ORIGINAL ARTICLE

IJPHY

Effect of Additional Hip Strengthening on Anterior Knee Pain, Strength, and Health Status in Patients with Total Knee Replacement: A Pilot Randomized Clinical Trial

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ABSTRACT

Background: Total knee replacement (TKR) is a standard surgical option for advanced-stage knee osteoarthritis. The primary indication of TKR is incapacitating knee pain. 75% to 89% of patients undergoing TKR reports a satisfactory reduction in pain. However, some patients develop anterior knee pain post-TKR. Therefore, different treatment strategies are used for the management of pain post TKR. In the present study, we aimed to evaluate the additional effects of hip strengthening on pain, muscle strength, and health status in TKR patients.

Methods: We randomized patients into two groups: knee group and knee hip group. The knee group (n=6) did knee flexors and extensors strengthening. The knee hip group (n=6) performed knee strengthening with additional hip abductors, lateral rotators, and extensors strengthening exercises. Both groups received four-session/week for six weeks. The pain was measured on NPRS, muscle strength on a hand-held dynamometer, and health status using the WOMAC scale. The data was collected at the baseline and post intervention (six weeks).

Results: The knee hip group shows more marked improvements in pain than the knee group, t value =3.3 (p=0.012). The data did not suggest any difference in knee muscle strength between the groups. Hip muscle strength showed a significant difference. Health status significantly improved in the knee hip group compared to the knee group, t value = 4.68 (p=0.005).

Conclusion: We can conclude that a six-week hip muscle strengthening exercise program effectively improves pain, muscle strength, and health status than a conventional knee strengthening program.

Keywords: strengthening exercise, knee pain, health status, muscle strength, dynamic valgus.

Received 02nd February 2021, accepted 08th May 2021, published 09th June 2021

www.ijphy.org

10.15621/ijphy/2021/v8i2/990

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INTRODUCTION

Osteoarthritis (OA) is a chronic disease with multifarious etiology. The overall prevalence of knee osteoarthritis (KOA) in India is 28.7%, and studies suggest a constant rise in prevalence and disease burden associated with KOA is on the rise [1,2]. End-stage KOA is linked to pain and disability. Total knee replacement (TKR) is a reliable treatment for improving a patient's functional status and pain[3]. Studies report reliable pain reductions after TKR, with a reported decrease in pain between 75% to 89% [4]. However, some patients have persistent pain, and studies show that 8% of patients undergoing TKR report anterior knee pain [5]. In literature, anterior knee pain (AKP) is one of the most common causes of persistent problems after TKR [4].

The causes of AKP post TKR can vary and are usually described as either functional or mechanical [4]. With new advancements in implant designs, the mechanical causes of AKP are on the decline, although functional causes are still prevalent. Muscle imbalances and dynamic valgus are categorized as functional causes [4]. Quadriceps weakness is a well-documented muscle dysfunction in KOA patients, and it persists after TKR [6–8]. It is also well known that quadriceps weakness results in improper loading of the patella and the extensor apparatus; this may be assumed as a contributing factor for AKP in TKR patients [4,9–11]. The other causative factor is dynamic valgus.

Dynamic valgus is an abnormal movement pattern associated with weak hip muscles, specifically the abductors and lateral rotators [12–15]. It is postulated that the tibia and femur's abnormal motions in transverse and frontal planes may increase the patellofemoral compartment load [12,15]. In addition, a delayed activity of gluteus maximus on EMG has been related to abnormal patella tracking [13]. This observation of dynamic valgus and incorrect loading of the patellofemoral joint has been targeted in patients with patellofemoral pain to improve their symptoms and function [14]. In addition, many studies have used targeted hip strengthening to treat patellofemoral pain [16–22]. However, focused hip-strengthening exercises for treating anterior knee pain have not been evaluated post TKR.

