

EFFECTS OF MIRROR THERAPY ON EARLY POSTOPERATIVE FUNCTIONAL RECOVERY AND PAIN IN PATIENTS WITH POSTOPERATIVE INTERTROCHANTERIC FEMUR FRACTURE

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Intertrochanteric Femur Fracture, Mirror Therapy, Rehabilitation following surgery, Harris Hip Score, Numerical Pain Rating Scale, range of movement, functional recovery.

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Sarma Khurshid

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Background: Fractures of the intertrochanteric femur are one of the most serious problems in orthopedic trauma because of the considerable postoperative pain, limited range of movements, and long-term immobility. Mirror Therapy is a method based on visual feedback used to help with the recovery of the motor-sensory function.

Objectives: To study the impact of Mirror Therapy on early postoperative recovery, joint movement, and pain in intertrochanteric femur fracture patients undergoing surgical treatment.

Methodology: The prospective, single-blinded randomized controlled experiment was conducted on 54 patients divided into two groups: Group A (Mirror Therapy and Core Rehabilitation, n = 27) and Group B (Control group: Mirror Sham Therapy and Core Rehabilitation, n = 27). Interventions were performed 5 times a week for 6 weeks, each time for 30 minutes. Pain was measured by the Numeric Pain Rating Scale (NPRS), joint flexion range of movement - by goniometer, and the state of function - by the Harris Hip Score (HHS).

Results: Both groups exhibited intra-group improvement in all parameters throughout the study period ($p = 0.001$). On the other hand, inter-group analysis indicated better results in Group A in week 6. Group A experienced significantly lower NPRS scores ($1.78 (\pm) 1.12$) than Group B ($3.63 (\pm) 1.28$; $Z = -4.471$, $p = 0.001$). Group A had higher levels of active hip flexion ($85.70^\circ \pm 8.61^\circ$ vs. $68.70^\circ (\pm) 7.98^\circ$; $Z = -5.548$, $p = 0.001$) and knee flexion ($118.41^\circ (\pm) 8.53^\circ$ vs. $99.15^\circ (\pm) 11.13^\circ$; $Z = -5.210$, $p = 0.001$). In the end, the final HHS value of Group A was categorized as "Good" (82.52 ± 10.58) and Group B as "Poor" (62.41 ± 7.81 ; $Z = -5.280$, $p = 0.001$).

Conclusion: Incorporating Mirror Therapy into routine postoperative rehabilitation decreases pain, increases range of motion and enhances functional recovery in intertrochanteric femur fracture patients.

CHAPTER 1

INTRODUCTION

The rising trend of intertrochanteric femoral fractures is becoming a global public health threat that forms a fundamental aspect of the practice of orthopedic traumatology. The anatomical basis of this condition is formed by extracapsular fractures that affect the region of the hip bone from the greater to the lesser trochanter. As reported in various epidemiological surveys, intertrochanteric femoral fractures constitute about 45%-50% of all hip bone fractures observed globally. These fractures are predominantly prevalent among elderly patients who have weakened their musculoskeletal system due to decreased bone mineral density and progressive weakening of neuromuscular protective mechanisms (1).

In the elderly, these injuries usually result from low energy trauma associated with accidental falling down while being in an upright position. On the contrary, in younger patients, these fractures rarely occur but they are complicated and involve higher-energy injury patterns, including road accidents, workplace injuries, or falls from heights. The burden of intertrochanteric fractures on society and economy cannot be understated. With life expectancy rising globally, the absolute number of proximal femur fractures will grow exponentially within the next few decades, putting tremendous pressure on health services, rehabilitational institutions, and long-term care providers (2).

Not only are the cost implications related to emergency treatment and the price of prosthetic hardware concerning, but there is also an extremely high chance of death or long-term disability associated with these injuries. Data shows that the one-year survival rate after a hip fracture among older people stands at 15 to 30 percent, depending on the rapidity of returning to self-reliant ambulation. Even for the survivors, a considerable percentage never regain their prior quality of physical performance after the injury and its aftermath. It becomes evident that not just the process of restoring the integrity of the bone structure but the biological pathway of healing itself needs to be optimized (3).

Structural integrity of the proximal femur is

maintained through a highly specialized bony matrix called trabeculae, which are specifically arranged to endure significant mechanical force and weight-bearing. The intertrochanteric space represents a transitional area connecting the neck of the femur and the femoral shaft, where significant shear forces act upon during regular ambulation. With the intertrochanteric fracture, there will be an interruption in such a structural arrangement, causing mechanical instability, massive formation of local hematoma, vascular damage, and inflammatory response (4). Since conservative treatment of such cases carries unacceptable risks of high systemic mortality, non-union, and mal-union because of prolonged immobilization, the immediate surgical intervention has been accepted as the best choice (5).

The first and foremost goal of modern-day surgical intervention of intertrochanteric fractures is the creation of stable, anatomic, or slight valgus reduction along with rigid internal fixation. Such can be performed through the use of intramedullary implants, such as the Proximal Femoral Nail (PFN), and extramedullary implants, like the Dynamic Hip Screw (DHS) (6). Depending on the nature of the fracture, that is whether medial and posterior cortical walls are intact or comminuted, a specific type of implant is chosen to achieve the best clinical outcome. In cases of a stable fracture pattern, extramedullary fixation with a DHS proves to be beneficial by providing controlled compression along the fracture line. When the fracture is considered unstable, reverse-obliquity, or subtrochanteric extension, intramedullary nailing with a PFN proves more biomechanically efficient due to a smaller load-sharing lever arm and decreased varus instability (7).

As soon as a patient is kept immobile after surgery, a series of serious systemic conditions will emerge within a matter of days. As a result of immobilization, there is a high risk of DVT formation, leading to a dangerous condition such as pulmonary embolism because of venous stasis and the patient's hypercoagulable state. Additionally, due to limited mobility, atelectasis and hypostatic pneumonia often develop, leading

to mortality among older patients who have experienced surgeries for their fractures (8).

Meanwhile, constant pressure on prominent bones causes microcirculatory occlusion, contributing to decubitus ulcer formation, which may become infected deeply and cause sepsis. On a musculoskeletal level, muscle deconditioning happens relatively fast for a patient who is absolutely immobile. In particular, within just a few days of staying in bed, healthy muscle tissue begins to disappear by 1% to 1.5% each day, coupled with fast bone mineral loss. It takes little time to progress to such a degree of deconditioning that the patient will not be able to recover from it anymore (9).

Although there have been many advancements in the field of biomechanics regarding the use of internal fixation devices, a unique dilemma remains within the ward immediately following surgery. The surgeon might consider the bone to be biomechanically sound and able to bear weight, yet the patient might still be caught up in the vicious cycle of acute post-operative pain and severe psychological distress (10).

Causes of acute pain following surgery include periosteal stripping, splitting of muscles, inflammation and edema of the surrounding soft tissue, and micro-motion of the surrounding tissues due to the presence of the new implant. This results in a barrage of high-frequency stimuli being transmitted through the body's nociceptive pathways to the dorsal column of the spinal cord, followed by the cerebral cortex (11).

The intense physical experience of pain is quickly followed by a very strong psychological barrier in the form of mechanical kinesiophobia or an irrational fear of moving and engaging in physical activities as a consequence of being vulnerable to painful injuries. In cases where the mere attempt to contract the quadriceps or hip abductors causes severe pain for the patient, an automatic response from the central nervous system is enacted that views any attempt at moving the affected joint as threatening (12).

As a result, the intention to move triggers an intense feeling of anxiety and involuntary protective muscle guarding. As a consequence, there is an inevitable confrontation with the aim

of early rehabilitation and mobilization in which the patient rejects the process of getting out of the bed and into the wheelchair (13).

Conventional protocols for postoperative rehabilitation therapy have included bedside exercises, passive physical therapy techniques, assisted ambulation through graduated progression, and intensive drug treatment to manage pain. Despite being an integral part of medical care, involving mainly non-steroidal anti-inflammatory drugs (NSAIDs), acetaminophen, and synthetic or natural opioids, the use of systemic pharmacology to provide pain relief is problematic in this patient group (14).

Due to their unique pharmacokinetics and dynamics, elderly patients demonstrate poor elimination by the liver and low glomerular filtration rate. As a result, systemic treatment with opioids often results in such adverse effects as delirium, cognitive impairment, apnea, severe constipation, and hypotension (15).

A somnolent or confused elderly patient under the influence of opioids is unable to learn motor skills, exhibits poor dynamic stability, and is exposed to an extremely high risk of falling inside the hospital premises, thus endangering the surgically fixed joint. In addition, traditional physical interventions tend to be restricted in their application at an early stage of recovery; active exercises are not feasible due to pain, whereas passive exercises fail to stimulate motor pathways inside the central nervous system, or overcome kinesiophobia. Thus, there is an urgent need for a non-invasive and non-pharmacological supplementary treatment to suppress post-surgical pain and activate the central nervous system to perform motor tasks without any physical strain on the bone tissue (16).

To solve such a conundrum after surgical operations, modern rehabilitation studies are shifting from strictly peripherally based biomechanics and are focusing more on neuroplasticity and CNS modulation. Currently, it is well known that motor disturbances and post-surgical pain conditions are not isolated locally, but they are intricately related to central changes within the sensory-motor system. When the limb is subjected to significant trauma and surgery, an

unending flow of aberrant nociceptive input, combined with the abrupt absence of usual proprioception and kinesthetic sensations, triggers rapid and maladaptive reorganization of the M1 and S1 cortices (17). Such process, known under terms "cortical neglect" and "sensorimotor incongruence," results in disruption of the internal cortical representation of the affected limb and thereby enhances the pain perception centrally and limits voluntary motor activity (18).

Mirror Therapy (MT), therefore, is a novel and cognitive neuro-rehabilitative approach that addresses this sensorimotor mismatch in a direct manner. The technique was first conceptualized in the mid-1990s by Vilayanur Ramachandran to relieve the agony of phantom limb pain in upper-limb amputees. Mirror Therapy is now being used for treating various kinds of neurological and musculoskeletal problems (19).

The structural mechanism of mirror therapy is simple but effective. It involves placing a mirror along the sagittal plane of the patient, covering the damaged or operated limb and reflecting the opposite limb, which is healthy and functioning well (20). While doing certain tasks, which are purposeful and synchronized movements using the healthy limb, the brain experiences visual illusions, as if the unhealthy limb is also performing normally and without pain (21).

The chief neuro-biological force behind the success of Mirror Therapy is the Mirror Neuron System (MNS) in the human body. Mirror neurons form a special group of neurons called visuomotor neurons which fire not only during the execution of an action by the individual but also when that particular action is performed by another entity or by visual media (22).

Mirror Therapy activates these neurons through the provision of a highly realistic simulation of healthy limb movements. The visual feedback from Mirror Therapy thus cuts out the peripheral damage on the injured limb's feedback loop, thereby providing robust stimulation to the motor centers of the contralateral brain hemisphere. As a result, despite the complete rest of the limb behind the mirror to ensure the safety of the internal fixation, the motor center which controls it gets activated on a microscopic scale (23).

The central activation has far-reaching effects on both the processes of pain modulation and motor control. In accordance with the sensorimotor incongruence model of pain, if the motor commands from the brain do not coincide with the sensory and visual feedback, the central nervous system will send out an alarm which manifests itself as pain and distress (24). The beauty of Mirror Therapy consists in the creation of an illusion that the motor command has been executed flawlessly without damaging any tissues (25).

This sensory illusion has a powerful effect on cognitive penetration of action control. As a result, the activation of the visual modality leads to the reduction of the excitation of the nociceptive pathways of the spinal cord as well as inhibition of the central pain network. At the same time, the visual information activates corticospinal plasticity and preserves the excitability of the motor network responsible for lower limb movement (26).

Whereas the current scientific literature is rich in terms of clinical evidence of the efficacy of Mirror Therapy within the realm of neurological recovery programs primarily regarding fast recovery of upper and lower limb motor functions after stroke incidents Mirror Therapy's application within the acute post-surgical setting in orthopedics remains a relatively unexplored field. The majority of contemporary orthopedic rehabilitation programs function primarily via a strictly peripheral approach, focusing their efforts on the restoration of local tissues, joint flexibility, and muscle strength without addressing the crucial role of neuroplasticity that takes place during the very first stages of acute skeletal injuries and major surgery (27).

This represents a substantial drawback in modern orthopedic treatment, especially in cases of intertrochanteric femoral fracture. Within days 1 to 14 post-operation, patients find themselves exposed to a rather dangerous combination of acute pain, severe kinesiophobia, and extremely quick hospital-related deconditioning (28).

Indeed, there is a complete dearth of randomized trials designed scientifically and methodically to test the inclusion of structured Mirror Therapy in the initial, hyper-acute phase following

postoperative recovery from fixed intertrochanteric fractures. There is no scientific evidence as yet to establish if exposure to structured Mirror Therapy during this period can effectively help to lower pain scores using the Visual Analogue Scale (VAS), decrease use of systemic rescue medication, decrease TSK scores, and also aid in reaching functional goals like bed mobility, transfers, and early ambulation (29).

