Original Article

Effectiveness of Specific Quadriceps Modification and MET in Postoperative Phase I Rehabilitation Program of Fracture Shaft of the Femur

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Abstract

Objective: To assess the efficacy of specific quadriceps modification exercises and MET in phase I rehabilitation after surgical fixation of femoral shaft fractures: the study aims to reduce pain intensity, enhance knee range of motion (ROM), and improve quadriceps strength and control in the affected leg.

Background: The study aims to evaluate the outcomes of postoperative rehabilitation for femoral shaft fractures using MET and modified quadriceps exercises to address functional deficits during phase 1 recovery.

Design: A study was conducted with 10 subjects aged 18 to 70, divided into groups A and B (n=5 each). Post-surgery, range of motion (ROM), knee extensor strength, and pain levels (VAS) were assessed. Subjects underwent a 2-week postoperative rehabilitation program. Statistical analysis was performed to compare outcomes between day 1 and discharge.

Results: The study found significant improvements in both groups, with the experimental group showing greater reductions in pain, increased knee flexion in supine lying ($P \leq 0.001$) and short sitting ($P \leq 0.002$), extension ($P \leq 0.01$) ROM, as well as improved quadriceps strength and control.

Conclusion: The study indicates significant improvements in pain reduction, increased range of motion (ROM), and quadriceps muscle strength in both groups. However, the experimental group, which received MET and modified quadriceps exercises, showed greater improvements compared to the control group.

Keywords: Specific quadriceps modification exercises, MET, ROM, Femur shaft fracture

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Introduction

A femoral shaft fracture typically results from severe trauma like falls from heights, road accidents, direct impacts, or industrial mishaps. Given the traumatic nature and extensive surgical intervention involved, soft tissue damage is common, which can hinder patients' return to their prior level of function. Even after adequate bone healing, patients often experience ongoing impairments and functional limitations that persist long after the initial injury and surgery. Function limitations and impairments following femoral shaft fracture are often linked to soft tissue injuries sustained during trauma or surgery. These include hip abductor weakness causing a Trendelenburg gait, anterior knee pain, quadriceps femoris muscle weakness, and reduced gait and walking endurance. These issues stem from structural damage and inflammation, impacting mobility and functional recovery post-injury. Hip abductor weakness is assumed to be an iatrogenic complication of femoral intramedullary nailing, and open plating which involves a lateral approach to the femur with associated dissection of the vastus lateralis and inadequate postsurgical rehabilitation Quadriceps muscle is important in most weight-bearing functional activities and protect the structure of the knee. "Quadriceps femoris muscle weakness is common following femoral fracture, with or without surgical intervention. Peter Krustrup et al (2004)[38] describe quadriceps muscle weakness as an important contributor to disability. After a femoral fracture, there is a reduction in fast-twitch muscle fiber size in the quadriceps and these fibers are important in generating leg extensor power. D. A. Rice and P.J. McNair et al [28] describe that marked weakness of quadriceps muscle weakness is partly due to muscle atrophy and partly ongoing neural inhibition prevents the quadriceps from being fully activated, a process known as atherogenic muscle inhibition. The focus is on addressing quadriceps muscle inhibition (QMI) post-femoral surgery, where pain, inflammation, joint laxity, and structural damage contribute to AMI. This inhibitory condition limits quadriceps activation, potentially leading to muscle atrophy and hindering rehabilitation efforts. The rehabilitation program integrates conventional and experimental approaches, emphasizing isometric quadriceps contractions with ankle dorsiflexion, TheraBand exercises, and MET. MET includes post-isometric relaxation (PIR), utilizing Golgi tendon organs to relax muscles after contraction, facilitating muscle lengthening and enhancing mobility recovery. From the Golgi tendon organ, the afferent nerve impulses enter the dorsal root of the spinal cord and meet with inhibitory motor neurons impulse and therefore prevent further contraction, the tone decreases with results in the agonist relaxation and lengthening". [9, 25, 26, 25, 26, 34.] Specific quadriceps modifications consist of pain-free exercises such as ankle dorsiflexion, ankle dorsiflexion with inversion, use of a small wedge, and static weight lifts. This provides a faster progression of treatment and a subsequently shorter rehabilitation period.[29]

