

## Original Research Article

### **The effect of multi-angle isometric quadriceps exercise on pain and dynamic balance after total knee arthroplasty – a randomised controlled trial**

#### **Abstract**

##### Purpose

A decline in maximal quadriceps strength and dynamic balance is observed in patients with knee osteoarthritis, and may influence the prognosis of Total Knee Arthroplasty (TKA). The objective of this study is to identify the effectiveness multi-angle isometric quadriceps exercise in improving pain, dynamic balance, and function after TKA.

##### Methods

A randomised controlled trial was undertaken, recruiting 20 patients who underwent TKA and who fulfil the study criteria. The participants were randomly divided into two groups, Group I (experimental) receiving multi-angle isometric quadriceps exercises along with conventional physiotherapy, whereas Group II (control) received conventional physiotherapy alone. The treatment was provided twice daily for three weeks. The pain levels using Visual Analogue Scale, dynamic balance using Timed Up and Go test, and active knee flexion range of motion using Goniometer was assessed before the first treatment session, and after three weeks of treatment. The statistical analysis was performed using Student's t test.

##### Results

Significant improvements were observed for pain, dynamic balance, and knee flexion range of motion post intervention in both groups. However, the improvements were higher in the experimental group than that of controls when comparing the mean difference of outcomes.

##### Conclusion

From this study it was concluded that the multi-angle isometric quadriceps exercise improves pain, dynamic balance, and knee flexion range of motion in patients who underwent total knee arthroplasty.

Key Words

Balance, Isometric Exercise, Pain, Range of Motion, Total Knee Replacement

## **INTRODUCTION**

Osteoarthritis is a degenerative joint disease, occurring primarily in older person, characterized by erosion of the articular cartilage, hypertrophy of bone at the margins i.e., osteophytes, subchondral sclerosis, and a range of biochemical and morphologic alteration of the synovial membrane and joint capsule (1). Osteoarthritis is a common disease associated with significant morbidity. This is particularly apparent at the knee joint, one of the commonest sites to be affected. As prevalence of osteoarthritis increases with age and aging is associated with decreasing physiological function, the combination has major health implications (2).

Total knee arthroplasty is one of the most common and successful orthopaedic surgeries in the treatment of end-stage knee osteoarthritis. In 2013, over 60,000 total knee arthroplasty surgeries were performed in India annually (3). Dramatic reductions in knee pain and increased functional performance enhance quality of life after total knee arthroplasty. Acute impairments in pain, swelling, joint stability, range of motion, and patellar mobility are common following total knee arthroplasty. In addition, patients exhibit a 60% reduction in quadriceps strength, 17% reduction in walking speed and 50% reduction in stair-climbing speed post-surgery (4).

Dynamic balance and maximal quadriceps strength declines with age and may be even more impaired in patients with knee osteoarthritis. Proprioceptive information is derived from afferents in the muscles, ligaments, capsule, menisci and skin to arthrokinematic and muscle reflexes which play an integral role on knee joint stability (5). Balance is controlled by sensory input from the vestibular, visual and somatosensory system, central processing and active motor responses from muscles to remain the centre of mass within the base of support (6).

Quadriceps is one of the most important muscles surrounding the knee joint and its function has a crucial role in balance, stability of the knee and functional activities. Quadriceps weakness potentially could contribute to increased impulse loading of the knee joint (7). The quadriceps muscle is the primary dynamic stabilizer of the knee in sagittal plane. Therefore it is possible that weakness of the quadriceps, either absolute or relative to the hamstrings may adversely redistribute compressive and shear stress at the knee joint (7). Isometric exercise defined as the “exercise in which a muscle contracts and produces force without an appreciable change in length of the muscle and without visible joint motion” (8). The isometric exercise improves the quadriceps strength by either to a learning effect or increased activation of the muscle as a result of changes in the motor unit firing patterns. Isometric exercise improves muscle strength only at the joint angle at which the training takes place (9).

Strengthening of knee musculature is thought to play a significant role in restoring stability of the knee joint, in turn improving the dynamic stability (10). Multi-angle isometric is exercise in which a muscle contracts in different angles and produces force without an appreciable change in length. Multi-angle isometric exercises have been used in persons with orthopaedic problems to improve the dynamic balance and range of motion and it increases strength in quadriceps muscle (11). Paucity in literature exist regarding the effect of this exercise regime

in patients with TKA. The objective of this study is to identify the effectiveness multi-angle isometric quadriceps exercise in improving pain, dynamic balance, and function in patients who underwent TKA.