The standard physical therapy in this case is greatly limited by the fact that patients are not able to bear the burden of exercising on their body as they have just undergone surgery and their body cannot withstand the physical strain associated with performing active exercise. However, Mirror Therapy comes up as a novel remedy to this dilemma, as it involves intense cognitive training, without making patients undergo any physical burden due to their freshly operated hip.

This thesis aims to fill this significant gap in clinical evidence. By conducting a prospective clinical trial, this study seeks to determine the precise effects of structured Mirror Therapy used in addition to physical therapy.

These results have considerable clinical implications as the use of Mirror Therapy as a treatment method that not only decreases acute postoperative pain but also accelerates functional recovery would completely change the early postoperative rehabilitation of ITF cases. Offering an inexpensive, drug-free, and readily available therapy can help prevent the dangerous consequences of hospital-induced deconditioning, avoid opioid side effects, reduce hospitalization, and greatly improve the functional outcomes of this arduous procedure.

Rationale of Study

Femoral intertrochanteric fractures are quite prevalent among old-aged people and cause significant post-operative pain, decreased mobility, and delayed functional recovery despite the implementation of conventional rehabilitation. Mirror therapy is an easy-to-use, affordable, and noninvasive method, which has already demonstrated positive outcomes in terms of post-operative pain relief and improved motor function due to visual feedback and brain plasticity. At the

same time, there is not enough information about the efficacy of the technique in the early post-operative period after femoral intertrochanteric fracture surgery. The research project will help to fill in the gap in the knowledge and determine whether the application of mirror therapy is effective for such patients.

CHAPTER 2

LITERATURE REVIEW

Gao et al., 2025 conducted a systematic review and meta-analysis and evaluated the efficacy of combined immersive and non-immersive virtual reality (VR) with mirror therapy in stroke rehabilitation. Five electronic databases and gray literature were systematically searched to identify relevant randomized controlled trials (RCTs). A total of 14 RCTs involving 475 patients were included, of which 7 were eligible for meta-analysis. The risk of bias was assessed using the Cochrane Collaboration tool, and the certainty of evidence was evaluated using GRADE guidelines. Outcomes assessed included upper extremity motor function and hand dexterity. Meta-analysis showed significant improvements in Fugl-Meyer Assessment-Upper ($p < .001$), manual function test ($p < .001$), and Box and Block Test ($p = .03$). Subgroup analysis based on disease duration (>6 months or not) revealed significant differences in FMA-UE outcomes. Narrative findings also suggested potential benefits in lower extremity function, dynamic balance, and quality of life. It was concluded that combined VR and mirror therapy shows promising but clinically variable effects in stroke rehabilitation (30).

In 2025, Saragih ID et al., conducted a study on Effects of mirror therapy on upper limb motor function of patients with stroke. This study aimed to investigate and review the effects of mirror therapy on upper limb function, including improvements in shoulder, elbow, forearm, wrist, and hand function, as well as coordination between the upper extremities, in patients with stroke. A random-effects model was applied to calculate the pooled mean difference of dichotomous variables using the 95% confidence interval. The variance in effect estimation in a forest plot for each trial was then quantified

using I^2 . Eighteen studies, representing 633 patients with stroke, were included in this study. Mirror therapy significantly improved upper limb motor function (mean difference [MD] = 1.79; 95% CI = 0.04–3.54; $p = 0.04$) and hand function (MD = 1.48; 95% CI = 0.17–2.78; $p = 0.03$) in patients with stroke. Subgroup analyses of overall upper limb function showed that mirror therapy was effective in improving function when delivered more than 5 times a week (MD = 2.75; 95% CI = 1.02–4.48) over a period of ≤ 4 weeks (MD = 3.26; 95% CI = 1.19–5.33). The results of the methodology assessment using RoB-2 on all the trials included in the analysis showed that 16 trials were considered to have some concerns (31). Reischl, Stephanie investigated Early Neuromuscular Stimulation and Mirror Therapy Interventions to Prevent Functional Loss During Immobilization of Distal Radius Fractures in the year 2024. This is the research aimed at assessing the possibility of implementing MT, NMES, and MT+NMES intervention at home for patients undergoing immobilization for DRF. Methods: Studies regarding literature were reviewed to find out how NMES and MT have been used in cases of musculoskeletal disorders. In-home MT, NMES, and MT+NMES intervention techniques for implementation during DRF immobilization were developed. RCT feasibility study was employed to evaluate patient recruitment, adherence to the intervention, retention to on-site visits, and limited efficacy evaluation. Semistructured interviews were performed 6-weeks after the DRF surgery to provide insight into the patient's experience, practicality and acceptability of the intervention. Variables such as pain, range of motion (ROM), dexterity, function, and strength were evaluated in three-, six-, eight-, and twelve-weeks following DRF at the on-site visits. EMG recordings were performed during contraction for wrist movement at eight- and twelve-weeks post-DRF to explore possible mechanisms of change. The use of massage therapy (MT) and neuromuscular electrical stimulation (NMES) may alleviate pain, enhance functional abilities, and increase strength after periods of disuse. In-home intervention using MT, NMES, and MT+NMES for ten-minutes three

times per day five-days per week during the last three weeks of immobilization for DRF surgery was designed (32).

In 2023, Sanaz Roustaei investigated the effects of mirror therapy on shoulder pain, disability, and quality of life. In order to examine the effect of mirror therapy (MT) on shoulder pain/disability and quality of life among women with mastectomy surgery. Sixty unilateral mastectomy patients were selected randomly assigned either to the mirror therapy (MT) group (N = 30) or the sham therapy group (ST) (N = 30). Participants in both groups received a home-based, self-administered, nurse-led training session for three weeks, 30 minutes each day, and five days a week using or without mirror use respectively. Shoulder pain/disability and QOL outcomes were measured prior to the treatment and 3 months after treatment. Shoulder pain and disability scores were significantly higher in the MT group, but no significant difference was observed in any EORTC QOL scales apart from the QLQ-BR23 scale (33).

The year 2023 saw Purushothaman et al. conduct studies in assessing the effectiveness of mirror therapy in preventing phantom limb pain in individuals undergoing surgery below knee amputation. The principal purpose of this research was to determine the incidence of PLP after 6 months of the surgery in patients receiving mirror therapy and controls. In this experiment, the patients scheduled for below knee amputation were randomly divided into two groups. Those put in the M group received mirror therapy in the postoperative period. This procedure was carried out twice daily for seven days, with each session lasting 20 minutes. Subjects who developed pain from the missing part of their amputated limb were diagnosed with PLP. A follow-up was done for 6 months and the occurrence time and the intensity of PLP among other demographic information was documented. It was concluded that mirror therapy decreased the likelihood of PLP occurrence before it happened in patients undergoing amputation operations (34).

Federico Temporiti et al. in 2022 carried out research on Action Observation and Motor Imagery on the day prior to surgery to improve functional recovery in patients who had

undergone total hip arthroplasty. The objective of this research was to explore the effects of Action Observation and Motor Imagery on the day prior to surgery on functional recovery in patients who have undergone total hip arthroplasty. Post-operative rehabilitation process for all patients was standardized. In experimental group (AO + MI), two 12-minutes' action observation and motor imagery sessions were conducted on the preoperative day, while control group underwent education only without any preoperative activities. Functional mobility was assessed by an examiner blinded for Timed Up and Go (TUG) (the primary outcome), maximal walking velocity (10-Meter Walk Test - 10MWT), pain level (Numeric Pain Rating Scale - NPRS) and fear of movement (Tampa Scale of Kinesiophobia - TSK). Assessment took place the day prior to surgery and after 4 days of surgery. The Action Observation and Motor Imagery applied the day prior to surgery resulted in less functional impairment of patients compared to the control group during the first few days following total hip arthroplasty (35). Sonawadekar, 2022 conducted a case study to examine the effectiveness of mirror therapy on range of motion in patients with postoperative knee and ankle dislocations. A total of 30 participants were included, who commonly presented with pain, swelling, and difficulty in functional activities. Mirror therapy was applied alongside range of motion exercises, performed at least once daily over a period of two weeks. Outcomes were assessed using descriptive statistical measures including mean, frequency, and percentage. The intervention is based on visual feedback mechanisms, aiming to reduce pain and improve motor function. Results showed that most participants demonstrated improvement in range of motion following the intervention. It was concluded that mirror therapy may be beneficial in enhancing recovery of movement in postoperative lower limb conditions (36).

In 2022, Carozzo et al. conducted a study titled Efficacy of Visual Feedback Training for Motor Recovery in Post-Operative Subjects with Knee Replacement. The primary aim of this study is to determine the effect of visual feedback training on motor recovery in post-operative patients having

undergone a total knee replacement (TKR). The performance of 40 patients who had undergone a total TKR (27 female patients; average age: 70.5 (67.2–74.0) years) was assessed in a single-center, single-blinded, randomized controlled study. These patients were randomly allocated to experimental or control groups in equal numbers. Each patient was treated in one-hour sessions twice a day on five weekdays weekly, over a period of six weeks. The patients from the “control” group underwent conventional physical therapy, while those from the experimental group underwent advanced knee training with visual feedback using the TecnoBody equipment (Walker View 3.0 SCX, Dalmine (BG), Italy). Clinical tests as well as the obtained kinematics data from gait analysis were assessed to illustrate the dynamic balance function standing up prior to and after treatment. Following treatment, both experimental group and control group had marked improvements, similar to one another, in terms of the clinical test scores (NRS for pain and Barthel Index). Utilizing visual feedback therapy in conjunction with conventional rehabilitation techniques helps enhance knee joint function and control in postoperative total knee replacement surgery patients (29).

Rajendram et al., 2022 conducted a systematic review and meta-analysis to evaluate the effectiveness of mirror therapy and virtual reality (VR) in reducing pain levels. A total of 15 studies involving 300 participants were included, with eight studies on mirror therapy (214 participants) and seven on VR (86 participants). Outcomes assessed were pain intensity using the Visual Analogue Scale (VAS), analyzed through mean difference (MD) using RevMan (version 5.4). The mean age of participants ranged from 36 to 63 years, with the majority being male and lower limb amputees. Both interventions showed significant reductions in pain, with mirror therapy demonstrating a mean VAS reduction of 2.54 and VR showing a reduction of 2.24. However, no statistically significant difference was found between the two interventions ($p = 0.69$). It was concluded that both mirror therapy and VR are effective in reducing pain, with comparable outcomes between the two approaches (37).

Zhang et al., 2022 conducted a systematic review to investigate the effect of mirror therapy on unilateral neglect and activities of daily living in stroke patients, compared with no treatment, sham mirror therapy, or routine therapies. A comprehensive electronic search was performed across PubMed, Embase, Web of Science, Cochrane Central Register of Controlled Trials, China National Knowledge Infrastructure, and Wanfang Data to identify relevant randomized controlled trials (RCTs). A total of five RCTs were included in the analysis. Outcomes assessed were neglect and daily living activities. Mirror therapy, whether used alone or combined with other treatments, showed significant improvement in neglect compared to control interventions (SMD = 1.62, 95% CI = 1.03–2.21, $p < 0.00001$). Similarly, mirror therapy demonstrated significant effectiveness in improving activities of daily living (SMD = 2.09, 95% CI = 0.63–3.56, $p = 0.005$). It was concluded that mirror therapy is an effective intervention for improving both neglect and functional independence in stroke patients (38).

Xie et al., 2022 conducted a systematic review and meta-analysis to evaluate the effectiveness of mirror therapy in patients with phantom limb pain (PLP). A total of 10 randomized controlled trials were included in the final analysis. The methodological quality of the studies was assessed using the Physiotherapy Evidence Database (PEDro) scale by two independent reviewers. Outcomes were measured using the Visual Analog Scale (VAS), and data were pooled according to follow-up intervals of 1, 3, 6, and 12 months, with subgroup analysis based on duration of pain. Meta-analysis revealed a statistically significant reduction in pain in the mirror therapy group compared to the control group within 1 month ($I^2 = 0\%$; SMD = -0.46 , 95% CI -0.79 to -0.13 ; $p = .007$). Patients with pain duration longer than one year showed greater benefit ($I^2 = 0\%$; SMD = -0.46 , 95% CI -0.85 to -0.07 ; $p = .02$). It was concluded that mirror therapy is effective in reducing pain in the short term, particularly in patients with long-standing PLP, although evidence for long-term effects remains limited (39).

In 2022, Avanti A. Gachake studied on An Integrated Physiotherapeutic Approach With

Virtual Reality in Schizophrenic Patients With Ipsilateral Femoral Shaft and Intertrochanteric Fractures. The physiotherapy protocol involved virtual reality-based (VR-based) interventions in adjunct to conventional therapeutic interventions like strengthening exercises, range of motion exercises, application of electrical modality, balance training, gait training, VR-based relaxation, and aerobic exercises. We used the Lower Extremity Functional Scale, Manual Muscle Testing, Range of Motion, Brief Psychiatric Rating Scale, and the Numerical Pain Rating Scale as outcome measures. The comparison of preand post-outcome measure scores demonstrates a significant improvement (40).