Methodology

An experimental trial was conducted on subjects aged 18 to 70 years who met specific criteria: internal fixation of femoral shaft fracture, unilateral leg involvement, and no complicating factors like head injury or soft tissue damage. Patients with bilateral involvement, neurovascular issues, or other medical conditions affecting the study protocol were excluded. Ethical approval was obtained from the research committee at the Himalayan Institute of Medical Sciences for Dr. Arun pathak on 26/06/2018, reference no. - SRHU/HIMS/RC/2018/167, and subjects provided informed consent. Ten eligible subjects were randomly assigned to either Group A (postoperative femur fracture rehabilitation program) or Group B (postoperative experimental exercise protocol). The McGill Pain Questionnaire (MPQ) assessed pain intensity, knee range of motion was measured using a Goniometer, and quadriceps muscle strength was evaluated with a modified sphygmomanometer. [14, 15, 16, and 17.] MPQ was taken on the post of day one and day of discharge, The modified sphygmomanometer (MST) demonstrated adequate criterion-related validity as well as test-retest and intern–rater reliability. It is a portable, inexpensive, and promising method to be used within clinical settings worldwide for the assessment of the strength of the LL.[18, 19, 20, 21, 22.] To measure quadriceps muscle strength patients are placed supine. An inflated cuff is placed under the popliteal fossa with the knee in position in 30^0 of flexion. The inflated bag was set to its load of 80 mmHg. The subject was asked to voluntarily contract their quadriceps muscle as much as possible by keeping the inflated cuff under the popliteal fossa. Three readings were taken and recorded and the meaning of it was considered as a maximum voluntary contraction. To measure the ROM at the knee, a universal Goniometer provides a simple objective assessment of a patient's initial status and progress depending on the reliability and validity of the measurements. [30, 31]

GROUP A Intervention: Phase I of the femur fracture rehabilitation protocol, spanning 1 to 2 weeks from postoperative day 1, included several key components. Patients received ice pack therapy over the incision for 15 minutes and kept their knee elevated in full extension to minimize swelling. Exercises focused on enhancing joint mobility with AROM and PROM exercises for the hip, knee, and ankle, alongside toe pumps. Aggressive pursuit of full knee extension aimed to prevent flexion contracture. Ankle movements (dorsiflexion, plantar flexion, eversion, inversion) were facilitated using Thera band in sets of 10 repetitions, 3 sets, twice daily. Quadriceps sets and gravity-minimized hip abduction slides were introduced to activate knee extensors and hip abductors, performed with 10 repetitions per set, 3 sets per session, twice daily. To prevent knee joint contracture, patients performed posterior lower extremity stretches and elevated the involved limb with the heel propped up for 10 minutes, 3-4 times daily. By the second day,

partial weight-bearing (25%) commenced using a walker, promoting gradual recovery and mobility. The uninvolved lower extremity was moved forward past the involved limb and the cycle was repeated [3,4,5].

GROUP B Intervention: Over a 2-week period, the femur fracture rehabilitation protocol included targeted interventions to promote recovery and mobility. Patients received ice pack therapy over the incision area and maintained knee elevation in full extension to reduce swelling. Exercises commenced immediately with isometric quadriceps contractions using ankle dorsiflexion, progressing to include ankle inversion and small wedge utilization under the knee joint for added challenge. Ankle pumps involving plantar flexion, dorsiflexion, eversion, and inversion were performed. Active assisted exercises for hip abduction, adduction, and knee bending were initiated, advancing to active range of motion exercises and stool or supine lying heel sliding as tolerated. On the second day, partial weight-bearing (25%) began with walker assistance, emphasizing gradual weight transfer and mobility. Post-isometric relaxation (PIR) exercises commenced on day 3, focusing on muscle contraction against resistance followed by relaxation cycles to enhance flexibility and recovery. This structured program aimed to optimize early rehabilitation outcomes following femur fracture surgery.