## **METHODS**

A randomised controlled trial was undertaken in our institution for testing the hypothesis. The study was conducted between December 2013 and March 2014. The study criteria for recruitment of the participants is as follows;

### *Inclusion Criteria*

- Patients who underwent unilateral total knee arthroplasty – Day 3 or 4
- Patients of age between 55 and 75 years, both male and female
- Patients who had uneventful recovery post-surgery and shifted to ward/room
- Patients who can perform Timed Up and Go test with or without walking aids under supervision

### *Exclusion Criteria*

- Patients with associated neurological, respiratory, or cardiovascular conditions limiting exercise performance
- Patients who had any post-operative complications, unstable, or not co-operative
- Patients who are not willing to participate in the study

Those who fulfil the study criteria and are willing to participate in the study were explained regarding the procedure and the signed informed consent was obtained from them. Patients were then randomly divided into two groups using lottery method, and the allocation was concealed using opaque envelopes. Group I received experimental protocol and Group II received control protocol. The participants were blinded whether treatment they received is

experimental or control protocol. The interventions were provided twice daily, and for three weeks by an investigator who is a physiotherapist trained in musculoskeletal management. The protocols are detailed in Table 1. An investigator who was blinded to the allocation did the assessment of outcome measures before the interventions, and after three weeks of treatment.

For multi-angle isometrics, the patient is instructed to perform the exercise in five different angles. In supine lying the patient is asked to do the isometric quadriceps exercise in  $0^{\circ}$ ,  $30^{\circ}$ ,  $45^{\circ}$ ,  $60^{\circ}$ , and  $90^{\circ}$  of knee flexion. Therapists' hand is placed over the lower end of tibia. Patient is then asked to contract the quadriceps for ten seconds and relax for four seconds. The patient is instructed not to hold the breath. The exercise is repeated 10 times. All other active exercises were performed with 10 repetitions.

The pain level of the patients were assessed using Visual Analogue Scale, and rated between a score of zero to ten, zero being no pain and ten being the worse pain. The dynamic balance of the participants were assessed using Timed Up and Go test, and measured in seconds. The active knee flexion range of motion was assessed in supine lying using handheld Goniometer.

Independent t test analysis was used to assess significant difference between groups and paired t test analysis was performed to assess significant difference within groups. Descriptive statistics was used to report demographic parameters. The statistical analysis of the data was performed using Statistical Package for Social Sciences [SPSS] for Windows version 22.0 released 2013 Armonk, NY: IBM Corporation.

## **RESULTS**

A total of 20 participants were recruited and was equally randomised into two groups. The mean age of participants were  $62.1 \pm 5.2$  years. There were 14 males and 6 females in the

study population. Table 2 depicts the pre and post-intervention assessment of outcome measures.

Statistically significant improvements were observed for all outcomes after the intervention in both groups ( $p < 0.05$ ). However, Group I demonstrated higher mean difference when compared to Group II, showing a better prognosis with experimental protocol when compared to conventional exercises. There were no adverse effects or loss to follow-up reported during the study period.

## **DISCUSSION**

Total knee arthroplasty (TKA) has evolved towards a reliable and long-lasting surgical procedure, offering pain relief and improved function to many patients who suffer from degenerative arthritis of the knee. Improvements in surgical technique and prosthesis design continue to enhance long-term outcomes (12). The ability to restore mobility without pain and limping in more than 90% of cases has led surgeons to offer this operation to younger patients (13). Instability and limited range of motion are listed as important limiting factors to normal function, even in patients with a well-functioning TKA.

The current study evaluated the effectiveness of multi-angle isometric quadriceps exercise in improving pain and dynamic stability after total knee arthroplasty. The results suggest that the multi-angle isometric quadriceps exercise has a better effect in improving pain and dynamic stability compared to conventional treatment protocols.

Individuals with end-stage knee osteoarthritis have quadriceps weakness prior to total knee arthroplasty. Following surgery, quadriceps weakness becomes more profound and does not recover to the level of healthy adults. Quadriceps weakness has potential to impact function greatly, as quadriceps strength is related to stair climbing ability, gait speed, chair

rise ability, and risk for falling (14). The quadriceps strength decreases by as much as 60%. The mechanism for this profound, acute decrease is primarily explained by deficits in quadriceps voluntary activation rather than atrophy. This significant reduction of pain may be due to the maximal isometric voluntary contraction of the quadriceps and the hamstring muscles, aiding in the release of the endorphins, thus increasing the pain threshold through the descending suppression pathway (15).