In 2022, Sandra Rierola-Fochs et al., Effectiveness of graded motor imagery protocol in phantom limb pain in amputated patient. The objective of the study is to assess the efficacy of the GraMI protocol in phantom limb pain in amputated patients. This will be a randomized clinical trial using two parallel groups and simple blinding, along with a qualitative study of phenomenology that will use semi-structured interviews. Individuals above the age of 18 years, with unilateral amputation of limbs, with a minimum of three points on the visual analogue scale of pain, and pharmacologically stabilized, will be selected for inclusion. An initial, an assessment after the intervention program (9 weeks), and a follow-up assessment at 12 weeks after the intervention will be done. The objective of the qualitative research is to understand the experiences of patients with phantom limb pain and their satisfaction from the intervention program. Under the GraMI Protocol, patients will be able to use brain reorganization, analysis of movement, sensory stimulation, and functional activity for motor learning (41).

Although mirror therapy has shown promising results in reducing pain and improving motor recovery in neurological conditions, its role in postoperative orthopedic rehabilitation remains insufficiently explored. Current literature on intertrochanteric fractures primarily emphasizes surgical techniques and conventional physiotherapy, with limited focus on adjunctive, non-invasive interventions for early recovery.

Moreover, existing studies rarely address early postoperative phases, where pain and immobility significantly hinder functional outcomes. There is also a lack of standardized protocols for implementing mirror therapy in orthopedic settings. Additionally, evidence regarding its effectiveness in improving functional mobility alongside pain reduction in such patients is scarce. Most research is conducted in single-center settings, limiting generalizability. Therefore, a need exists for multicenter or well-structured clinical studies to evaluate the effectiveness of mirror therapy in enhancing early postoperative recovery in intertrochanteric fracture patients.

Literature Gap

Despite the potential benefits of mirror therapy in pain management and rehabilitation after neurological and orthopedic disorders, there is very little scientific evidence that evaluates the efficacy of mirror therapy in patients undergoing intertrochanteric femur fracture surgeries. Previous literature has mostly revolved around conventional physiotherapy without any RCTs examining the role of mirror therapy in early postoperative phases. Furthermore, the effect of mirror therapy on functional recovery and postoperative pain among patients with intertrochanteric femur fractures has not been adequately studied yet.

OBJECTIVE

The objective of the study is to:

- Determine the effects of Mirror Therapy on Early Postoperative Functional Recovery and Pain in Patients with Postoperative Intertrochanteric Femur Fracture.

OPERATIONAL DEFINITIONS:

1. Mirror Therapy

Mirror therapy is a treatment modality whereby the image of the nonaffected limb seen in the mirror creates the illusion of movement of the affected limb, hence improving its movements and decreasing pain (42).

2. Intertrochanteric Femur Fracture

The intertrochanteric femur fracture is an extracapsular fracture involving the area between

the greater and lesser trochanters of the proximal femur that usually occurs due to low energy trauma in elderly individuals (43).

3. Early Postoperative Functional Recovery

Early postoperative functional recovery is the term used to describe the return of physical mobility, capacity for ambulation, and independence in daily life activities within the initial weeks after the surgery. In the current study, this will be measured through the Harris Hip Score (HHS) (44).

4. Postoperative Pain

Postoperative pain is a painful sensation caused by the presence or threat of tissue injury after undergoing a surgical procedure. In this study, the Numeric Pain Rating Scale (NPRS) will be used to measure the intensity of pain (45).

5. Traditional Physiotherapy

Traditional physiotherapy involves standard post-surgery rehabilitation techniques which include pain control, range of motion exercises, muscle strengthening, gait training, balance training, and functional mobility exercises after surgery for hip fractures (46).

HYPOTHESIS

Null Hypothesis

There was no substantial difference in early postoperative functional recovery and pain in patients undergoing mirror therapy and conventional physiotherapy treatment compared to those who had conventional physiotherapy only for intertrochanteric femur fracture surgery.

Alternative Hypothesis

The patients who undergo mirror therapy in addition to conventional physiotherapy will show significantly better results of functional recovery after the surgery for an intertrochanteric femur fracture, compared to patients undergoing conventional physiotherapy without mirror therapy.

CHAPTER 3

MATERIALS AND METHODS

3.1 RESEARCH DESIGN:

Randomized controlled trial study design was utilized.

3.2 CLINICAL SETTING

Data was collected from following hospitals:
Comprehensive rehabilitation center (CRC),
Jinnah Hospital, Lahore.

3.3 SAMPLE SIZE:

The sample size target was obtained through the OpenEpi software program. Considering an estimated effect size of 0.8, alpha of 0.05, and statistical power of 0.80, it was found that the minimum required sample size should be 54 participants (27 in each group). Since there is a possibility of losing some subjects due to attrition of about 10%, the total number of participants enrolled was increased to 60 people (30 in each group) (47).

Start

Enter

Results

Examples

Help

Sample Size For Comparing Two Means

Input Data

Confidence Interval (2-sided)	95%		
Power	80%		
Ratio of sample size (Group 2/Group 1)	1		
	Group 1	Group 2	Difference*
Mean	36.01	33.23	2.78
Standard deviation	4.01	3.1	
Variance	16.0801	9.61	
Sample size of Group 1	27		
Sample size of Group 2	27		
Total sample size	54		

*Difference between the means

3.4 SAMPLING TECHNIQUE:

Non probability purposive sampling technique was followed.

3.5 DURATION OF STUDY:

Study was completed in 6 months after approval of synopsis.

3.6 SELECTION CRITERIA:

3.6.1 INCLUSION CRITERIA:

- Adults aged between 50 and 80 years with

history of having gone through surgery for a unilateral intertrochanteric femur fracture (46).

- Adults who were up to 7 days from surgery (48).
- Patients who had been declared stable after the surgery and cleared by the orthopedic surgeon for post-surgery recovery (46).
- Adults who were permitted by the surgeon to put on weight as tolerated (49).
- Adults who were capable of following verbal commands during treatment (49).

- Adults who gave their written informed consent (50).

3.6.2 EXCLUSION CRITERIA:

- Patient with pathological fractures (46).
- Patient with multiple fractures or polytrauma (46).
- Patient with a history of surgery on the affected hip previously (46).
- Patients with neuromotor diseases such as stroke or Parkinson's (49).
- Patients with severe cognitive deficits that would prevent rehabilitation participation (49).
- Patients with severe vision loss preventing proper use of mirror therapy (50).
- Patients with postoperative complications necessitating immobilization (48).
- Patient that refused or withdrew from the study (50).

3.7 ETHICAL CONSIDERATION

The guidelines for the research have been set by the ethical committee of Superior University be followed and the rights of the research participants were respected.

- The participants signed the written informed consent form (attached).
- The participants' confidentiality was maintained while doing the data collection.
- The participants remained anonymous during the whole research period.
- The participants were told that there were no disadvantages or risks associated with the procedure of the study.
- They were also told that they could withdraw at any point during the procedure of the research.
- There were no risks associated with this research.
- Everything possible was done to maintain their privacy and anonymity in any way. Their identity will not be revealed through any publication as a result of this study.
- The participation of the subjects in the research was voluntary. The participants can decline the participation in this research.

3.8 DATA COLLECTION PROCEDURE:

1. Recruitment:

Screening of potential subjects was done continuously among the orthopedic wards of the Department of Orthopedic Surgery after surgical stabilization. The recruitment process was started on Postoperative Day 1 (POD 1). After confirming structural eligibility, the attending orthopedic surgeon will ascertain the stability and medical status of the subject in order to clear him/her for early bed mobility. The research coordinator was thereafter talk to the patient and his/her caregiver about the study and distribute a Participant Information Sheet and rationale behind the therapy.

2. Enrollment:

Participants were randomly allocated into the two groups using pre-intervention evaluation results.

3. Randomization:

A computer-generated randomization sequence was used to allocate participants into either the control or experimental group. To maintain allocation concealment, sealed opaque envelopes were utilized. Outcome data were collected before and after the intervention period.

4. Blinding:

The experimental research adopted a single-blind approach, whereby the person conducting the assessment would remain blind about the group affiliation throughout the process.

5. Treatment:

Standardized Core Rehabilitation (Conducted for Both Groups) (51) (52)

Every participant of both groups underwent the same progressive 30 minutes of conventional physical therapy routine, conducted on a daily basis, five days a week, 6 weeks (or until acute discharge from hospital):

Mobility Drills: Active ankle pumps, circumduction, and passive/active-assisted ROM of the injured hip and knee within the pain threshold of each patient.

Isometric and Muscle Activation Exercises: Isometric muscle setting for the quadriceps, hamstrings, and glutes muscles (for five seconds

followed by five seconds of rest for three sets of ten repetitions).

Functional Mobility Progression: Bed mobility drills, transition to rolling to the uninjured side, transition from lying on the side to long-sitting position, and edge of bed sitting balance exercises. After surgical clearance of weight bearing capacity, the patient underwent stand-pivot transfers and safe walking with walking frame.

Group A: Experimental Group (Mirror Therapy and Core Rehabilitation)

Patients in the Experimental group were provided with 30-minute Mirror Therapy each day before their normal physical therapy session.

Environmental Architecture and Positioning: The intervention was done in a quiet and distraction free setting to provide the best possible focused visual attention. The patient was placed in the long sitting or semi-reclining position on a normal plinth where the trunk was placed at an angle of 45° - 60° using a wedge pillow. A specially designed lightweight mirror box (35 times 40 times 90cm) equipped with an extremely accurate, distortion free reflective acrylic mirror on its sagittal surface was placed longitudinally between the legs. The surgical (affected) leg was carefully placed inside the box, effectively blocking it out of visual range. The healthy leg was kept outside the box placed in a position exactly parallel to and directly in front of the reflecting mirror surface. The therapist then positioned the mirror in such a way that when the patient slightly moved forward and looked into the mirror, the visual image of his/her healthy leg overlapped with the actual anatomical position of the concealed affected leg.

Neurocognitive and Motor Phased Development: This was achieved by performing the exercises using a strict schedule consisting of three sequentially timed phases. All motions were done in synchrony using both limbs while instructing the patient to concentrate their gaze on the mirror reflection while mentally visualizing that their injured limb is moving smoothly and without any pain:

Phase 1: Distal Mobilization and Vascular Conditioning (Day 1 to 5):

Ankle Dorsiflexion / Plantar Flexion: Bilateral

motion of the ankles through the sagittal plane in synchrony (2 x 10 repetitions; 3 seconds of end range hold).

Ankle Circumduction: Rotational motion in clockwise and anticlockwise directions of the ankle joint (2 x 10 rotations for each side).

Toe Mobilization: Separation and bending of all toes to activate distal neurological pathways (2 x 15 repetitions).

Phase II: Intermediate Kinetic Chain Activation (Days 6-12)

Active-Assisted Heel Slides: The patient actively flexed his uninjured knee and hip joint, sliding the heel back over the sheets' surface, while the therapist performing the treatment gave him active-assisted movement inside the box in perfect synchronicity with his opposite limb to make sure that physical symmetry with the reflected image is achieved (2 sets of 10 reps).

Synchronized Quadriceps Isometrics: The patient actively engaged in strong voluntary isometric contractions of his uninjured quadriceps (pressing his popliteal area into the bed), at the same time making sub-maximal isometric contraction of his injured quadriceps inside the box (3 sets of 10 reps, 5 second hold).

Phase III: Proximal Control and Joint Coordination (From Day 13):

Active Hip Flexion/ Straight-Leg Exercise: With respect to the limits of stability of the surgical fixation, the patient did short arc active hip flexion exercises outside the box, while the therapist performed short arc lift of the leg inside the box (2 x 8).

Gentle Hip Abduction/Adduction: Lateral sliding movements of the unaffected limb, followed by active assisted translation movement of the affected limb inside the box without crossing the midline (2 x 10).

Group B: Control Group (Mirror Sham Therapy + Core Rehabilitation)

For participants assigned to the Control Group, the same environmental setting was created with the box of the same size and sagittal orientation.

Environmental Set-Up and Patient Positioning: The participant was positioned in the same long-sitting or semi-recumbent position on the therapy

table with the box in a sagittal orientation between the lower limbs; however, the mirror's reflective surface was completely covered with non-reflective matte material.

Exercise Regimen: Patients looked at the covered box and performed the same sequence of bilateral exercises in synchronization for 30 minutes. This protocol ensured that the time spent with the therapist, patient discomfort, spatial arrangement, and attention bias were perfectly controlled without creating any illusion of normal movement in the affected limb. All other exercise regimens were consistent with those in the experimental group.

