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The Efficacy of Motor Imagery Training on Range of Motion, Pain and Function of Patients After Total Knee Replacement

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ABSTRACT

THE EFFICACY OF MOTOR IMAGERY TRAINING ON RANGE OF MOTION, PAIN AND FUNCTION OF PATIENTS AFTER TOTAL KNEE REPLACEMENT

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The present study examined the potential of motor imagery training and investigated the role of motor imagery instructions (audio) to improve knee range of motion after a total knee replacement. The participants were randomly assigned to either an experimental motor imagery group (n=4) or a control group (n=6). Both groups performed specific exercises to improve their knee range of motion and strengthen their muscles. Participants in the Motor Imagery group performed a motor imagery training exercise for a knee flexion stretch on the stairs prior to performing the actual exercise. The motor imagery group demonstrated a significantly greater increase in knee range of motion when compared to the control group.

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Introduction

Osteoarthritis (OA) is the largest source of physical disability in the United States, most commonly affecting the knee joint (Mizner et al., 2005), largely due to the fact that the knee joint absorbs forces during standing, walking, and running (Jordan et al., 2003). Total knee arthroplasty (TKA) is a surgical replacement of a degenerated or malformed joint, administered to patients with OA, particularly when more conservative treatments have failed (Mizner et al., 2005). The goals of TKA are to reduce pain, improve range of motion and functional ability, and to improve the patient's overall quality of life (Escobar et al., 2007).

Total knee arthroplasty (TKA) is the most commonly performed musculoskeletal procedure in the United States, with close to 700,000 performed annually. Future projections of TKA rates anticipate 3.5 million procedures being performed annually by the year 2030. Knee range of motion (ROM) and physical functional performance are major outcomes after TKA. Preoperative measures of joint function and functional performance are robust predictors of postoperative outcomes (Bade et al., 2014). Reacquiring normal knee range of motion status post TKA is vital for function in daily life. For example, 10 to 100 degrees of knee ROM is necessary for sit to stand transfers from a standard chair (Rowe et al., 2000). Stair climbing requires approximately 20 to 100 degrees of knee ROM, while 0 to 130 degrees is required to enter a bathtub (Rowe et al., 2000).

Some patients that undergo TKA experience complications that require further manipulation under anesthesia. The most prevalent of these complications is knee stiffness, which affects approximately 6 to 7% of patients following TKA (González Della Valle et al., 2007). The definition of what comprises knee stiffness has varied in the literature. Kim et al. describe stiffness as knee flexion contracture of > 15° and/or < 75°, whereas Christensen et al. have defined it as an arc of knee motion < 70° (Mohammed et al., 2009). The cost of manipulation surgeries was $36,848 in 2005 and has been expected to increase to $56,918 in 2030 (Lavernia et al., 2006).

Motor imagery (MI) is a term introduced by cognitive neuroscientists to describe mental rehearsal of voluntary movement without body movement (Jeannerod et al., 1995). It is important to differentiate motor imagery from visual imagery. Motor imagery, where the subject rehearses movements using a kinesthetic feeling of movement, activates many of the same motor and sensory regions of the brain which are active during overt movement. This is contrasted by visual imagery, where the subject produces a visual representation of their moving limbs from the perspective of an external observer (Dickstein & Deutsch, 2007) which activates primarily the visual processing of the brain (Milton et al., 2008). Kinesthetic MI induces changes in corticomotoneuronal connections (Stinear et al., 2006). Evidence suggests that MI improves motor performance, motor learning, and motor relearning (Dickstein & Deutsch, 2007). Improvements in motor control may be related to the activation of similar cortical motor areas as those activated during voluntary movement (Lotze et al., 1999; Kimberley et al., 2006). Brain areas engaged in the actual performance of movements are also active during motor imagery (Kimberley et al., 2006). Functional MRI studies have illustrated that the same cortical areas of the brain are engaged when performing motor imagery as they are during a motor task (Lotze et al., 1999). Some studies using fMRI also found activation in the primary motor cortex (Gerardin et al., 2000). The premotor, supplementary motor, cingulate and parietal cortical areas, the basal ganglia, and the cerebellum, are not only involved during the actual execution of a movement but also during the imagination of a movement (Hanakawa et al., 2003). The imagination of different moving body parts activated the precentral gyrus in a somatotopic manner (Stippich et al., 2002).