We hypothesized that adding hip strengthening exercises to a traditional rehabilitation program (comprising knee strengthening) will better reduce anterior knee pain. Secondly, we wanted to analyze whether there will be a difference in the two treatment groups regarding strength and health status.

MATERIALS AND METHODS

Study Design

This pilot study was a block randomized pre-test-post-test experimental design with two parallel treatment arms.

Patients

We included patients in the study if they (1) were 50 years or older, (2) had a history of anterior knee pain for ≥three months, (3) had undergone unilateral total knee arthroplasty, (4) pain on ascending/descending stairs, prolonged sitting, or walking, (5) TKR surgery must be more than one year old. They were excluded if they (1) had any mechanical issues evident on X-rays, (2) had any history of neurological disease, (3) gave any history of any other orthopedic surgery to the lower limbs.

Ethics

Ethical clearance was obtained from the Institutional Ethics Committee, Jamia Millia Islamia. The study adhered to ethical principles as per the WMA Declaration of Helsinki – Ethical Principles for Medical Research Involving Human Subjects. All eligible patients had signed the informed consent before participating in the study. Participation was voluntary, and they can withdraw from the study at any point in time.

Procedure

Patients were recruited from Physiotherapy OPD of ESIC Hospital, Okhla Phase 1, from February 2014 to December 2014. They were tested for all the criterion measures before randomization to the two treatment arms. Patients were blinded to treatment allocation, though the therapist was not blinded to treatment protocol and group allocation. On the initial visit, baseline characteristics and the outcome measures were documented. After randomization, patients received a group-specific protocol. Both groups underwent supervised sessions lasting one hour to one hour thirty minutes. All patients received interventions four days per week for six weeks. The rehabilitation protocol is highlighted in appendix 1.

Outcome Measures

Pain

The intensity of pain was measured with the help of a numeric pain rating scale (NPRS). NPRS is an 11-point pain scale with 0 as no pain and ten as extreme pain (e.g., "pain as bad as you can imagine" and "worst pain conceivable"); it is reliable and valid for pain assessments in musculoskeletal pain disorders [23,24]. We asked the patient to mark three pain ratings (1) current pain, (2) best pain experienced in the last 24 hours, and (3) worst pain felt in 24 hours. An average of all three ratings represented the patient's level of pain over the previous 24 hours.

Strength

Strength was measured using the construct maximal voluntary isometric contraction (MVC). MVC for Knee flexors and extensors and Hip flexor & extensor, abductor, extensor, and lateral rotators was measured using the Lafayette MMT system. (Model no. 01165; accuracy- ±1% over full scale or ±0.2% lbs.) [25]. The testing protocol was adapted from Thorborg and colleagues [26]. Patients performed two maximal isometric contractions for 3 seconds with a 1-minute interval between the trials for all the muscle groups. An average of three trials was recorded and used for analysis.

Health Status

Western Ontario and McMaster Universities (WOMAC) is a valid and reliable disease-specific, self-administered questionnaire with 24 items grouped into three dimensions: pain, stiffness, and physical function [27,28]. High scores on the scale suggest an increased disease-associated disability. Patients were asked to fill the questionnaire and, a total score was used in the analysis. There are two scaling versions for WOMAC: one uses a 100 mm visual analog scale (VAS) (VA3 series), and the other uses a five-point Likert scale (LK3 series) [29]. We used the Likert version of the scale.

Data Analysis

Statistical analysis was done using SPSS 21.0. Data were assessed by a Shapiro- Wilk test for the normal distribution. The demographic characteristics and outcome measures were compared between the control and experimental groups at baseline using an independent t-test. We used paired t-test to evaluate the effects of a given treatment in two groups for all outcome measures such as pain (NPRS), maximum voluntary contraction of Knee flexors and extensors & hip flexors, extensors abductors and lateral rotators, and health status (WOMAC). An independent t-test was used to test the difference between groups with the significance level set at p< 0.05.