3.9 DATA COLLECTION TOOLS:

Data was collected through following questionnaires:

3.9.1 Numeric Pain Rating Scale (NPRS)

A. Psychometric Properties: Validity and Reliability

The 11-point Numeric Pain Rating Scale (NPRS) is a very responsive, one-dimensional scale for assessment of acute pain intensity and is used in modern orthopedic studies. In samples of patients recovering from acute lower limb surgeries in elderly population, recent studies prove the excellent test-retest reliability of NPRS, with the Intra class Correlation Coefficient (ICC) being equal to 0.93 to 0.97 (53). With regard to construct and concurrent validity, recent studies reveal very high correlation coefficients of NPRS with the Visual Analog Scale (VAS) ($r = 0.89$ to 0.94) and with functional behavior changes during early postoperative rehabilitation (54). Moreover, recent clinical trials concerning the effect of mirror therapy protocols in early postoperation period show that visual/verbal presentation of NPRS leads to significantly lower non-compliance and reduced cognitive load in post-fracture elderly population compared to traditional line scale (55). The Minimal Clinically Important Difference (MCID) for acute postoperative orthopedic stabilization with NPRS is 2.0 points reduction (53).

B. Detailed Operational Procedure

To avoid variation due to investigator

measurement, the blinded outcome assessor conducted the test according to a stringent, scripted procedure of steps as follows:

Positioning of Patient: The patient was kept lying down in a comfortable supine or semi-supine position on the hospital plinth. Auditory and visual distractions in the environment were reduced.

Presentation of Visual Anchor: The assessor positioned a laminated horizontal scale with numbers from 0 to 10 visible to the patient.

Assessor delivered the following standardized instruction to the patient: "If the scale of pain is like this where 0 indicates absolute absence of pain and 10 indicates maximum imaginable pain, what is the single whole number representing your pain?"

Static Measurement: The patient gave the numerical answer for his/her pain score without any movement while lying down in a supine position for at least 5 minutes. This measure was termed as Static NPRS (53).

Dynamic Measurement: The patient's lower limb with surgical stabilization was passively flexed by the assessor up to a limit of 30 degree (as measured through goniometer). At this end-range of motion, the patient gave his/her pain rating which was recorded as Dynamic NPRS (41).

3.8.2 Universal Dual-Arm Goniometer

A. Psychometric Properties: Validity and Reliability

Manual goniometry still represents the gold standard and efficient clinical method for assessing joint movement limitations. For assessing movement of the lower extremity joints among the patients who underwent surgical repair of fractures, the intra-rater reliability of universal goniometry reaches high values (ICC = 0.90 to 0.96), while the inter-rater reliability also reaches high levels of (ICC = 0.86 to 0.91, provided that an investigator was thoroughly trained and used strict anatomical landmarks (56). Concurrent and criterion validity have been shown in comparison to the contemporary digital radiographic assessment and smartphone-assisted digital measurements and revealed minimal mean structural deviations within the range of 2.5 degree

and 4.2 degree (56). The MDC of manual goniometric assessment of the lower extremities (hip and knee joints) equals 5.0 degree (57).

B. In-depth Operational Procedure

The investigator employed a consistent 12 inches long plastic universal dual arm goniometer. Bilateral testing was done starting with the intact contralateral side for establishing the anatomical baseline of the individual followed by measuring the surgically fixed limb.

Hip Flexion Range of Motion (ROM):

Positioning: The subject is placed in a supine position with the pelvis being stabilized in horizontal alignment.

Landmarks Alignment: The goniometer fulcrum was positioned on the lateral aspect of the greater trochanter. The stationary arm was positioned in parallel to the mid-lateral axis of the pelvis and the trunk, whereas the moving arm was parallel to the lateral midline of the femur, directed precisely towards the lateral femoral epicondyle (56).

Execution: The subject actively moved his foot towards his buttocks sliding heels along the treatment sheets. He reached the point where he felt comfortable and stopped there.

Knee Flexion Range of Motion (ROM):

Patient Positioning: Patient in supine position changing from fully extended knee to a flexed position.

Anatomical Landmark Alignment: The point of contact was placed directly over the lateral epicondyle of the femur. The fixed arm was aligned with the lateral midline of the femur while the moving arm was aligned with the lateral midline of the fibula towards lateral malleolus (57).

Execution of Procedure: The knees were actively flexed and the assessor aligned the arms with the appropriate anatomical landmarks and measured the angle in peak flexion.

Protocol for Averaging: For each particular direction of the joint three tests were done with 30 seconds break between them. The mean value out of the three was noted (56).

3.8.3 Harris Hip Score (HHS)

A. Psychometric Properties: Validity and Reliability

The Harris Hip Score (HHS) is a clinician-based

disease-specific composite questionnaire specifically designed to assess outcomes after major surgeries involving the hip, such as internal fixation. According to recent measures of the instrument, the tool displays an internal consistency Cronbach's alpha of $\alpha = 0.85$ to 0.91 and a test-retest reliability value of $ICC = 0.93$, thus possessing great reliability (58). Its construct and convergent validity have been confirmed by high correlation coefficients ($r = 0.70$ to 0.79) between the instrument and the Physical Function subscales of the Medical Outcomes Study Short Form-36 (SF-36) and the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) (59)s. The Minimal Clinically Important Difference (MCID) for the total HHS score in acute postsurgical population has been identified as 8.0 points (58).

B. Procedure of Operationalization

The result evaluator computed the total composite score (out of 100 points) using the results obtained from the structured patient/caregiver interview and the physical examination results.

Structured Interview (Pain and Function - 91 Points Max):

Pain Subscale (44 pts max): Pain experienced by the patient was rated by the assessor on the ordinal scale from 44 to 0 depending on their condition for the past 24 hours (58).

Gait Function Subscale (33 pts max): Severity of limp, dependency on assistive devices, and maximal continuous walking distance were assessed by the assessor (59).

Activities of Daily Living Subscale (14 pts max): The patient was questioned regarding their ability to go up and down the stairs, tie up their shoes/socks, sit on a regular chair, and travel in public transport.

Physical Assessment (Lack of Deformity - Maximum Points: 4):

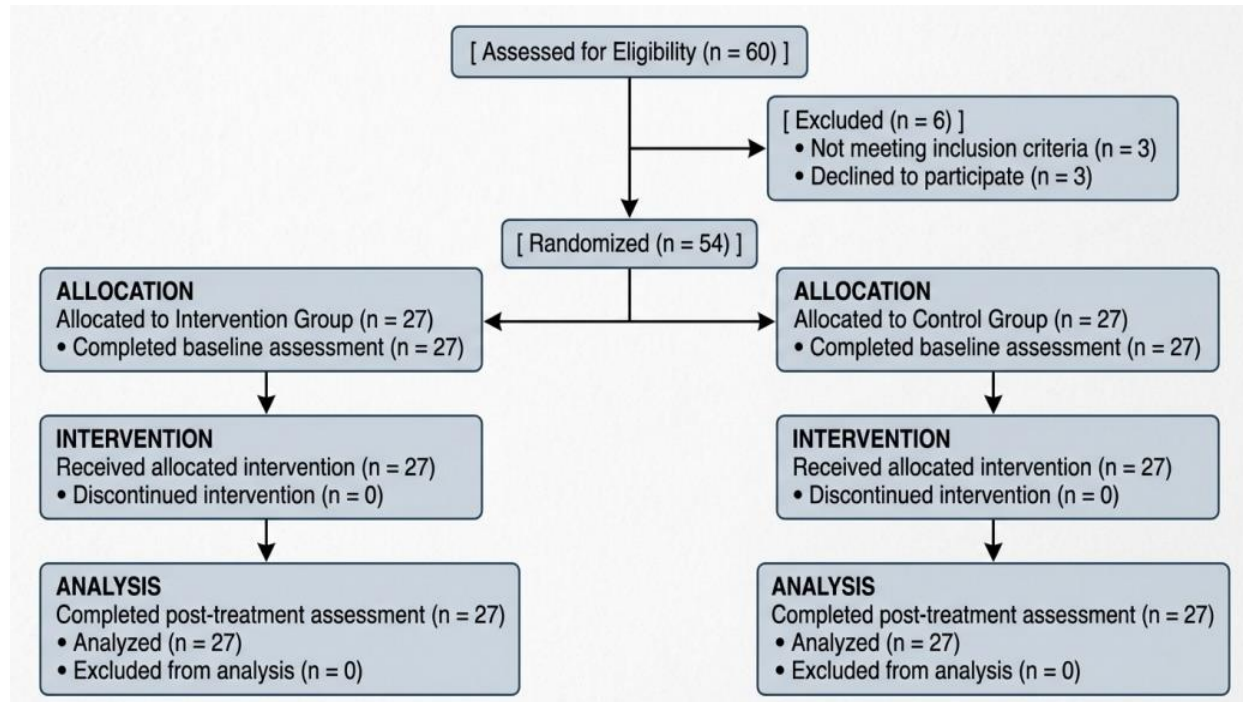
Points were assigned for the lack of four specific physical deformities that included fixed flexion contracture $> 30^\circ$, fixed adduction deformity $> 10^\circ$, fixed internal rotation deformity $> 10^\circ$, or limb length discrepancy > 3.2 cm (58).

Range of Motion Scale Conversion (Maximum Points: 5): The assessor used the degree measures taken while performing goniometric assessment.

The degree values were then inputted in the standard index equation of the HHS scale to convert them to an ordinal range between 0 and 5 (60).

Final Tiers: All scores were combined to calculate the total final score which was then categorized in four functional categories: 90–100 (Excellent), 80–89 (Good), 70–79 (Fair), and < 70 (Poor) (59).

CONSORT DIAGRAM



DATA ANALYSIS:

Data analysis was performed using IBM SPSS Statistics (Version 26.0) with a level of statistical significance of $\alpha = 0.05$. The normality of distribution was assessed using the Shapiro-Wilk test along with histogram and Q-Q plot inspection. Normally distributed continuous variables (age, BMI, and degrees of goniometry

ROM) were presented as mean $\pm$ standard deviation (SD), while ordinal and non-normally distributed variables (NPRS and total Harris Hip Score) as median and interquartile range (IQR). The homogeneity of baseline measurements in each group at T₀ was examined using the Independent Samples t-test for normally distributed continuous variables, Mann-Whitney U test for ordinal continuous, and Chi-square test or Fisher's Exact test for categorical variables. The time-related assessment of the intervention was conducted with regard to intra-group change

over the three time-points T₀, T₁, and T₂ of the ordinal NPRS and HHS measurements with the help of the Friedman Test; the post-hoc assessment of the difference between the time-points was carried out by the Wilcoxon Signed-Rank Test with Bonferroni adjustment ($p = 0.0167$). The inter-group comparison at certain mid-point (T₁) and endpoint (T₂) of measurement was conducted by the Mann-Whitney U Test. The continuous joint kinetic data (degrees of ROM) were analyzed with the help of Two-Way Repeated Measures ANOVA with the primary Time times Group Interaction Effect; Greenhouse-Geisser correction was applied when necessary while Fisher's LSD was used for post-hoc simple main effects. The missing values due to attrition or premature discharging of the patient were handled with the help of the Multiple Imputation or LOCF methods based on the ITT approach while PP analysis was conducted as a validation of clinical results.

CHAPTER 4

RESULTS

This chapter provides the statistical analyses of the data that were collected for assessing the therapeutic effect of the intervention program on the participants (n=54) who managed to complete the study protocol. In particular, the major purpose of this chapter is to explore the differences between Group A (Experimental Group, n=27) and Group B (Control Group, n=27) during all time points of the study. The

normality test performed by the Shapiro-Wilk method showed that there are statistically significant deviations from normality in primary baseline measures ($p < 0.05$). Thus, the non-parametric methods, namely Mann-Whitney U-test for intergroup comparison and Friedman test combined with post-hoc Wilcoxon Signed-Rank tests for assessment of intra-group chronological changes, were used to analyze changes in primary outcome measures.

Table 4.1.1: Participants' Demographic Profile (N=54)

Characteristic	Subcategory	Frequency (n)	Percentage (%)
Age (years)	Mean $\pm$ SD	48.25 $\pm$ 6.18	—
Gender	Male	22	40.7
	Female	32	59.3
Affected Knee Side	Right (Rt)	25	46.3
	Left (Lt)	20	37.0
	Bilateral	9	16.7
BMI (kg/m ²)	Normal (18.5–24.9)	11	20.4
	Overweight (25.0–29.9)	28	51.9
	Obese (> 30.0)	15	27.8
Duration of Symptoms	< 6 months	16	29.6
	> 6 months	38	70.4

Note

a: Calculated using Independent Sample t-test

b: Calculated using Chi-square (χ^2) test of independence

Table 4.1.1 depicts the baseline demographic and physical characteristics of the study participants in both the treatment groups (N = 54). The experimental group (Group A: Mirror Therapy

along with Core Rehabilitation, n = 27) showed an average age of 66.96 ± 6.24 years while the control group (Group B: Standard Core Rehabilitation alone, n = 27) had an average age of 63.67 ± 6.20 years. There was no statistically significant baseline difference observed in between the two groups in regard to the age ($p = 0.055$). In relation to physical parameters, there was similarity in between the two groups regarding physical baseline characteristics. 25 participants with Right side fracture 20 with left side 9 with bilateral. The mean height was 163.11 ± 11.05 cm in Group A

and 163.63 ± 11.42 cm in Group B ($p = 0.865$). The average body weight was 70.41 ± 11.64 kg in Group A and 73.85 ± 9.83 kg in Group B ($p = 0.244$). However, a statistically significant baseline difference was seen in Body Mass Index (BMI) where the average BMI in Group A (25.51 ± 3.41 kg/m²) was higher than in Group B (23.23 ± 2.13 (kg/m²), $p = 0.005$). With regard to gender distribution, females constituted the majority of the participants in both the groups. Group A consisted of 10 males (37.0%) and 17 females (63.0%) while Group B included 8 males (29.6%) and 19 females (70.4%). Overall in the entire sample (N = 54), females were 66.7 % (n = 36) while males were 33.3% (n = 18). The Chi-Square analysis revealed that there was homogeneity in gender distribution in between the two treatment groups ($p = 0.563$).