Task-oriented motor program may promote neuroplasticity, increase functional capacity, generate greater cortical changes, and promote better motor learning to improve motor skills in daily functions (Santos, 2013). When mental practice was added to conventional physical therapy, there were functional and clinical improvements (Santos, 2013).

The response time of a motor task decreased in the MI group compared to the non-MI group, and decreased in the kinesthetic MI group compared to the visual MI group following hand immobilization for one day in healthy subjects (Meugnot et al., 2014). These findings suggest that MI contributes to motor task reaction time and kinesthetic MI is a more effective way of performing MI practice (Meugnot et al., 2014). Motor imagery training may help improve range of motion. Flexibility of both the hip and ankle joints increased in young female swimmers after motor imagery training with muscle stretching compared to the control group (Guillot et al., 2010). These findings support the notion that MI training combined with motor practice or muscle stretches improves flexibility and range of movements in healthy humans.

Additionally, it was found that motor imagery training can have positive effects on pain. According to Moseley, adding motor imagery to the traditional medical treatment of chronic regional pain syndrome (CRPS) has a strong effect on treatment of pain and swelling (Moseley, 2004). His findings show that patients who converted over from the control group to the MI group had the same significant results. About 50% of the patients no longer fulfilled the diagnostic criteria for CRPS (Moseley, 2004). In a future study of Moseley's, graded motor imagery was again found to reduce pain and disability in a relatively homogenous group of patients with chronic CRPS (Moseley, 2006). Motor imagery training may also have a positive effect on functionality in patients post total knee replacement. Motor Imagery training improves assessment scores and functionality for the paretic limb in post stroke patients. (Stevens et al., 2003).

The objectives of this study were to establish the effects of MI in people after TKA. More specifically, to determine if the addition of motor imagery training when combined with a standard course of outpatient physical therapy is efficacious in improving knee range of motion for acute total knee patients, in improving functional outcomes, and will lead to a decrease in pain.

Methods

10 subjects were recruited with a unilateral TKA secondary to Osteoarthritis from Staten Island University Hospital North. Subjects aged from 50 to 80 years (mean = 64.7). The control group consisted of 6 patients with a mean age of 63.8 (4 female, 2 female). The MI group consisted of 4 patients with a mean age of 66.0 (2 female, 2 male). The subjects were required to have been admitted to the Outpatient Rehabilitation Department between 2-6 weeks post-surgery with an initial passive range of motion of knee flexion between 60-90 degrees. The subjects participated in Outpatient Physical Therapy three times a week for two months. Patients with Rheumatoid Arthritis or active cancer were excluded. Subjects who had a previous history of TKA or Open Reduction Internal Fixation (ORIF) on the same side as the surgery were also excluded from the study. Bilateral TKA's were omitted since effort may have been divided between two limbs. Patients with a history of any neurological disorder including Cerebral Vascular Attack (CVA), Multiple Sclerosis (MS), or Parkinson 's disease were also excluded.

Design

In this randomized controlled study, the patients were randomized into two groups: the experimental motor imagery group and the control group, which did not perform motor imagery. All participants, regardless of their group, received standard physical therapy status post total knee replacement.