RESULTS

A total of twelve patients (8 females and 4 males) participated in the study. The mean (SD) age of the patients in the knee group was 54.83 (4.215), and for the Knee Hip group, it was 55.0 (3.225). All other demographic and baseline characteristics are highlighted in table 1. The missing CONSORT flow diagram depicts the allocation of participants (figure 1)

Table 1: Baseline patient's characteristics of both the groups

Variable	Knee Group Mean (SD)	Knee-Hip Group Mean (SD)	*p*-value
Age (years)	54.83 (4.215)	55.0 (3.225)	0.940
Height (cms)	160.67 (7.421)	160.00 (7.348)	0.879
Weight (kg)	63.17 (6.646)	63.17 (6.524)	1.000
BMI	24.431 (1.368)	24.825 (1.747)	0.673
Pain (NPRS)	7.33 (0.81)	7.17 (0.75)	0.721
MVC KE	127.23 (21.85)	126.38 (7.58)	0.930
MVC HF	88.71 (17.62)	99.583 (6.37)	0.203
MVC HE	109.35 (9.53)	115.167 (6.37)	0.242
MVC HAb	83.01 (16.33)	97.91 (7.40)	0.81
MVC Hlr	69.95 (12.51)	80.16 (18.99)	0.297
WOMAC	49.83 (5.70)	54.83 (4.87)	0.134
WOMAC %	51.89 (5.95)	57.18 (5.11)	0.130

NPRS: Numeric Pain Rating Scale, MVC KF: maximum voluntary contraction knee flexors, MVC KE: maximum voluntary contraction knee extensors, MVC HF: maximum voluntary contraction hip flexors, MVC HE: maximum voluntary contraction hip extensors, MVC HAb: maximum voluntary contraction hip abductors, MVC Hlr: maximum voluntary contraction hip lateral rotators, WOMAC: Western Ontario and McMaster Universities questionnaire.

Within Group Differences

We found significant changes in both groups in all the studied parameters. There was a significant difference between baseline (mean = 7.33, SD = 0.816) and post-intervention (mean = 2.83, SD = 0.983), (p <0.001) in the knee group. There were similar improvements in pain in the knee hip group, baseline intensity (mean = 7.17, SD =0.753) and post-intervention pain intensity (mean = 1.33, SD =0.516), (p <0.001). Significant improvements were also observed for pre and post MVIC and WOMAC. The within-group differences are highlighted in Table 2 (Knee Group) and Table 3 (Knee-Hip group).

Table 2: Within-group difference between pre-treatment and post-treatment outcome measures for knee group, data is presented as mean (SD)

Variable	Pre	Post	*p-Value*	*t*
Pain (NPRS)	7.33 (0.816)	2.83 (0.983)	0.001*	13.175
MVC KF	93.48 (9.21)	110.65(9.54)	0.001*	21.220
MVC KE	127.23 (21.85)	146.98 (19.63)	0.001*	14.910
MVC HF	88.71 (17.62)	90.25 (18.22)	0.002*	-6.104
MVC HE	109.35 (9.53)	110.55 (9.73)	0.009*	-4.174
MVC HAb	83.01 (16.33)	84.21 (16.22)	0.005*	-4.819
MVC Hlr	69.95 (12.51)	71.76 (12.28)	0.001*	-8.906
WOMAC	49.83 (5.70)	35.00 (5.06)	0.001*	9.150

*Abbreviations: NPRS: Numeric Pain Rating Scale, MVC KF: maximum voluntary contraction knee flexors, MVC KE: maximum voluntary contraction knee extensors, MVC HF: maximum voluntary contraction hip flexors, MVC HE: maximum voluntary contraction hip extensors, MVC HAb: maximum voluntary contraction hip abductors, MVC Hlr: maximum voluntary contraction hip lateral rotators, WOMAC: Western Ontario and McMaster Universities questionnaire. *significant difference=p<0.05*