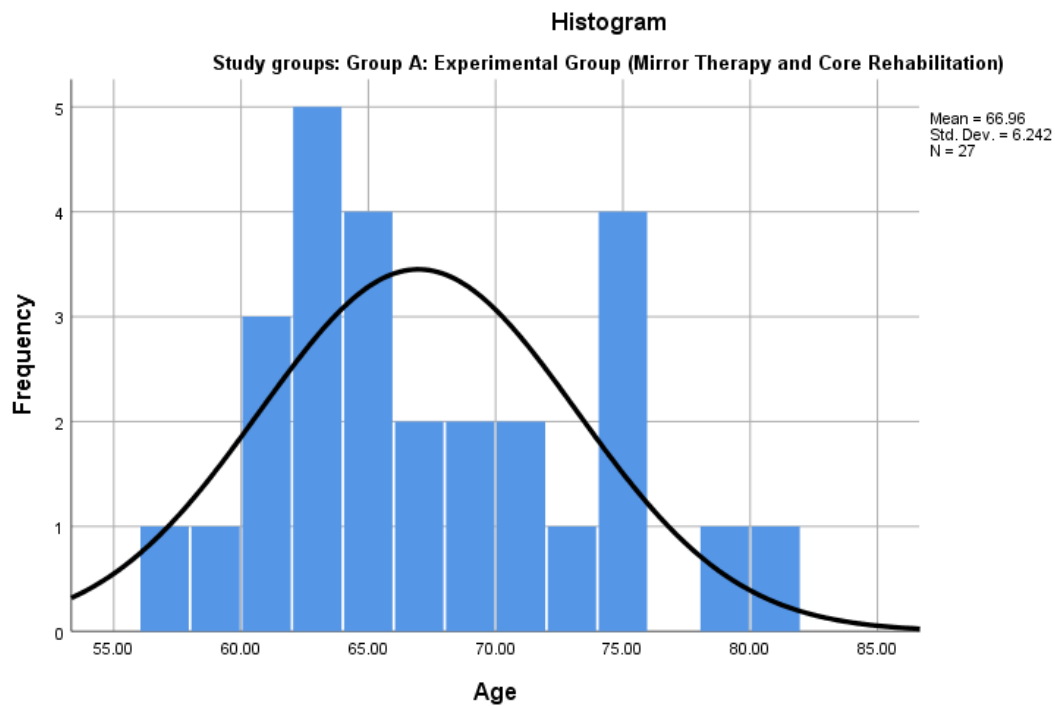


Figure 4.1.1: Age Group A

The experimental group (Group A: Mirror Therapy along with Core Rehabilitation, $n = 27$) showed an average age of 66.96 ± 6.24 years

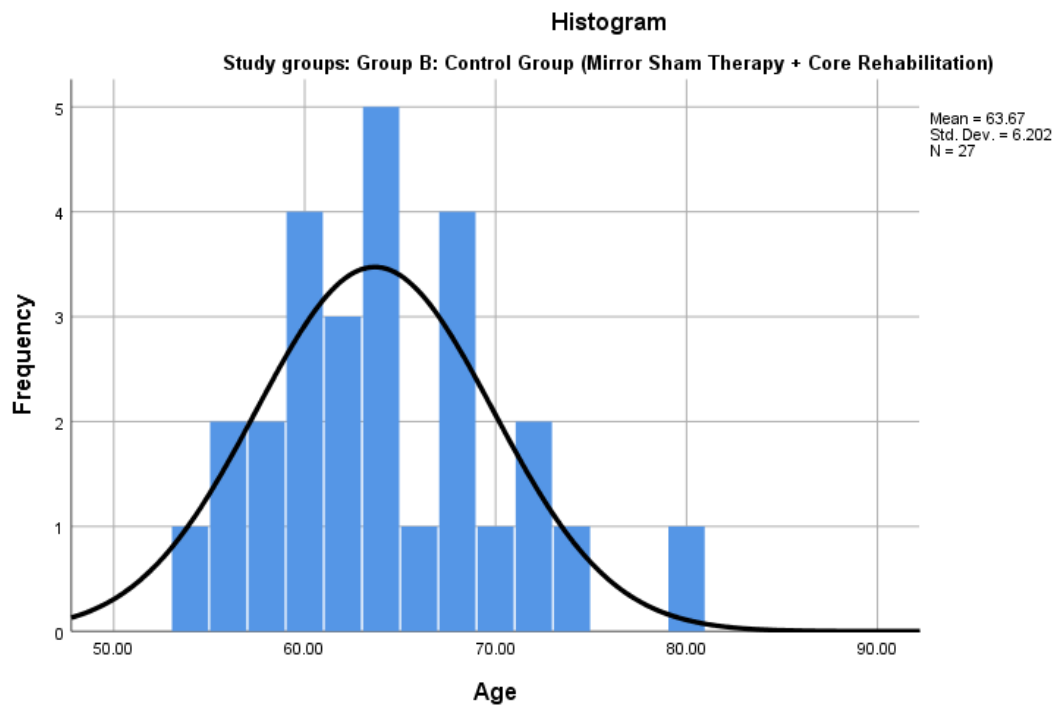


Figure 4.1.2: Age Group B

The control group (Group B: Standard Core Rehabilitation alone, $n = 27$) had an average age of 63.67 ± 6.20 years.

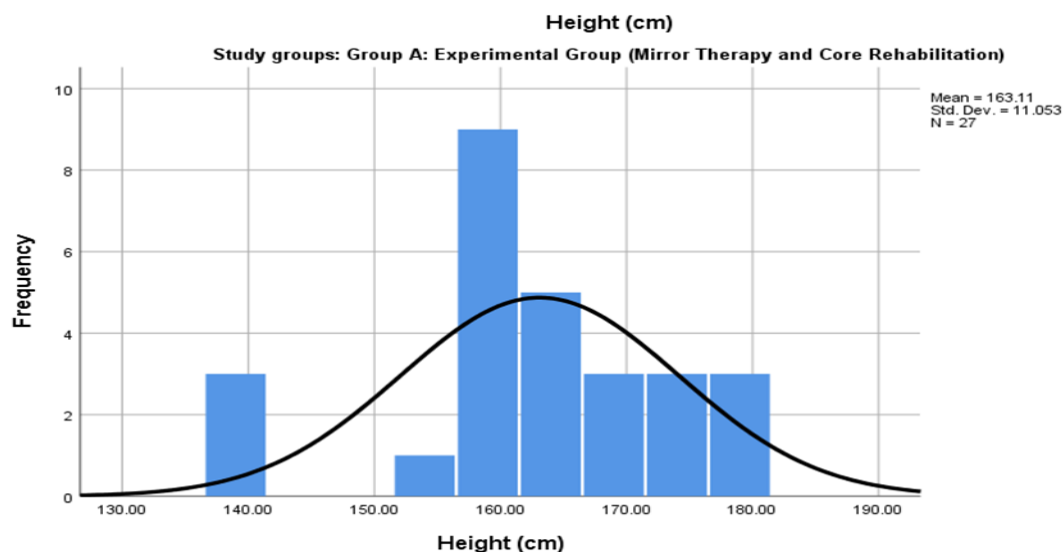


Figure 4.1.3: Height Group A

The mean height was 163.11 ± 11.05 cm in Group A and 163.63 ± 11.42 cm in Group B ($p = 0.865$).

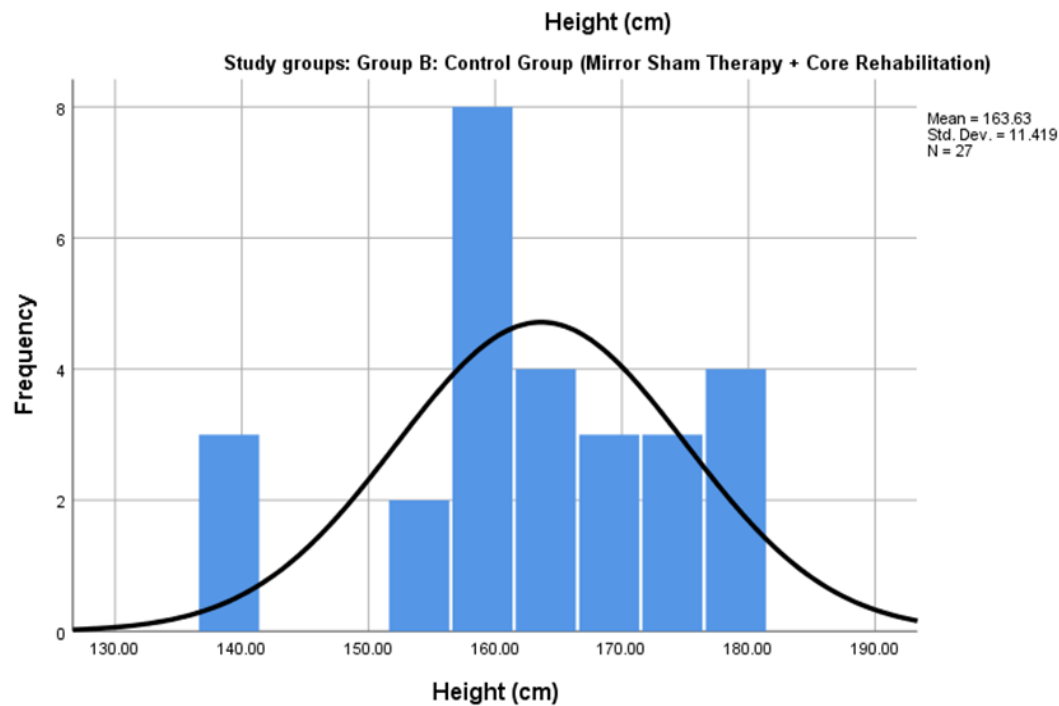


Figure 4.1.4: Height Group B

The mean height was 163.11 ± 11.05 cm in Group A and 163.63 ± 11.42 cm in Group B ($p = 0.865$).

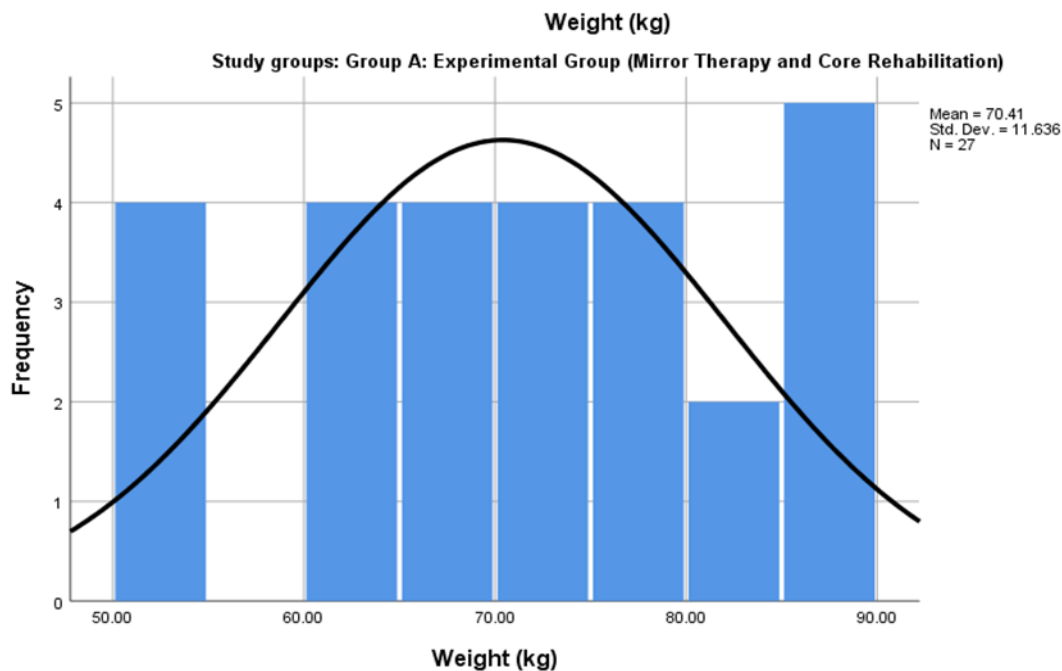


Figure 4.1.5: Weight Group A

The average body weight was 70.41 ± 11.64 kg in Group A and 73.85 ± 9.83 kg in Group B ($p = 0.244$).