Patients actively participated in physical therapy under the supervision of a licensed physical therapist 3 times per week for 2 months after being admitted to the Outpatient Rehabilitation Physical Therapy Department. Both patient groups followed the protocol unless otherwise noted. Moist heat was applied to the affected knee for 20 minutes before exercise. Exercises included Quad sets with Straight Leg Raise (SLR), Short Arc Quads (SAQ), and Bridging which were performed for 20 repetitions with a five second hold, twice a day unless otherwise stated. Seated knee Flexion Stretch on steps (5 repetitions with a 20 second hold), Step Ups, and Step Downs exercises were also performed twice a day. Aerobic training included the Bike, NuStep, and Kinetron for eight minutes each. Ice packs were applied to the affected knee for ten minutes following exercise. Patients in the MI group actively imaged themselves performing 2 exercises during initial application of moist heat each Physical Therapy session (10 minute audiotape).

Firstly, they performed MI of a Knee Flexion Stretch on the stairs (five repetitions for 20 seconds). During MI, patients imagined performing this stair stretch and then performing the stretch. Secondly, the MI group performed MI of a seated knee flexion stretch where they imagined themselves using their unaffected leg to stretch their affected leg into knee flexion while sitting supported. Patients were given the option of a rest period of 2 minutes between sets to reduce the effects of fatigue (Borda et al., 2014). Those in the MI group performed their motor imagery exercises twice a day. All participants received standard physical therapy gait training techniques aimed at improving patient independence without reliance on assistive devices.

Patients performed their Home Exercise Program (HEP) of the above activities daily. They were supplied with images and text of the exercises (Skou et al., 2012). Patients had to fill out a log to document their participation. The log indicated whether the exercises were performed, how many times they were performed a day, and how long they held each stretch.

Range of motion (ROM) was assessed each visit by a physical therapist who was blinded to the subject's group and the average was calculated per week (Lin et al., 2009). The center of a standard goniometer was positioned over the lateral knee joint space with the arms aligned with the lateral midline of the femur using the greater trochanter as reference, and the lateral midline of the fibula using the head of fibula and lateral malleolus as reference. The Lower Extremity Functional Scale (LEFS) was used monthly to assess functionality level of the affected leg (20 items subjectively graded on a 4-point scale). A visual analog scale, consisting of a 10 cm line where the subject was asked to indicate how intense their pain was with the "most intense pain possible" to the extreme right of the line, and no pain at the extreme left of the line, was utilized on a monthly basis to assess pain levels.

Data Collection/Analysis

SPSS version 22.0 was utilized for data analysis. The threshold for significance was a 95 % confidence interval with p-values <0.05 for significance. A one-way ANOVA with repeated measures was conducted using a linear model to analyze all the factors of the data. The factors compared between MI and control groups included ROM, function, and pain.

Results

Baseline measures for both groups were taken for each of the three factors (ROM, pain, and function) and were compared to the final measurements taken on the last week of treatment. Initial measures showed decreased ROM and function, and increased pain. Final measures showed increased ROM and function, and decreased pain. These findings can be seen in Figures 1-3. ROM values collected from both groups were averaged weekly, and these averages were compared between the groups (Figure 4).

Results showed that ROM was significant when the control group was compared to the MI group, with a p-value of 0.029. Patient function between MI and control group was also found significant, with a p-value of 0.043. Pain analysis between groups was not significant, with a p-value of 0.726.

