into two groups. Both group A (OKCE) and group B (CKCE) revealed significant reductions in discomfort and knee extension lag after the 6-week intervention. Group A's mean pre-treatment VAS score dropped from 3.13 to 0.60, while group B's dropped from 2.27 to 0.33. Both groups experienced significant pain reduction, with group B exhibiting a marginally greater improvement. In a similar vein, both groups' knee extension range of motion increased; group A's extension lag decreased from 13.2° to 2.73°, while group B's improved from 12.0° to 1.6°. Although both interventions were effective, group B achieved comparatively better final outcomes in terms of pain reduction and near-complete restoration of knee extension.

Table 4 Intragroup Comparison of Pre-Post-Treatment of Both Groups

Outcome measure	Group A				Group B				
	Pretreatment Mean (SD)	Post treatment Mean (SD)	t value	p-value	Outcome measure	Pretreatment Mean (SD)	Post treatment Mean (SD)	t value	p-value
Range of Motion	13.2±2.51	2.73±1.38	19.96	0.00	Range of Motion	12.00±2.420	1.60±1.54	19.52	0.00
Visual Analogue Scale	3.13±2.15	0.6±1.38	11.76	0.00	Visual Analogue Scale	2.277±0.88	0.33±0.48	12.61	0.00

III. DISCUSSION

This study aimed to determine if closed kinetic chain activities were more beneficial than open kinetic chain workouts for increasing knee range of motion in people with extension lag after total knee replacement. The main causes of knee extension lag, a common postoperative problem in patients following total knee replacement, are weak quadriceps and hindered active knee extension. Approximately 80% of quadriceps strength is required to complete the final 20 degrees of knee extension, making targeted rehabilitation critical for recovery. Several physiotherapy methods have been proven to be useful in addressing extension lag, including strength training, functional exercises, proprioceptive training, and both open and closed kinetic chain exercises. Lieber (1993) states that muscle shortening impairs the formation of actin–myosin cross-bridges, which lowers force output and causes active insufficiency, which might show up as muscle lag. The necessity of therapies that encourage the best patterns of muscle activation and loading is further supported by this physiological basis. Olagbegi et al.'s earlier study showed that closed kinetic chain exercises greatly enhanced functional results and balance confidence in patients after total knee arthroplasty when paired with conventional physiotherapy. According to their findings, compared to solitary exercise methods, CKC exercises may encourage more effective neuromuscular control and functional loading.

The findings of the current investigation are consistent with this data. The increased efficiency of CKC exercises may be explained by their incorporation of weight-bearing, co-contraction around the knee, and engagement of several

joints and muscles. In contrast, open kinetic chain workouts generally isolate the knee extensors and provide modest functional loads. OKC exercises may be less successful in meeting the functional demands necessary for full knee extension during daily activities, even though they are still helpful for isolated quadriceps strengthening.

Both groups in this trial underwent conservative workouts for six weeks of treatment. When compared to group A, group B, which engaged in closed kinetic chain workouts, showed more improvements in functional activities, knee extension range of motion, and pain reduction. The findings indicate that CKC exercises provide a more effective approach for reducing extension lag and enhancing postoperative recovery in individuals after TKR.

The statistical analysis demonstrated considerable improvements within both groups; however, group B consistently outperformed group A in all assessed outcomes. This supports the adoption of the alternative hypothesis (H11), confirming that closed kinetic chain workouts are more effective than open kinetic chain activities in improving knee extension, lowering discomfort, and enhancing functional performance in patients with extension lag post-TKR.

➤ *Limitation*

- The sample size was small.
- Samples were taken from Visnagar
- The trial intervention lasted only 6 weeks, which is shorter than expected.

➤ *Suggestions and Recommendations*

- A larger sample size is necessary for future research.
- The study can have a longer treatment period.
- Long-term follow-up is feasible for this investigation.
- Additional studies with varying outcomes can be conducted using the same intervention.

IV. CONCLUSION

The study concluded that the treatment regimen used by Group B, Close Kinetic Exercise with Conservative Exercise, is more effective in reducing Extension lag in post-total knee replacement patients than Group A, Open Kinetic Chain Exercise with Conservative Exercise.

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