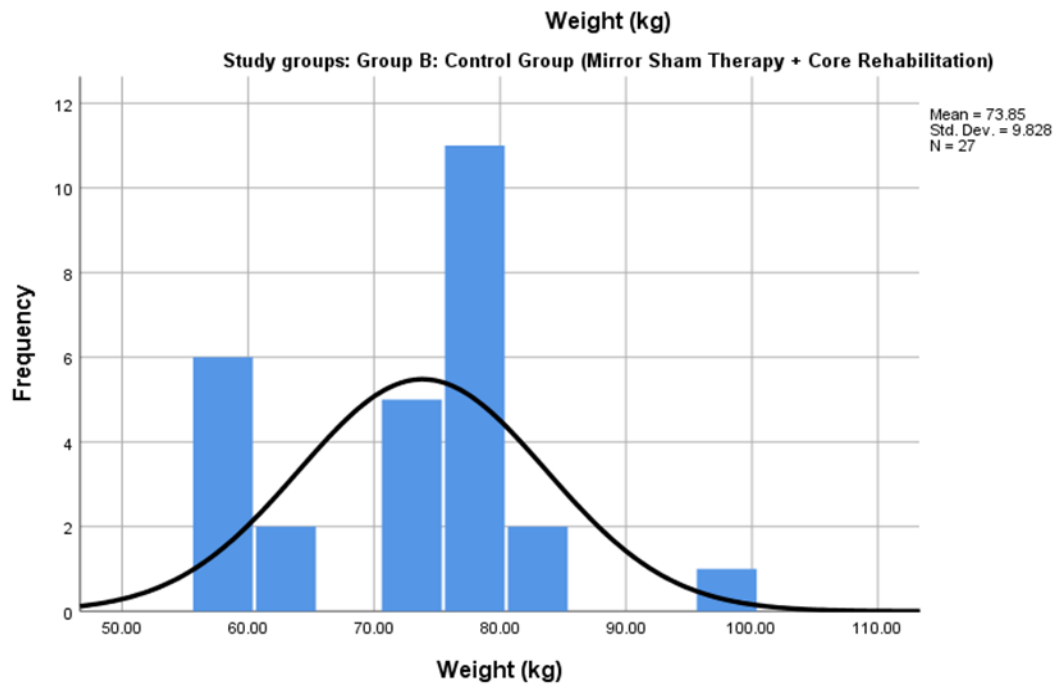


Figure 4.1.6: Weight Group B

The average body weight was 70.41 ± 11.64 kg in Group A and 73.85 ± 9.83 kg in Group B ($p = 0.244$).

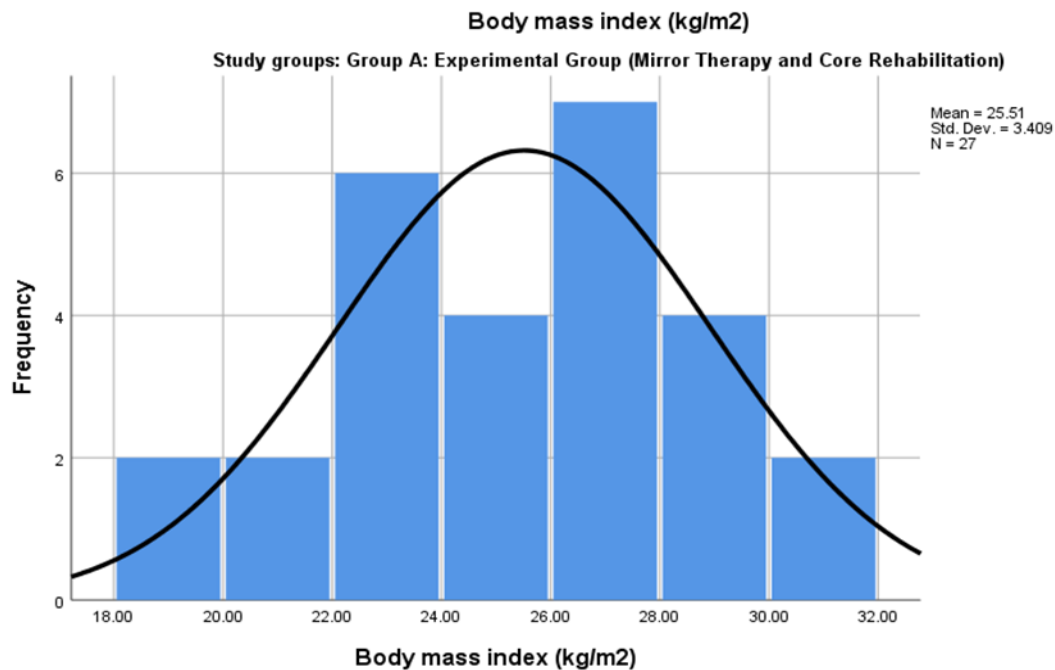


Figure 4.1.7: Body Mass Index Group A

However, a statistically significant baseline difference was seen in Body Mass Index (BMI)

where the average BMI in Group A (25.51 ± 3.41 kg/m²) was higher than in Group B (23.23 ± 2.13

(kg/m²), $p = 0.005$).

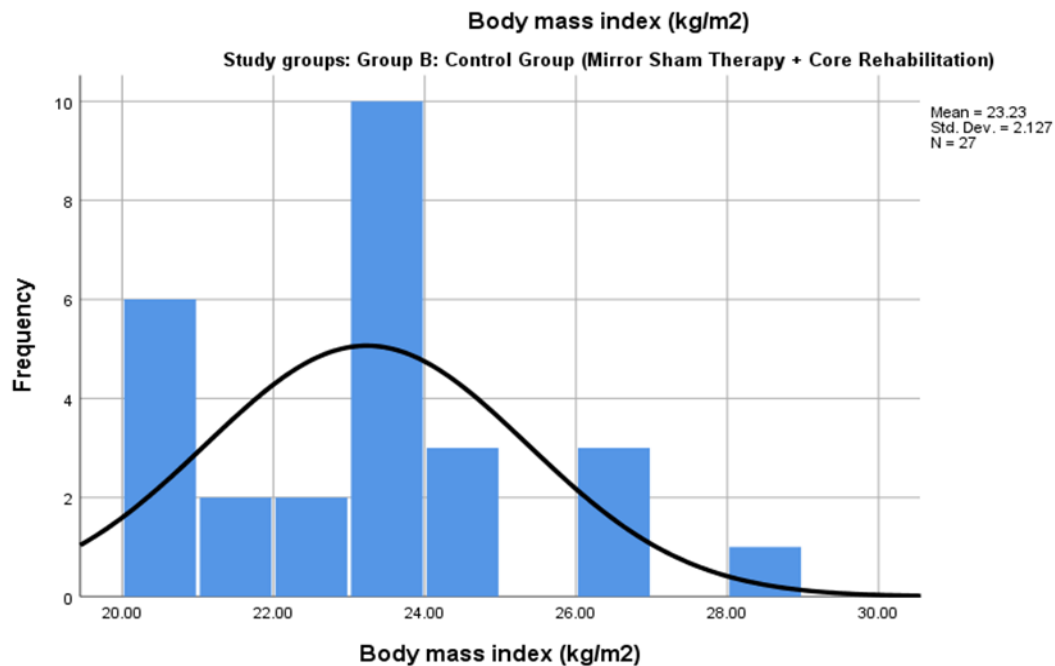


Figure 4.1.7: Body Mass Index Group B

However, a statistically significant baseline difference was seen in Body Mass Index (BMI) where the average BMI in Group A (25.51 ± 3.41 kg/m²) was higher than in Group B (23.23 ± 2.13 (kg/m²), $p = 0.005$).

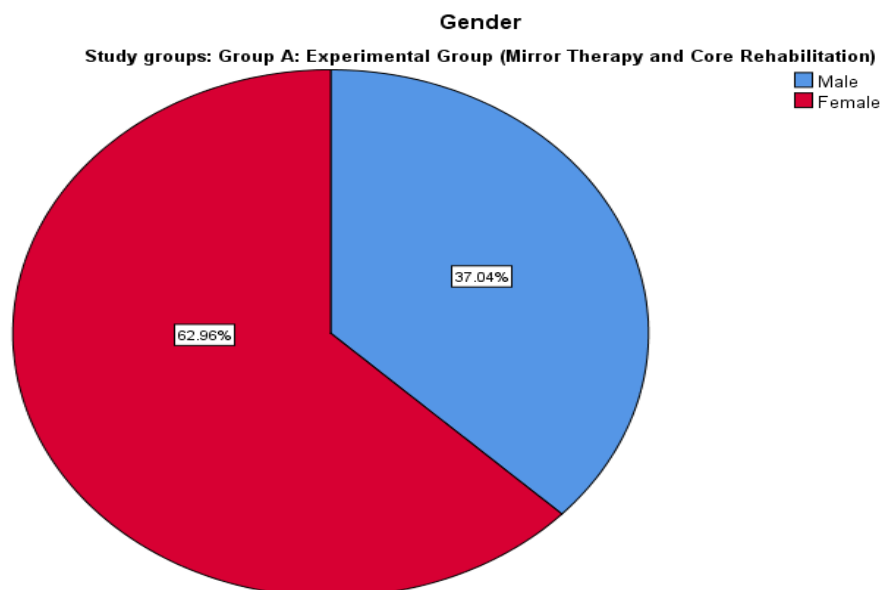


Figure 4.1.9: Gender Group A

With regard to gender distribution, females constituted the majority of the participants in both

the groups. Group A consisted of 10 males (37.0%) and 17 females (63.0%) while Group B included 8 males (29.6%) and 19 females (70.4%).

Overall in the entire sample (N = 54), females were 66.7 % (n = 36) while males were 33.3% (n = 18).

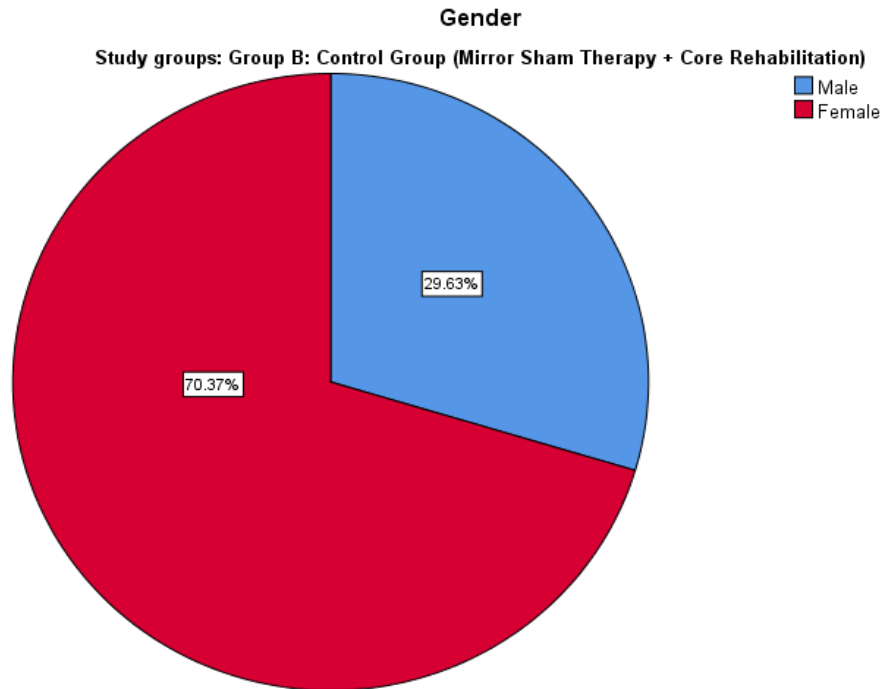


Figure 4.1.10: Gender Group B

With regard to gender distribution, females constituted the majority of the participants in both the groups. Group A consisted of 10 males (37.0%) and 17 females (63.0%) while Group B

included 8 males (29.6%) and 19 females (70.4%). Overall in the entire sample (N = 54), females were 66.7 % (n = 36) while males were 33.3% (n = 18).