Table 3: Within-group difference between pre-treatment and post-treatment outcome measures for knee hip group, data is presented as mean (SD)

Variable	Pre	Post	*p-value*	*t*
Pain (NPRS)	7.17 (0.753)	1.33 (0.516)	0.001*	14.533
MVC KF	95.66 (9.70)	119.18 (12.49)	0.001*	-10.013
MVC KE	126.38 (7.58)	145.93 (12.86)	0.001	-7.285
MVC HF	99.58 (6.37)	121.45 (8.94)	0.001*	-15.054
MVC HE	115.16 (6.37)	132.83 (6.30)	0.001*	-28.177
MVC HAb	97.91 (7.40)	117.83 (10.38)	0.001*	-11.237
MVC Hlr	80.16 (18.99)	106.01 (14.62)	0.001*	-10.064
WOMAC	54.83 (4.87)	24.00 (6.00)	0.001*	26.760

Abbreviations: NPRS: Numeric Pain Rating Scale, *MVC KF: maximum voluntary contraction knee flexors, MVC KE: maximum voluntary contraction knee extensors, MVC HF: maximum voluntary contraction hip flexors, MVC HE: maximum voluntary contraction hip extensors, MVC HAb: maximum voluntary contraction hip abductors, MVC Hlr: maximum voluntary contraction hip lateral rotators, WOMAC: Western Ontario and McMaster Universities questionnaire. *significant difference=p<0.05*

Between-group Differences

The between-group analysis revealed a significant difference between the groups after the study protocol in all the outcome measures except MVIC for knee flexors and extensors. Pain reduction (figure 2) was more in the knee hip group (*p=0.012*). Table 4 highlights between-group differences. The MVIC comparison pre- and post- for both the groups are depicted in figure 3.

Table 4: Between-group difference between pre-treatment and post-treatment outcome measures for knee group, data are presented as mean (SD)

Variable	Knee Group	Knee-Hip Group	*p-value*	*t*
Pain (NPRS)	2.83 (0.98)	1.33 (0.516)	0.012*	3.308
MVC KF	110.65 (9.54)	119.18 (12.49)	0.213	-1.33
MVC KE	146.98 (19.63)	145.93 (12.86)	0.915	0.11
MVC HF	90.25 (18.22)	121.45 (8.94)	0.007*	-3.76
MVC HE	110.55 (9.73)	132.83 (6.30)	0.001*	-4.70
MVC HAb	84.21 (16.22)	117.83 (10.38)	0.002*	-4.27
MVC HLr	71.76 (12.28)	106.01 (14.62)	0.001*	-4.39
WOMAC	35.00 (5.06)	24.00 (6.00)	0.005*	4.68

*Abbreviations: NPRS: Numeric Pain Rating Scale, MVC KF: maximum voluntary contraction knee flexors, MVC KE: maximum voluntary contraction knee extensors, MVC HF: maximum voluntary contraction hip flexors, MVC HE: maximum voluntary contraction hip extensors, MVC HAb: maximum voluntary contraction hip abductors, MVC Hlr: maximum voluntary contraction hip lateral rotators, WOMAC: Western Ontario and McMaster Universities questionnaire. *significant difference=p<0.05*

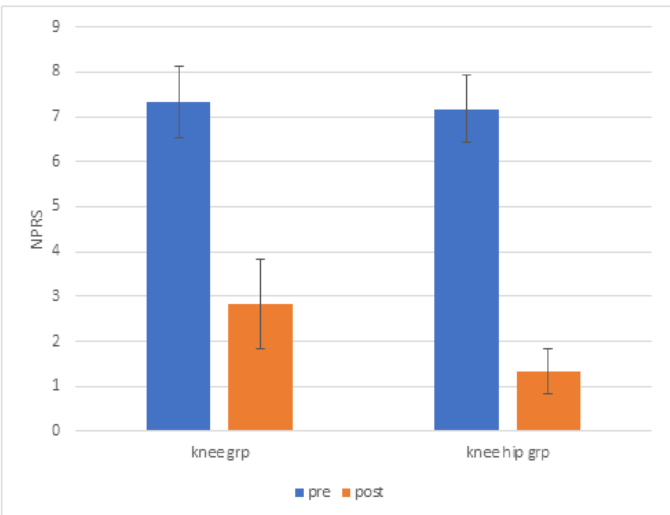

Figure 2: Between-group analysis of Pain (NPRS)