Statistical analysis

Data was analyzed using Microsoft Office Excel 2010 and Microsoft Office World 10 in Microsoft Windows Embedded 8.1 Industry Pro Build 9600. Intra and inter-groupanalyseswere done by using paired tests and independent t-tests and F – -testof two samples for variances in which the mean standard deviation (mean ±SD) of the variable was calculated. The level of significance wasset at $p \leq 0.05$.

Result

A total number of 10 subjects participated in the study. All subjects completed the study with no dropouts. There were no complications associated with either of the techniques during our clinical study with no subjects showing worsening pain or ROM.

The result of our clinical study is presented as inter and intra-group compression among two groupsbased on pain. The mean ageof Group Aand Group Bwas 15.81 ± 16.27 (range, 18 – 70) years respectively and the difference was not statistically significant (P = 0.8). Group A had 2 men, whereas Group B had 3 men, the two groups did not reach statistical significance (P = 0.878). The comparison among Group A and Group B based onthe BMI variable having mean ±SD of Group A and Group B were 2.0 ± 2.5. The difference was not statistically significant (P = 0.4).

Table 1: Comparison of pain and knee ROM within the two group

Compression of score	Group A			Group B		
	Post-op day 1	Day of discharge	P(within the group)	Post-op day 1	Day of discharge	P (within the group)
MPQ	7.8±1.13	4.2±1.4	0.001	7.8±1.13	3.46±1.36	0.001
ROM: Knee flexion (supine lying) Knee flexion (Short sitting) Knee extension in a short sitting	10±7.905	48±9.082	0.0001	22±9.08	88±16.8	0.0001
	46±8.21	*69±10.24*	*0.0008*	*49±7.41*	*111±7.41*	*0.0004*
	44±4.18	*29±5.47*	*0.013*	*40±7.07*	*8.4±1.14*	*0.0003*

Table 1 Comparison of pain and knee ROM within the two groups. There was an improvement in all the outcomes post 2 weeks in both groups. (P < 0.05).

The next data analysis involved the changes score of each of the outcomes measured between the two groups. Table 2shows changes in the pain intensity on the McGill pain questionnaire between the groups. The group shows statistical significance with P = 0.003.

Table 2: Comparison of change scores between the two groups

Compression	Group A	Group B	P value
MPQ	3.54±0.85	4.35±0.79	0.003
ROM			
Knee flexion (supine lying)	48±9.08	88±16.8	0.001
Knee flexion (short sitting)	69±10.24	111±7.41	0.0028
Knee extension	29±5.47	8.4±1.14	0.01
Quadriceps muscle strength	3.66±1.76	32.33±10.61	0.003

Table 2 shows changes in the flexion and extension ROM between the groups. The groups showed statistical significance with P= 0.05. Group B shows greater improvement in ROM extension (P = 0.01), flexion in supine (P =0.001), and extension in short sitting (P = 0.002).Table 2 shows improvement in quadriceps muscle strength by a Modified sphygmomanometer between the two groups with the P = 0.0003. However, Group B shows greater statistically significant improvement in the reduction of pain,increased knee ROM as wellincreased quadriceps muscle strength as compared with Group A.

Discussion

The study focused on comparing the effects of immediate post-operative application of Modified Isometric Exercise Therapy (MET) and quadriceps modification exercises on pain, knee range of motion (ROM), and quadriceps strength (QS) in femur shaft surgery patients. Both groups experienced reduced pain levels due to spinal block anesthesia, analgesic drugs, ice therapy, and limb elevation. However, the experimental group, which received MET and modified quadriceps exercises, showed greater pain reduction than the control group. MET induces hypoalgesia by activating muscle and joint mechanoreceptors, while ankle dorsiflexion inhibits quadriceps femoris contraction, reducing pain through the flexor withdrawal reflex.