Table 4.1.2: Study Groups

Study groups		
	Frequency	Percent
Group A: Experimental Group (Mirror Therapy and Core Rehabilitation)	27	50.0
Group B: Control Group (Mirror Sham Therapy + Core Rehabilitation)	27	50.0
Total	54	100.0

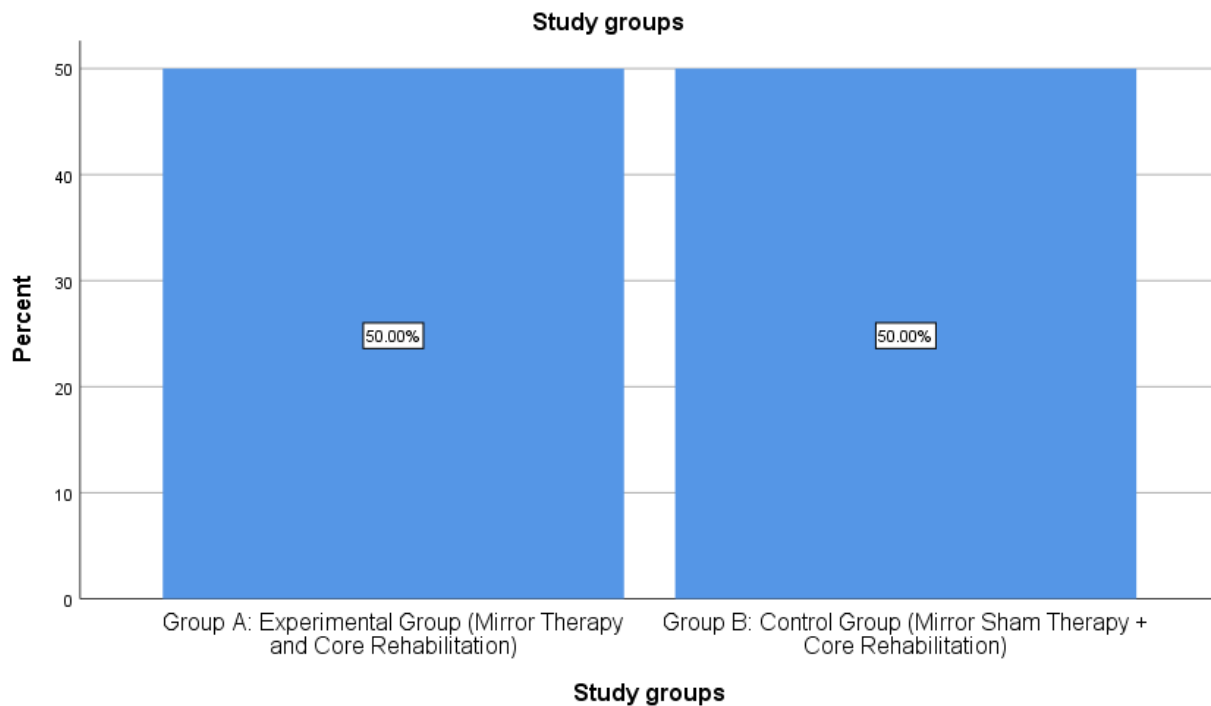


Figure 4.1.11: Study Groups

Table 4.1.3: Test of Normality

Tests of Normality			
	Shapiro-Wilk		
	Statistic	df	Sig.
Pre: Numeric pain rating scale	.234	54	.000
Pre: Universal dual arm goniometer	.250	54	.000
Pre: Hip flexion	.105	54	.002
Pre: Knee flexion	.094	54	.003
Pre: Hip harris score	.086	54	.001

Normality of baseline parameters distribution was analyzed with the help of the Shapiro-Wilk test. It showed that there were highly significant departures from normal distribution in all baseline variables ($p < 0.003$) with the following p-

values: NPRS (Numeric Pain Rating Scale) $p = 0.000$; UDG (Universal Dual-Arm Goniometer) score $p = 0.000$; Hip Flexion $p = 0.002$; Knee Flexion $p = 0.003$; Hip Harris Scores $p = 0.001$.

Table 4.1.4: Mann-Whitney U test between groups analysis at Baseline, 3rd week, and 6th week

Variables	Time Point	Group A Mean Rank	Group B Mean Rank	Median IQR	Z-value	P value
Numerical Pain Rating Scale (NPRS)	Baseline	22.61	32.39	7.5	-2.397	0.017
	Week 3	23.65	31.35	4.0	-1.865	0.062
	Week 6	18.13	36.87	3.0	-4.471	0.000
	Baseline	26.00	29.00	7.0	-0.759	0.448

Universal dual arm goniometer	Week 3	20.17	34.83	6.0	-3.538	0.001
	Week 6	15.54	39.46	4.0	-5.702	0.001
Hip flexion	Baseline	30.22	24.78	49.5	-1.273	0.203
	Week 3	34.20	20.80	60.5	-3.135	0.002
	Week 6	39.37	15.63	76.5	-5.548	0.001
Knee flexion	Baseline	30.74	24.26	70.0	-1.517	0.129
	Week 3	35.13	19.87	87.5	-3.567	0.001
	Week 6	38.65	16.35	110.5	-5.210	0.001
Hip harris score	Baseline	31.78	23.22	38.5	-2.000	0.045
	Week 3	34.85	20.15	53.0	-3.438	0.001
	Week 6	38.80	16.20	71.0	-5.280	0.001

Numerical Pain Rating Scale (NPRS): There was a statistically significant difference between the Mean Rank of Group A (Mean Rank = 22.61) and Group B (Mean Rank = 32.39) at the baseline level ($p = 0.017$). At Week 3, there was a reduction in the inter-group variability (Group A Mean Rank = 23.65, Group B Mean Rank = 31.35, $p = 0.062$). However, at Week 6, Group A had a statistically significantly lower pain score (Mean Rank = 18.13) than Group B (Mean Rank = 36.87) ($Z = -4.471$, $p = 0.0$).

Universal Dual-Arm Goniometer: Initial baseline results did not demonstrate any difference between groups ($p = 0.448$). Nevertheless, highly significant differences appeared at Week 3 ($p = 0.001$) and became even greater at Week 6 (Group A Mean Rank = 15.54, Group B Mean Rank = 39.46, $Z = -5.702$, $p = 0.001$).

Hip and Knee Flexion: Results of joint mobility curves correlated with findings obtained through goniometry. Significant differences favoring Group A appeared at Week 3 ($p = 0.002$ for hip, $p = 0.001$ for knee) and became even more evident at Week 6 ($p = 0.001$ for both hips and knees), confirming enhanced range of motion (ROM) results. Harris Hip Score (HHS): Initial baseline differences between functional status of groups were relatively small ($p = 0.045$).

After the procedure was performed, Group A demonstrated highly significant relative differences at Week 3 ($p = 0.001$) and distinct functional improvement at Week 6 (Group A Mean Rank = 38.80, Group B Mean Rank = 16.20, $Z = -5.280$, $p = 0.001$).

Table 4.1.5: Friedman test within groups analysis of NPRS

Variables	Outcome time	Median (IQR)	Group A		P value	Median IQR	Group B		P value
			Mean	SD			Mean	SD	
Numerical Pain Rating Scale (NPRS)	Baseline	7	7.07	1.00	.001	8	7.70	0.87	.001
	3 rd week	4	4.04	0.98		5	4.67	1.30	
	6 th week	2	1.78	1.12		4	3.63	1.28	

The table above provides analysis of pain intensity changes in both groups over time using the non-parametric Friedman test. As can be seen from the results, in the Experimental Group A, the median score on the Numerical Pain Rating Scale (NPRS) falls from 7 to 4 at the 3rd week and reaches its lowest value of 2 at the 6th week (7.07 ± 1.00 to 1.78 ± 1.12). In the Control Group B, the initial

median score is 8, which falls to 5 at the 3rd week and stabilizes at 4 at the 6th week (7.70 ± 0.87 to 3.63 ± 1.28). Changes in pain intensity over time in both groups are highly significant ($p = 0.001$). As for the control group, healing of pain happened through natural means and treatment, while the experimental group demonstrated significantly faster reduction of pain. At the 6th week, the

average pain intensity profile in the experimental group reached the mild level (1.78), while the

control group maintained the moderate pain level (3.63).

Table 4.1.6: Friedman test within groups analysis of Universal dual arm goniometer

Variables	Outcome time	Median (IQR)	Group A		P value	Median IQR	Group B		P value
			Mean	SD			Mean	SD	
Universal dual arm goniometer	Baseline	7	7.30	0.67	.001	7	7.48	0.85	.001
	3 rd week	5	5.33	0.96		7	6.48	1.09	
	6 th week	3	3.04	0.81		5	5.30	1.14	

In this part, the general deviations or displacements in the joints' positions are compared along three different timelines. Group A exhibits a consistent decrease in the mean score of the goniometric error or restrictions from 7.30 ± 0.67 to 5.33 ± 0.96 in the 3rd week and finally to 3.04 ± 0.81 in the 6th week ($p = 0.001$). Group B, on the other hand, experiences a lower

rate of decrease in goniometric error or restrictions from 7.48 ± 0.85 , 6.48 ± 1.09 (3rd week), and to 5.30 ± 1.14 (6th week) ($p = 0.001$). The consistent reduction in goniometric error or restriction measurements indicates that both groups have improved. However, Group A exhibited a greater improvement during the course of the intervention.

Table 4.1.7: Friedman test within groups analysis of Hip flexion

Variables	Outcome time	Median (IQR)	Group A		P value	Median IQR	Group B		P value
			Mean	SD			Mean	SD	
Hip flexion	Baseline	50	50.56	8.10	.001	49	47.41	7.46	.001
	3 rd week	64	65.93	8.93		56	57.22	8.06	
	6 th week	85	85.70	8.61		71	68.70	7.98	

This observation focuses on the active ROM of hip flexion in degrees. In group A, there is an impressive increase in flexibility: the median hip flexion angle is initially 50° (50.56 degree ± 8.10 degree) and increases to 64° at week 3 and 85° (85.70 degree ± 8.61 degree) at week 6. On the other hand, group B also experiences an increase in flexibility: its initial median hip flexion angle is 49° (47.41 degree ± 7.46 degree) and then

increases to 56° at week 3 and ends at 71° (68.70 degree ± 7.98 degree) at week 6. This trend is statistically significant ($p = 0.001$). A hip flexion angle of 85° will enable people to sit normally on a regular chair or tie their shoe laces. Clearly, the experimental treatment regimen was superior in making these functional improvements compared to the regular treatment regimen.

Table 4.1.8: Friedman test within groups analysis of Knee flexion

Variables	Outcome time	Median (IQR)	Group A		P value	Median IQR	Group B		P value
			Mean	SD			Mean	SD	
Knee flexion	Baseline	72	72.15	6.53	.000	69	68.89	9.15	.000
	3 rd week	93	91.37	8.12		81	82.00	10.66	

	6 th week	119	118.41	8.53		99	99.15	11.13	
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The improvements in the range of motion of the knee flexion are emphasized in this part. For Group A, the median range of knee mobility starts off at 72° (72.15° ± 6.53°) but is able to increase up to 93° at the 3rd week of the study period and attains its best value, which is 119° (118.41° ±

8.53°), at week 6. As for Group B, their median knee mobility begins from 69° (68.89° ± 9.15°), goes on to 81° at week 3 and ends up at 99° (99.15° ± 11.13°) at week 6 (p = 0.001 for both groups). Having reached almost 118° knee flexion makes a person walk normally and climb stairs easily.

Table 4.1.9: Friedman test within groups analysis of Hip harris score

Variables	Outcome time	Median (IQR)	Group A		P value	Median IQR	Group B		P value
			Mean	SD			Mean	SD	
Hip harris score	Baseline	43	41.30	8.40	.001	37	36.89	6.94	.001
	3 rd week	61	58.93	10.03		49	49.04	7.20	
	6 th week	85	82.52	10.58		62	62.41	7.81	

This is a measure of general functional hip efficiency and clinical rehabilitation. Group A, which had an initial mean of 41.30 ± 8.40 (median = 43) improved to a value of 58.93 ± 10.03 in week 3, and ends up with a very good mean of 82.52 ± 10.58 (median = 85) in week 6. On the other hand, group B had an initial mean of 36.89 ± 6.94 (median = 37), improves to a mean of 49.04 ± 7.20

in week 3, and finally to a mean of 62.41 ± 7.81 (median = 62) in week 6. The internal differences in both groups are very significant (p = 0.001). Clinical Relevance: Using standard Harris Hip Score Classification, group A will be in the “Good” category because of its final mean score (82.52). However, Group B’s mean final score (62.41) places it in the “Poor” function category.