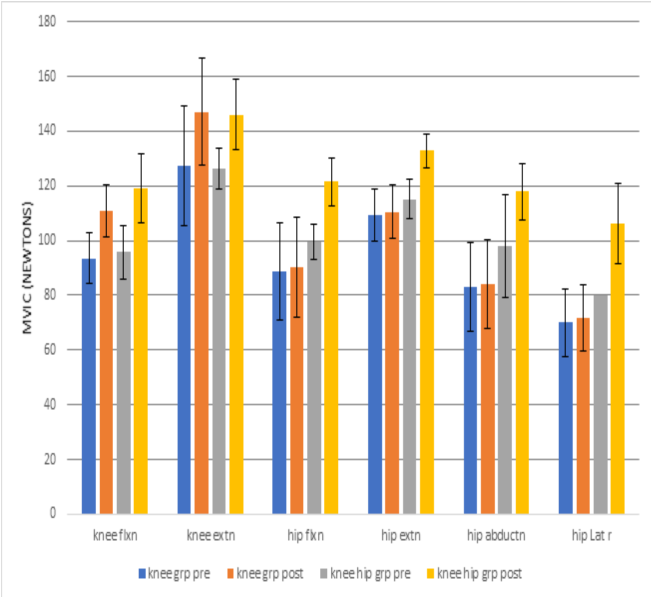

Figure 3: Between-group analysis of MVIC (Measured on a hand-held dynamometer)

DISCUSSION

The study results indicate that incorporating hip-strengthening exercises in patients with anterior knee pain post-TKR significantly reduced pain, improved muscle strength and health status. In our study, the primary outcome measure was pain, and two secondary outcome measures were muscle strength and WOMAC. In addition, all outcome measures showed significant between-group as well as within-group differences.

Pain intensity measured on NPRS revealed a significant reduction between the group, although this difference was slight (1.5 mean difference). We did not consider this to be a clinically meaningful change though it was statistically significant. The minor difference between groups could be due to the nature of the study with not many participants. The within-group improvements in NPRS met the clinically essential criteria as a 2-point reduction is considered a clinically meaningful change that exceeds the bounds of measurement error [30]. A ≥2 point decrease in NPRS post-treatment is termed as "much better improvement" [31]. Changes in muscle strength could explain the pain reduction in our study. It has been hypothesized that better strength reduces articular surface loading [32]. However, there are contradictory reports that strength gains do not alter joint biomechanics and tibio-femoral compressive loads during walking in adults with knee osteoarthritis [33,34]. An improvement in strength and function would have increased confidence and self-efficacy and reduced self-reported pain intensity. Our results of the reduced intensity of pain were in agreement with other studies [35,36].

Our secondary outcome strength was measured as torque (Newtons) using a hand-held dynamometer. Strength measurements showed a significant difference between groups post-intervention. A change of 18.36% for the knee flexors and 15.52% for the knee extensors was observed in the knee group. The hip muscle strength changes were negligible and were also not clinically significant. In the knee hip group, a change of 21.96% for hip flexors, 15.34% for hip extensors, 20.34% for abductors, and 32.24% for lateral rotators was observed. Knee muscles also showed a significant pre-post difference for the knee hip group.