The increase in range of motion can be due to greater level of activation or recruitment of motor units at different angles (16). Large fast motor units are recruited at higher forces and it is possible that during maximal voluntary contractions there are some units that are never recruited in the untrained state. Training is therefore seen as a way of facilitating the recruitment of these large and fast motor units (17). The time taken for the Timed Up and Go Test is reduced in both the groups, the improvement can be due to the neural adaptation occurred with exercises. The first possibility arises from the fact that quadriceps composites of a number of separate muscles. The different muscles may have different joint angles thereby extending the useful working range of the muscle group, so that the training response would appear to be maximal at the angle corresponding to the optimal length of the individual muscle (18). The second possibility arises as a result of a change in length of the muscle fibres. If the training were to be carried out at either very long or very short fibre lengths, where the forces generated were well below the maximum, then either a lengthening or shortening of the muscle might occur by the addition or loss of sarcomeres at the ends of the muscle fibres (19).

Physiologically, exercise may also result in endocrine, paracrine or autocrine responses that stimulate muscle growth (20). It is unlikely that endocrine changes are the major stimulus since hypertrophy is often limited to a single muscle group on one side of the body. Nevertheless a certain concentration, or pattern of release, of hormones such as insulin, growth hormone or testosterone, may have permissive action acting in conjunction with local

changes associated with the working muscles (21). Localized changes in paracrine hormones such as insulin-like growth factor-1 may be very important in regulating tissue growth (22). Therefore the short duration intervention of multi-angle isometric quadriceps exercise has significantly reduced the pain and increased the joint range of motion and dynamic stability.

The study poses few limitations. The sample population was small, limiting the generalisation of the results. We did not assess the muscle strength before and after intervention due to non-availability of resources. Long term follow-up of the experimental protocol, with advanced assessment equipments may help in exploring the mechanism of improvement and sustained benefits with multi-angle isometric quadriceps exercise.

## **CONCLUSION**

The study identified that multi-angle isometric quadriceps exercise improves pain, dynamic balance, and knee flexion range of motion in patients who underwent total knee arthroplasty, and found to be superior to conventional treatment protocols.

## **REFERENCE**

1. Loeser RF, Goldring SR, Scanzello CR, Goldring MB. Osteoarthritis: A disease of the joint as an organ. *Arthritis Rheum.* 2012 Jun;64(6):1697–707.
2. Mondam S, Babu S, Kumar R, Prakash J. A Comparative Study of Proprioceptive Exercises versus Conventional Training Program on Osteoarthritis of Knee. *Res J Recent Sci.* 2012;1(12):31–5.
3. Vaidya S V., Jogani AD, Pachore JA, Armstrong R, Vaidya CS. India Joining the World of Hip and Knee Registries: Present Status—A Leap Forward. *Indian J Orthop.* 2021 May 16;55(S1):46–55.

4. Thomas AC, Stevens-Lapsley JE. Importance of Attenuating Quadriceps Activation Deficits After Total Knee Arthroplasty. *Exerc Sport Sci Rev.* 2012 Apr;40(2):95–101.
  - Abulhasan JF, Grey MJ. Anatomy and physiology of knee stability. *J Funct Morphol Kinesiol.* 2017;2(4).
5. MacKinnon CD. Sensorimotor anatomy of gait, balance, and falls. *Handb Clin Neurol.* 2018;159:3–26.
6. Segal NA, Glass NA, Torner J, Yang M, Felson DT, Sharma L, et al. Quadriceps weakness predicts risk for knee joint space narrowing in women in the MOST cohort. *Osteoarthr Cartil.* 2010 Jun;18(6):769–75.
7. Levangie PK, Norkin CC. *Joint Structure & Function: A Comprehensive Analysis.* 4th ed. Philadelphia: FA Davis; 2005.
8. Manske RC, Reiman MP. Muscle Weakness. In: *Physical Rehabilitation.* Elsevier; 2007. p. 64–86.
9. Mizner RL, Petterson SC, Snyder-Mackler L. Quadriceps Strength and the Time Course of Functional Recovery After Total Knee Arthroplasty. *J Orthop Sport Phys Ther.* 2005 Jul;35(7):424–36.
10. Anwer S, Alghadir A. Effect of Isometric Quadriceps Exercise on Muscle Strength, Pain, and Function in Patients with Knee Osteoarthritis: A Randomized Controlled Study. *J Phys Ther Sci.* 2014;26(5):745–8.
11. Leopold SS. Minimally Invasive Total Knee Arthroplasty for Osteoarthritis. *N Engl J Med.* 2009 Apr 23;360(17):1749–58.
12. Bhatia D, Bejarano T, Novo M. Current interventions in the management of knee osteoarthritis. *J Pharm Bioallied Sci.* 2013;5(1):30.
  - Schroeder MJ, Acuña SA, Krishnan C, Dhaher YY. Can Increased Locomotor Task Difficulty Differentiate Knee Muscle Forces After Anterior Cruciate

Ligament Reconstruction? J Appl Biomech. 2022;38(2):84–94.