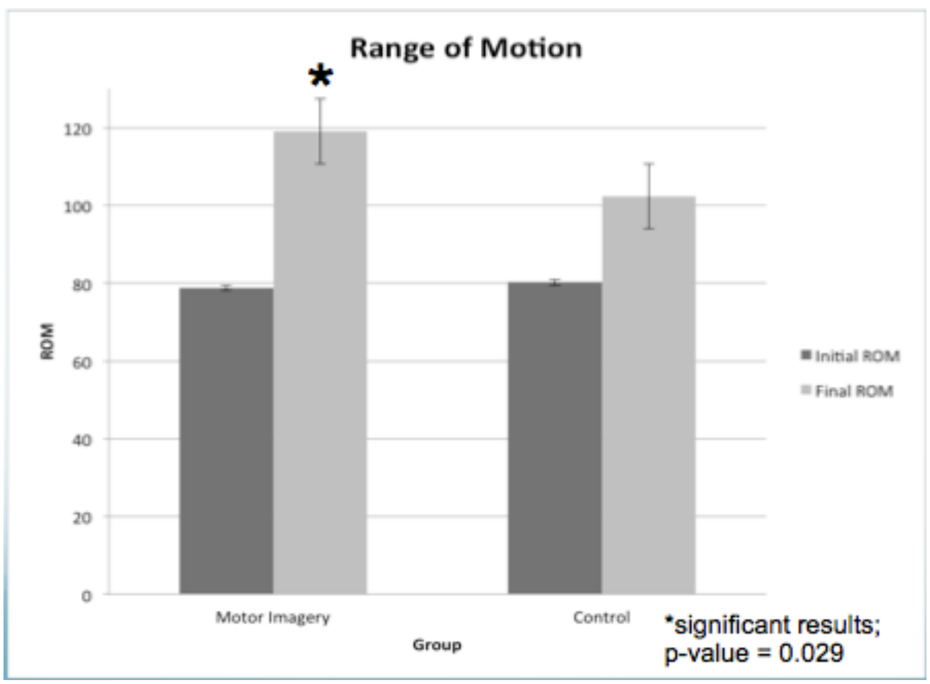

Figure 1 depicts the comparison between initial and final measurements of ROM for both groups (MI and Control).

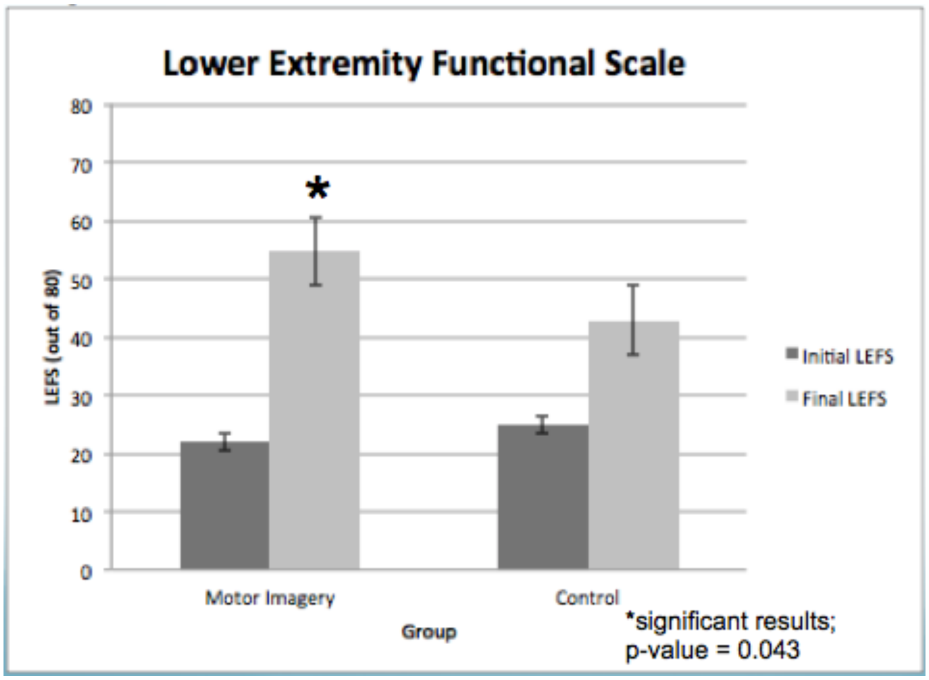

Figure 2 depicts the comparison between initial and final measurements of function for both groups (MI and Control).