Evidence suggests patients with Knee osteoarthritis have muscle dysfunction; this persists after surgery [37,38]. Literature shows that strengthening exercises can reduce this dysfunction [10,34–36,39,40]leading to greater medial compartment loading in people with knee osteoarthritis. Our study showed improvements in muscles' torque-producing capacity, suggesting a decline in strength deficits associated with TKR. Improvement in muscle strength usually happens through two mechanisms: hypertrophy and neural adaptations that enhance nerve-muscle interaction. Vecchio and colleagues demonstrated that strength adaptations might be linked to increased net excitatory synaptic input or adaptations in the motor neurons' properties. Our study proposes that strength adaptations can be ascribed to motor unit recruitment and rate coding [41].

Health status in our study was measured using WOMAC. Total WOMAC scores improved in both groups; there were 14.83 points increase in the Knee group. The knee hip group exhibited an improvement of 30 points. The change score met the MCID for both groups; in TKR subjects, as in such cases, MCID is reported as a change of 17 points [42]. The remarkable increase in WOMAC score in both groups can be attributed to improved muscle strength, contributing to patients' ability to perform activities more efficiently and confidently.

There is limited specific research against which we can compare our results. Most studies have evaluated the effect of hip strengthening in TKR patients on pain, function, and health status at different postoperative duration [6,35,40,43]activation, and functional recovery after total knee arthroplasty. KwangSun (2020) studied the effect of hip strengthening on pain, physical function, and gait in patients who underwent TKR within three months to one year, like our selection criteria. They reported significant improvement in pain and function like our studies. Their study's treatment protocol consisted of 12 weeks rehabilitation program with four weeks of supervised treatment and homebound exercises from the 5th week to the 12th week. On the other hand, we used intensive six-week strength training with four visits per week. Our study specifically measured improvements in strength, whereas they did not objectively measure it.

The study has implications for clinical practice. When combined with traditional rehabilitation, hip strengthening may improve strength and pain in a specific population of TKR patients who present with persistent AKP. However, there were several limitations to our study. First, there was no blinding in the study, which could have inserted bias in the trial. Second, the study was conducted at one center with a specific selection criterion, reducing the study's external validity. Third, considering the type of study, the number of participants was less; moreover, there was no long-term follow-up.

CONCLUSION

A six-week hip strengthening program additional to traditional rehabilitation improved pain, strength, and health status in anterior knee patients after knee replacement.

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Appendix 1

Protocol for Knee Group

1. The treatment session started with ROM exercises for hip and knee in supine lying potions; all the motions were repeated for ten to fifteen repetitions with 3 seconds end range holds.
2. Self-stretches (5 repetitions with 30 seconds hold)
   - Gastrocnemius
   - Soleus
3. Exercises with TheraBand*
   - Seated Knee Extensions
   - Hamstring curls (prone lying)
4. Straight leg raise (30 Degrees) with end range hold (15-30 seconds hold)
5. Cryotherapy at the end of the session for ten minutes

Protocol for Hip Knee Group

1. The treatment session started with ROM exercises for the hip and knee in supine lying positions; all the motions were repeated for ten to fifteen repetitions.
2. Self-stretches (5 repetitions with 30 seconds hold)
   - Gastrocnemius
   - Soleus
3. Exercises with TheraBand*
   - Seated Knee Extensions
   - Hamstring curls (prone lying)
   - Clamshell Exercise
   - Internal and external rotation of the hip (high sitting)
   - Hip Extension (Standing)
   - Hip abduction (Side-lying SLR)
   - Sit to Stand.
   - Walking sideways (walk each side for 1 minute and repeat it twice).
4. Cryotherapy at the end of the session for ten minutes

***Note:**

1. The color of the band was selected based on repetitions. If the patient could do ten repetitions with no repetition left in reserve, that color band was selected.

2. For exercises performed with band 3 sets of ten repetitions were used as baseline, which was later progressed depending on individual patients ‘capacity. Sideways walk was also progressed in terms of time and repetitions.

Figure 1: CONSORT Flow Diagram