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 fulfils 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 isometricquadriceps 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 particularlyapparent at the knee joint, one of the commonest sites to be affected. As prevalence ofosteoarthritis increases with age and aging is associated with decreasing physiologicalfunction, the combination has major health implications (2).

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

Dynamic balance and maximal quadriceps strength declines with age and may be even moreimpaired in patients with knee osteoarthritis. Proprioceptive information is derived fromafferents in the muscles, ligaments, capsule, menisci and skin to arthrokinematic and musclereflexes 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 masswithin the base of support (6).

Quadriceps is one of the most important muscles surrounding the knee joint and its functionhas a crucial role in balance, stability of the knee and functional activities. Quadricepsweakness potentially could contribute to increased impulse loading of the knee joint (7).Thequadriceps muscle is the primary dynamic stabilizer of the knee in sagittal plane. Therefore itis possible that weakness of the quadriceps, either absolute or relative to the hamstrings mayadversely 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 anappreciable 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 orincreased 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 takesplace (9).

Strengthening of knee musculature is thought to play a significantrole 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 producesforce without an appreciable change in length. Multi-angle isometric exercises have been usedin persons with orthopaedic problems to improve the dynamic balance and range of motionand 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 trail 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 envelops. 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 0^0, 30^0,45^0,60^0, and 90^0 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 flexionrange 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±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 was 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 surgicalprocedure, offering pain relief and improved function to many patients who suffer fromdegenerative arthritis of the knee. Improvements in surgical technique and prosthesis designcontinue to enhance long-term outcomes (12).The ability to restore mobility without pain andlimping in more than 90% of cases has led surgeons to offer this operation to youngerpatients (13).Instability and limited range of motion are listed as important limiting factors tonormal 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 suggests that the

multi-angle isometric quadriceps exercise hasbetter effect in improving pain and dynamic stability compared to conventional treatment protocols.

Individuals with end stage knee osteoarthritis have quadriceps weakness prior to total kneearthroplasty. Following surgery, quadriceps weakness becomes more profound and does notrecover to the level of healthy adults quadriceps weakness has potential to impact functiongreatly, 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 mechanismfor this profound, acute decrease is primarily explained by deficits in quadriceps voluntaryactivation rather than atrophy.Thesignificant 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 ofmotor units at different angles (16).Large fast motor units are recruited at higher forces and it ispossible that during maximal voluntary contractions there are some units that are neverrecruited in the untrained state. Training is therefore seen as a way of facilitating therecruitment 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 thefact that quadriceps composites of a number of separate muscles. The different muscles mayhave 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 theoptimal length of the individual muscle (18).The second possibility arises as a result of a changein length of the muscle fibres. If the training were to be carried out at either very long or veryshort fibre lengths, where the forces generated were well below the maximum, then either alengthening or shortening of the muscle might occur by the addition or loss of sarcomeres atthe ends of the muscle fibres (19).

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

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

The study pose 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.

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TABLES

Table 1. Protocols used in Experimental and Control Group

Experimental Group (Group I)	**Control Group (Group II)**
Week 1	
• Multi-angle isometrics at 0^0, 30^0, 40^0, 60^0 and 90^0, in supine lying and high sitting • Isometric Hamstrings in supine • Heel slides in supine • Straight leg raising • Passive patellar mobilisation • Ambulate without walker with minimal to moderate assistance • Stair climbing	• Isometric Quadriceps at 0^0 in supine lying • Isometric Hamstrings in supine • Heel slides in supine • Straight leg raising • Passive patellar mobilisation • Ambulate without walker with minimal to moderate assistance • Stair climbing

Week 2-3	
• Continue multi-angle isometrics in supine lying and high sitting • Isometric Hamstrings • Straight leg raising in supine, side-lying and prone lying • Gait training • Passive patellar mobilization • Passive knee extension to 0^0 in sitting • Standing weight shifts - forward and sideways	• Isometric Quadriceps and Hamstrings • Straight leg raising in supine, side-lying and prone lying • Gait training • Passive patellar mobilization • Passive knee extension to 0^0 in sitting • Standing weight shifts - forward and sideways

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