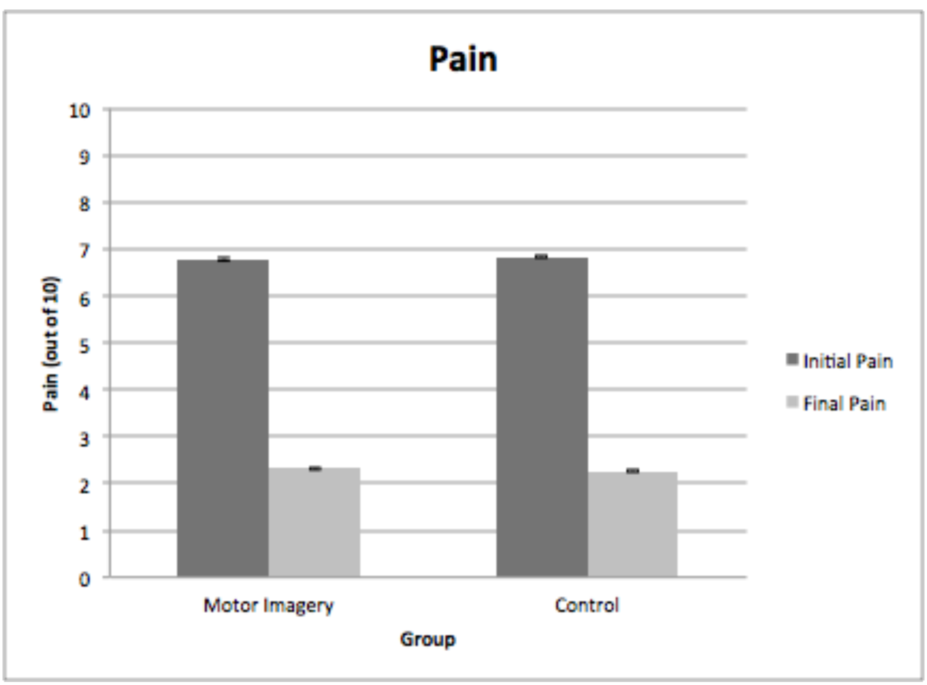

Figure 3 depicts the comparison between initial and final measurements of pain for both groups (MI and Control).

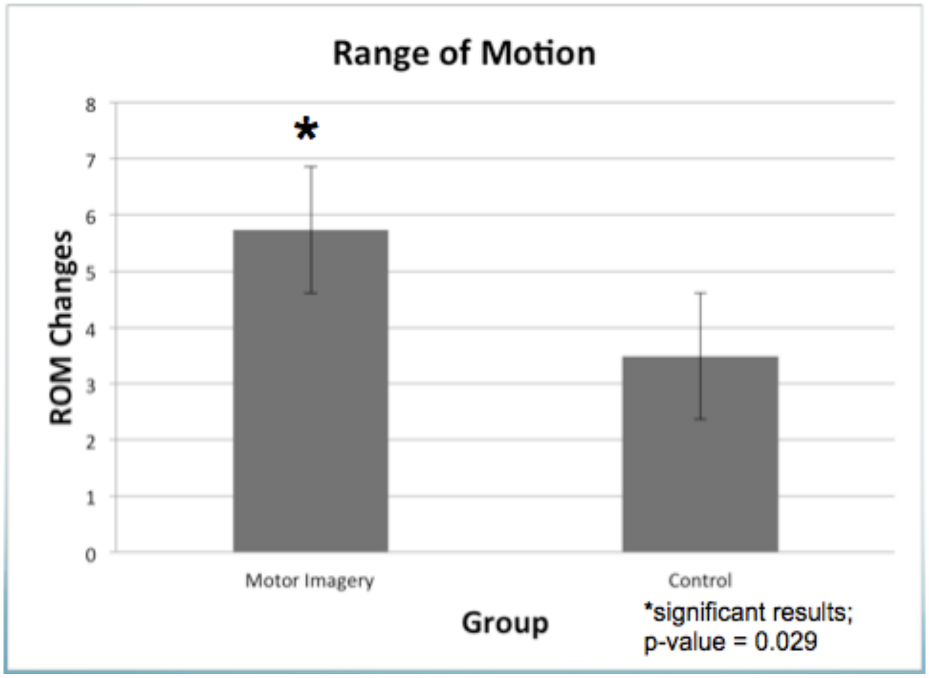

Figure 4 depicts the averaged improvement in ROM per week for both groups (MI and Control).