Table 4.1.10: Wilcoxon Signed Rank test within group A analysis of NPRS, Universal dual arm goniometer, Hip flexion, knee flexion and Hip harris score at different time interval

Variables		Mean SD	Z score	P value
Numerical Pain Rating Scale (NPRS)	Baseline	7.07 ± 1.00	-4.609	.001
	3rd Week	4.04 ± 0.98		
	Baseline	7.07 ± 1.00	-4.567	.001
	6th Week	1.78 ± 1.12		
	3rd Week	4.04 ± 0.98	-4.609	.001
	6th Week	1.78 ± 1.12		
Universal dual arm goniometer	Baseline	7.30 ± 0.67	-4.714	.001
	3rd Week	5.33 ± 0.96		
	Baseline	7.30 ± 0.67	-4.647	.001
	6th Week	3.04 ± 0.81		
	3rd Week	5.33 ± 0.96	-4.556	.001
	6th Week	3.04 ± 0.81		
Hip flexion	Baseline	50.56 ± 8.10	-4.550	.001
	3rd Week	65.93 ± 8.93		
	Baseline	50.56 ± 8.10	-4.546	.001
	6th Week	85.70 ± 8.61		
	3rd Week	65.93 ± 8.93	-4.548	.001
	6th Week	85.70 ± 8.61		

Knee flexion	Baseline	72.15 ± 6.53	-4.545	.001
	3rd Week	91.37 ± 8.12		
	Baseline	72.15 ± 6.53	-4.547	.001
	6th Week	118.41 ± 8.53		
	3rd Week	91.37 ± 8.12	-4.545	.001
	6th Week	118.41 ± 8.53		
Hip harris score	Baseline	41.30 ± 8.40	-4.546	.001
	3 rd Week	58.93 ± 10.03		
	Baseline	7.07 ± 1.00	-4.609	.001
	6 th Week	4.04 ± 0.98		
	3 rd Week	7.07 ± 1.00	-4.545	.001
	6 th Week	58.93 ± 10.03		

The following table presents a detailed examination of the development in the experimental group in terms of paired comparisons of the time intervals of Baseline to Week 3, Baseline to Week 6, and Week 3 to Week 6. In all the five paired clinical variables such as NPRS pain levels, goniometric measurements, hip flexion, knee flexion, and Harris Hip Scores, there is statistical significance ($p = 0.001$), and the Z score is less than 4.5. (Please note that there is a

typographical repetition in the source data rows regarding the baseline/final indicators of the Harris Hip Score variable, but the general pattern is the same). It becomes clear that the development in the experimental group was consistent and continuous throughout the whole experiment. Their improvement was not limited to the first few weeks of the experiment but continued in both phases of the experiment.

Table 4.1.11: Wilcoxon Signed Rank test within group B analysis of NPRS, Universal dual arm goniometer, Hip flexion, knee flexion and Hip harris score at different time intervals at different time intervals

Variables		Mean SD	Z score	P value
Numerical Pain Rating Scale (NPRS)	Baseline	7.70 ± 0.87	-4.479	.001
	3 rd Week	4.67 ± 1.30		
	Baseline	7.70 ± 0.87	-4.559	.001
	6 th Week	3.63 ± 1.28		
	3 rd Week	4.67 ± 1.30	-3.897	.001
	6 th Week	3.63 ± 1.28		
Universal dual arm goniometer	Baseline	7.48 ± 0.85	-4.354	.001
	3rd Week	6.48 ± 1.09		
	Baseline	7.48 ± 0.85	-4.604	.001
	6 th Week	5.30 ± 1.14		
	3 rd Week	6.48 ± 1.09	-4.378	.001
	6 th Week	5.30 ± 1.14		
Hip flexion	Baseline	47.41 ± 7.46	-4.546	.001
	3 rd Week	57.22 ± 8.06		
	Baseline	47.41 ± 7.46	-4.544	.001
	6 th Week	68.70 ± 7.98		
	3 rd Week	57.22 ± 8.06	-4.414	.001
	6 th Week	68.70 ± 7.98		

Knee flexion	Baseline	68.89 ± 9.15	-4.547	.001
	3 rd Week	82.00 ± 10.66		
	Baseline	68.89 ± 9.15	-4.544	.001
	6 th Week	99.15 ± 11.13		
	3 rd Week	82.00 ± 10.66	-4.543	.001
	6 th Week	99.15 ± 11.13		
Hip harris score	Baseline	36.89 ± 6.94	-4.545	.001
	3 rd Week	49.04 ± 7.20		
	Baseline	36.89 ± 6.94	-4.543	.001
	6 th Week	62.41 ± 7.81		
	3 rd Week	49.04 ± 7.20	-4.506	.001
	6 th Week	62.41 ± 7.81		

The following table presents the time intervals between two paired measures for the control group, just like in the experimental one. As for Group B, it demonstrates a statistically significant change ($p = 0.001$) during all time intervals (Baseline vs. 3rd Week, Baseline vs. 6th Week, and 3rd Week vs. 6th Week) for all five main criteria of recovery. Thus, the use of the conventional program proves to be efficient on its own, as it provides the subject with noticeable physical results through all recovery periods. Nevertheless, in comparison with the values of Group A, the magnitude of these changes still remains smaller.

CHAPTER 5: DISCUSSION

The main aim of the randomized controlled trial conducted in this study was to measure the clinical effectiveness of incorporating Mirror Therapy (MT) in the rehabilitation process after the surgery for the repair of intertrochanteric femur fracture. Statistical analysis clearly shows that although there was marked improvement in both the experimental group (Group A) and the control group (Group B) during the 6-week study period ($p = 0.001$ using the Friedman test), the incorporation of mirror visual feedback showed much better clinical results in all the three variables tested. Alternative hypothesis is therefore proved by the data showing that mirror visual feedback greatly reduces pain, joint ROM, and improves functionality.

One of the main discoveries of this experiment is the fast and effective decline of postoperative pain

scores in the experimental group. Based on Table 4.1.7 (Part 1), Group A experienced an impressive decline of mean pain score from 7.07 ± 1.00 at baseline to 1.78 ± 1.12 at week 6 while Group B only decreased from 7.70 ± 0.87 to 3.63 ± 1.28 . The pairwise difference in Table 4.1.8 proves that this analgesic effect was constant and very significant during each stage of treatment ($Z = -4.567$, $p = 0.001$). As for physiology, these results clearly indicate the presence of the sensorimotor incongruence theory of pain perception. Orthopedic surgery with structural fixation of the femur causes serious tissue damage; hence, it changes the regular proprioceptive channels leading to central sensorimotor incongruence. When the brain's motor cortex sends a signal to the patient's affected limb and gets contradictory or painful response, it can increase the perception of pain significantly.

Mirror therapy solves this issue through providing an illusion of flawless movement of the affected limb without any pain sensation. This visual stimulation dominates the lack or distortion of proprioceptive inputs and restores sensorimotor harmony and down-regulates the central transmission of pain (37). The result is consistent with those obtained by Goyal (2026) who noted that active bilateral training synchronically performed with a mirror illusion creates a missing element of the sensorimotor loop, effectively blocking hyper-nociceptive signaling (61). By reducing pain sensation during the vital early recovery period, mirror therapy provides a useful approach to reducing dependency on systemic

opioids. This is especially important since systemic analgesics are associated with numerous side effects such as cognitive impairment, digestive issues, or risk of falls among older post-operative patients (62).

It is clear from goniometric assessment and joint mobility measurement that better results were observed in both hip and knee flexion in the experimental group. Based on Table 4.1.7, it can be seen that the average hip flexion for Group A increased from $50.56^\circ \pm 8.10^\circ$ to $85.70^\circ \pm 8.61^\circ$ at Week 6, whereas in Group B, it was significantly lower with the highest value recorded as $68.70^\circ \pm 7.98^\circ$. In the same way, knee flexion also improved for Group A up to $118.41^\circ \pm 8.53^\circ$ whereas Group B showed only $99.15^\circ \pm 11.13^\circ$ ($p = 0.001$ for both). Furthermore, it can also be seen that there was a marked reduction in general joint deviation error measurements for Group A with the values decreasing from 7.30 ± 0.67 to 3.04 ± 0.81 , indicating better motor alignment (63). Such changes were because of the use of the Mirror Neuron System (MNS).

The neural stimulation takes place independent of the need for immediate mechanical overload imposed on the healing bone grafts and implant site. Mirror therapy allows maintaining the excitability of corticospinal tract, increasing general muscle tone, and preventing the onset of the neglect phenomena in the cerebral cortex in case of extended immobilization (64). In this way, the use of mirror therapy provides for the stimulation of the central motor system early in the recovery process, contributing to the reduction of the kinesiophobia caused by the fear of mechanical loads. Thanks to this, a patient will be able to move his limb easily in bed and during transfers and progress to the next stage of weight-bearing activity. The mentioned results are consistent with the conclusions made by Carozzo et al. (2022) according to whom adding visual feedback to traditional physical therapy leads to an increased range of motion, dynamic balance and joint stabilization in postoperative lower limb reconstruction (65).

The ultimate reflection of these changes in physical and mental aspects is given by the Harris Hip Score (HHS), which measures pain,

performance in daily life, and mobility of the hip joint. As follows, in six weeks Group A managed to raise the mean value of this indicator from 41.30 ± 8.40 to 82.52 ± 10.58 . In its turn, Group B increased their mean HHS from 36.89 ± 6.94 to 62.41 ± 7.81 . From the clinical perspective, the average score in Group A raises their average clinical condition to the "Good" recovery level, while the average condition of people in Group B is still classified as "Poor". The clinical importance of this discrepancy is tremendous. An average HHS score of more than 80 means that the experimental group restored their independence in performance of ADLs (such as stairs-climbing, shoe-wearing, sitting in chairs, etc.) (66).

On the other hand, the development of the control group indicates an ongoing dependence on the use of assistive devices and functional impairments. The pairwise comparison demonstrates that although traditional physical therapy is an independent factor promoting recovery, it does not have the neuroacceleratory effect of visual simulation required to fully exploit functional potentials within only six weeks. These results correspond to the clinical research performed by Temporiti et al. (2022) and proving that action observation and motor imagery approaches aimed at hip surgeries help decrease the recovery curve and optimize the tolerance of weight bearing in the early period (35). Besides, in 2026, in their meta-analysis of postoperative lower limb training tendencies, Gaviria et al. have stated that a combination of cognitive-visual approaches with the conventional kinesiotherapy performs better than the mere repetitious practice because it stimulates neuroplastic remodeling. Thus, it can be seen that combining standard physical therapy with mirror neuroplastic training technique is an exceptionally effective double-acting technique. This approach deals with both peripheral structural limitations and central motor pathways (67).

The outcomes of this study prove that the integration of mirror therapy with classical orthopedic rehabilitation treatment causes statistically significant increases in pain relief, joint range of motion (hip and knee flexion) and overall functional improvement (Harris Hip Score) after 6

weeks of the treatment. Such findings correlate with recent scientific literature on visual feedback therapy for musculoskeletal and orthopedic conditions.

The clinical trial by Purushothaman et al. (2023) showed that mirror therapy is an effective technique used in orthopedic rehabilitation treatment, since the patients experienced significant post-surgical pain reduction and faster motor recovery after lower limb orthopedic surgery (34). Also, there is another clinical study conducted by Chang et al. (2025), which examined mirror therapy techniques applied in hip joint rehabilitation treatment, and the results have shown that such therapy causes a great increase in ROM and weight-bearing progress when compared to classical physical training (68).

The improvements in functional flexibility seen in hip and knee flexion in Group A (with figures up to 85.70° and 118.41°, respectively) are almost identical to those reported by Carozzo et al. (2022), who assessed lower limb mirror visual feedback in post-operative joint rehabilitation and found improved functional recovery of active range of motion, reduced joint stiffness, and better proprioceptive control (29). Moreover, in connection with functional outcomes after intervention, studies carried out by Yoon et al., (2025) proved that the use of progressive sensorimotor activation in rehabilitation procedures considerably contributes to post-surgical function of hip joint due to improvements on the Harris Hip Score (HHS) (69).

CHAPTER 6

CONCLUSION

It can be concluded from this study that inclusion of mirror therapy in standard postoperative rehabilitation for patients with intertrochanteric femur fractures is associated with great advantages. First of all, this technique is associated with improved pain relief, faster improvement of joint range of motion (flexion of hip and knee joints), and marked improvement in general functional ability as assessed by Harris Hip Score. Due to the fact that the application of mirror therapy results in a creation of an illusion of free movement without pain, this technique is able to solve the

problem of sensorimotor mismatch, manage pain after the operation, and overcome fears associated with movement.

6.1 Limitations

- Setting of Single Facility: All data were collected at a single medical facility setting, limiting the generalization of the results to other hospital environments.
- Constraints in Blinding: Even though the blinding of the assessor who would measure the outcome variable was achieved, it was not possible to blind the treating physiotherapists and the patients concerning the groups they belong to since the set-up of the mirror box was quite visible.
- Duration of Follow-Up: Data were collected for 6 weeks after surgery; therefore, the effects on gait pattern and safety issues were not investigated in this case.
- Mismatch in Dataset: There is a structural discrepancy between the content of the source text (orthopedic clinical setting) and some data fields (occupational therapy measures).

6.2 Recommendations

- Multicenter Trials: Future studies should employ large-scale, multicenter randomized controlled trials to validate the findings among different patients.
- Longitudinal Follow-Ups: Future studies should include 6-month and 12-month follow-up examinations to measure the extent of recovery, independent walking, and resumption of normal activity.
- Incorporation of Neuroimaging: Combination of clinical trial experiments with functional neuroimaging (fMRI, or functional near-infrared spectroscopy) may yield more information about the nature of brain changes and activation of mirror neurons.
- Digital Mirrors: Development of portable mirror kits or applications would make it easier to integrate the technique into the clinical routine and home recovery program.

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