13. Shakoor MA, Rahman MS, Azad AK, Islam MS. Effects of isometric quadriceps muscle strengthening exercise on chronic osteoarthritis of the knee. Bangladesh Med Res Counc Bull. 2010 Jul 17;36(1):20–2.
14. Paul J, Balakrishnan P. Effect of isometric quadriceps strengthening exercise at multiple angles in knee joint among normal adults. Int J Physiother. 2014;1(1):10–6.
  - Maclennan RJ, Mota JA, Thompson BJ, Stock MS. Effects of Strength and Conditioning on Maximal Isometric Strength, Motor Unit Behavior, and Concentric Isokinetic Peak Torque in Middle-School Boys?. J Strength Cond Res. 2022;36(5):1318–26.
15. Azegami M, Yanagihashi R, Miyoshi K, Akahane K, Ohira M, Sadoyama T. Effects of Multi-Joint Angle Changes on EMG Activity and Force of Lower Extremity Muscles during Maximum Isometric Leg Press Exercises. J Phys Ther Sci. 2007;19(1):65–72.
  - Mahmoud WS, Elnaggar RK, Ahmed AS. Influence of Isometric Exercise Training on Quadriceps Muscle Architecture and Strength in Obese Subjects with Knee Osteoarthritis. Int J Med Res Heal Sci [Internet]. 2017;6(3):1–9
16. Hoffmann C, Weigert C. Skeletal Muscle as an Endocrine Organ: The Role of Myokines in Exercise Adaptations. Cold Spring Harb Perspect Med. 2017 Nov;7(11):a029793.
17. Moller N, Jorgensen JOL. Effects of Growth Hormone on Glucose, Lipid, and Protein Metabolism in Human Subjects. Endocr Rev. 2009 Apr 1;30(2):152–77.
  - Ahmad SS, Ahmad K, Lee EJ, Lee YH, Choi I. Implications of Insulin-Like Growth Factor-1 in Skeletal Muscle and Various Diseases. Cells. 2020;9(8):1–15.

## TABLES

Table 1. Protocols used in Experimental and Control Group

Experimental Group (Group I)	Control Group (Group II)
<b>Week 1</b>	
<ul style="list-style-type: none"> <li>• Multi-angle isometrics at 0<sup>0</sup>, 30<sup>0</sup>, 40<sup>0</sup>, 60<sup>0</sup> and 90<sup>0</sup>, in supine lying and high sitting</li> <li>• Isometric Hamstrings in supine</li> <li>• Heel slides in supine</li> <li>• Straight leg raising</li> <li>• Passive patellar mobilisation</li> <li>• Ambulate without walker with minimal to moderate assistance</li> <li>• Stair climbing</li> </ul>	<ul style="list-style-type: none"> <li>• Isometric Quadriceps at 0<sup>0</sup> in supine lying</li> <li>• Isometric Hamstrings in supine</li> <li>• Heel slides in supine</li> <li>• Straight leg raising</li> <li>• Passive patellar mobilisation</li> <li>• Ambulate without walker with minimal to moderate assistance</li> <li>• Stair climbing</li> </ul>

Week 2-3	
<ul style="list-style-type: none"> <li>• Continue multi-angle isometrics in supine lying and high sitting</li> <li>• Isometric Hamstrings</li> <li>• Straight leg raising in supine, side-lying and prone lying</li> <li>• Gait training</li> <li>• Passive patellar mobilization</li> <li>• Passive knee extension to 0<sup>0</sup> in sitting</li> <li>• Standing weight shifts - forward and sideways</li> </ul>	<ul style="list-style-type: none"> <li>• Isometric Quadriceps and Hamstrings</li> <li>• Straight leg raising in supine, side-lying and prone lying</li> <li>• Gait training</li> <li>• Passive patellar mobilization</li> <li>• Passive knee extension to 0<sup>0</sup> in sitting</li> <li>• Standing weight shifts - forward and sideways</li> </ul>

Table 2. Pre and post-intervention data of study participants.

Outcome Measure	Group	Pre Test	Post Test	Mean Difference	p value
Visual Analogue Scale	I	4.2±0.5	1.3±0.2	-2.9	<0.05*
	II	4.7±0.7	2.3±0.3	-2.4	<0.05*
Timed Up and Go Test	I	28.04±5.2	22.95±5.0	-5.20	<0.05*
	II	31.19±4.8	26.05±5.3	-5.13	<0.05*
Active Knee Flexion Range of Motion	I	54.7±2.5	96.8±1.2	42.1	<0.05*
	II	54.2±3.8	88.8±2.4	34.6	<0.05*

*p*<0.05 represent significant difference