Discussion

The aim of this study was to establish the effects of MI in people after TKA. Motor imagery is described as mental rehearsal of voluntary movement without any actual body movement. As it activates similar cortical motor areas of the brain as those activated during voluntary movement (Dickstein & Deutsch, 2007), we hypothesized that motor imagery training when combined with a standard course of outpatient physical therapy is efficacious in improving knee range of motion for acute total knee replacement patients, in improving function, and will lead to a decrease in pain. After analyzing the data, a statistical significant difference was noted in regards to knee ROM for the experimental group in comparison to the control. Knee ROM was significantly increased in the motor imagery group. These findings are in agreement with Guillot and colleagues study in which young female swimmers increased in both hip and ankle joint flexibility in the motor imagery group when compared to the control group after both groups participated in standard physical therapy interventions. In addition, Williams et al's study combined PNF with MI training which was found to improve hip ROM when compared to the PNF group alone (Williams et al., 2004). Furthermore, patient function approached a significant difference between the groups; in addition function was found to have increased greatly within the motor imagery group. This is in agreement with Stevens et al's study, which showed an improvement in assessment scores and functionality in using motor imagery training for the paretic limb post stroke patients (Stevens et al., 2003). Our study failed to show a significant correlation to pain despite our hypothesis that it would decrease in patients who performed motor imagery practice. According to Moseley, adding motor imagery to the traditional medical treatment of CRPS has a strong effect on treatment of pain and swelling (Moseley, 2004).

There were a number of limitations in the study. This included an insufficient amount of participants in the study as well as in the MI group (n=4). This limitation may have been due to the specific range of motion requirements we had imposed (between 60-90 degrees of knee flexion). A range of motion of less than 60 degrees could indicate complications with the surgery; above 90 degrees may be high enough not to show a significant difference in the results as the initial range of motion reading was already nearly at the target range. This led to difficulties in recruiting subjects and it resulted in being able to recruit only 10 subjects for our study. The MI group only consisted of 4 participants, which may not be sufficient in order to ascertain the true effect of motor imagery. Measurements of range of motion were taken manually; this can lend itself to some form of human error. On the other hand, the MI training performed by the MI group focused primarily on stretching the involved knee via the stair stretch and the chair stretch. Perhaps our study may have yielded much more significant results if MI training had been performed for more than two exercises or if it addressed pain and function as well. Compliance may also have played a role in this experiment. Patients were instructed to perform MI training with their exercises two times per day. Confirmation of this practice may, in fact, be a limitation. While the participants reported appropriate compliance with the required procedures, the patients' daily logs may be insufficient in keeping track of this practice outside of the clinic. The incorporation of a recording given only to the MI group could have contributed to finding significant differences between the groups. The constant playing of the recording allows the patient to listen to the instructions more than once. This repetition could have aided the MI patients in gaining a better understanding of the exercises, and thus allowed them to perform significantly better. Nevertheless, it cannot be confirmed that the patients participated in MI training the correct way or understood their instructions, even with the observation of the subjects as they performed their exercises in the clinic. Twice a day for MI training may not have been enough. This could be a reason that patients' pain results were not significant. There is a recommended amount of time to affect change with various forms of exercise. Perhaps if more research is done, the same could be said for MI practice with this patient population. Could a more pronounced effect have been noted if the experimental group had practiced MI for a longer period of time per physical therapy session? Lastly, this study was not performed in a controlled lab environment. For that reason there were extraneous variables that we could not have controlled and which may have possibly influenced the results.

Conclusion

This study results suggest that motor imagery training after total knee replacement may improve knee range of motion and function, however, pain was not found to be impacted by motor imagery.

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