In analyzing knee range of motion (ROM), both Group A and Group B showed significant improvements in flexion and extension, with Group B demonstrating greater gains. Specific quadriceps modification exercises and active straight leg raise (SLR) techniques were key in enhancing knee extension ROM by addressing muscle weakness and optimizing patellar tracking through improved Q angle and motor firing activation. Proprioceptive neuromuscular facilitation (PNF) techniques like post-isometric relaxation (PIR) and reciprocal inhibition (RI), facilitated by Modified Isometric Exercise Therapy (MET), also contributed to improved knee flexion ROM during the 12-day rehabilitation period. These processes involve physiological mechanisms that relax muscles post-contraction and enhance joint mobility effectively, influenced by stretch reflex and other neurological factors.: (a) Muscle spindles sensitive to change in length and speed of change in muscle fibers; (b) Golgi tendon organs that detect a prolonged change in tension"[8,9,10,25].

Stretching a muscle triggers muscle spindles, which signal the spinal cords posterior horn cells (PHC), activating anterior horn cells (AHC) to increase motor impulses and muscle tension. Golgi tendon organs respond to sustained tension by inhibiting AHC impulses, promoting muscle relaxation. Prolonged muscle stretches enhance flexibility by overriding protective contraction, whereas rapid stretches induce immediate muscle contraction without sustained inhibition. Isometric contractions lead to post-isometric relaxation (PIR) through spinal feedback, reducing muscle tone briefly to facilitate muscle length manipulation. Reciprocal inhibition (RI) involves the contraction of agonist muscles inhibiting antagonists, promoting effective muscle control with a refractory period lasting about 20 seconds, less powerful than PIR. Klingles and Schleip (2014) [36] suggest a hydraulic effect within connective tissue structures temporarily enhancing movement freedom or range of motion after stretching or isometric contraction.NP Whitehead et al (2001) [37] reported that changes in both the series elastic and parallel elastic elements of sarcomeres, occurring during the active and passive phase of MET, can be seen as potential contributions.

In our clinical study, specific quadriceps modification exercises over 12 days significantly increased quadriceps muscle strength despite initial challenges with pain and inflammation around the incision and knee joint, especially at the patellofemoral joint (PFJ). Correct execution of exercises, such as using ankle dorsiflexion (DF) to reduce quadriceps contraction force, helped alleviate pain. Ankle DF also stretched calf muscles antagonistically, easing knee extension discomfort. Incorporating wedges enhanced PFJ stability by optimizing patellar positioning, strengthening the VMO (vastus medialis obliquus) to prevent lateral patellar displacement. These modifications effectively targeted muscle strengthening and joint stability during rehabilitation. The greater range allows longer time for activation of VMO to reduce lateral tracking, PNJ pain, reduce inflammation of either the plica or the infrapatellar fat pads and hence increase VMO strength"[29].

Conclusion

The basis of the current study and results showed a significant improvement in the reduction of pain and an increase in knee ROM and quadriceps muscle strength by postoperative rehabilitation program following fracture shaft femur. The results appear significant within the group as well as among the group. The dropout rate and small size may preclude any definite conclusion and results. Therefore, MET and modified QSs with different ankle positions are found more effective in the phase rehabilitation period (over 10 to 12 days) than in the control group.

Ethical Clearance : ethical approval was obtained from the research committee at the Himalayan Institute of Medical Sciences, Doiwala, Dehradun from Dr. Arun pathak on 26/06/2018, reference no. - SRHU/HIMS/RC/2018/167, and subjects provided informed consent.

Conflict of Interest: There was no conflict of interest reported among all authors of this clinical research.

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