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Effectiveness of the graded motor imagery to improve hand function in patients with distal radius fracture: A randomized controlled trial

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ABSTRACT

Study Design: Single-blinded randomized controlled trial.
Introduction: Pain management is essential in the early stages of the rehabilitation of distal radius fractures (DRFx). Pain intensity at the acute stage is considered important for determining the individual recovery process, given that higher pain intensity and persistent pain duration negatively affect the function and cortical activity of pain response. Graded motor imagery (GMI) and its components are recent pain management strategies, established on a neuroscience basis.
Purpose of the Study: To investigate the effectiveness of GMI in hand function in patients with DRFx.
Methods: Thirty-six participants were randomly allocated to either GMI ($n = 17$; 52.59 [9.8] years) or control ($n = 19$; 47.16 [10.5] years) groups. The GMI group received imagery treatment in addition to traditional rehabilitation, and the control group received traditional rehabilitation for 8 weeks. The assessments included pain at rest and during activity using the visual analog scale, wrist and forearm active range of motion (ROM) with universal goniometer, grip strength with the hydraulic dynamometer (Jamar; Bolingbrook, IL), and upper extremity functional status using the Disability of the Arm, Shoulder and Hand Questionnaire, and the Michigan Hand Questionnaire. Assessments were performed twice at baseline and at the end of the eighth week.
Results: The GMI group showed greater improvement in pain intensity (during rest, 2.24; activity, 6.18 points), wrist ROM (flexion, −40.59; extension, −45.59; radial deviation, −25.59; and ulnar deviation, −26.77 points) and forearm ROM (supination, −43.82 points), and functional status (Disability of the Arm, Shoulder and Hand Questionnaire, 38.00; Michigan Hand Questionnaire, −32.53 points) when compared with the control group (for all, $P < .05$).
Conclusion: The cortical model of pathological pain suggests new strategies established on a neuroscience basis. These strategies aim to normalize the cortical proprioceptive representation and reduce pain. One of these recent strategies, GMI appears to provide beneficial effects to control pain, improve grip strength, and increase upper extremity functions in patients with DRFx.

Introduction

Distal radius fractures (DRFx) are one of the most common types of fractures and account for approximately 15% of all fractures in middle-aged women and men.[1-4] Rehabilitation from DRFx may be complicated due to challenges associated with prolonged recovery times, discomfort, pain, and decreased mobility.[5] Common complaints after DRFx include weakness, pain, and stiffness.[5,6] Pain and edema are commonly seen at the early stages of DRFx, associated with soft tissue problems.[4,7]

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Conflict of interests: All named authors hereby declare that they have no conflicts of interest to disclose.

Ethical approval: All participants gave written informed consent to participants in the captioned study, and the research was approved by the Hacettepe University Ethics Committee (GO 14/06-06).

Clinical trial registration number is NCT02838446.

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Pain is one of the major risk factors inhibiting recovery, thereby resulting in poor functional outcomes in patients with DRFx.[4,8] The pain intensity score during the acute stage postinjury determines the patient's profile for rehabilitation and recovery.[4] Therefore, pain control at the early stages of rehabilitation is considered to be important for reducing the patient's long-term disability level.[9] Implementing pain management strategies in the DRFx rehabilitation program after injury may improve functional outcomes.[4,10]

According to recent evidence-based pain control theories, the neuromatrix paradigm codes pain characteristics according to cognitive, emotional, and sensorial dimensions.[11] Understanding the underlying mechanisms of the paradigm offers specific rehabilitation strategies that address cognitive, emotional, and sensory aspects of pain.[11,12] Graded motor imagery (GMI) is a relatively new approach in pain management.[13,14] GMI aims to organize cortical activation gradually and reduce cortical disinhibition, thereby preventing transition from an acute to a chronic pain state.[13-16] However, the underlying mechanisms of GMI are not yet fully understood. GMI uses 3 sequential strategies including left/right discrimination, explicit motor imagery, and mirror therapy. These stages are designed to optimize sensory-motor processing and gradually engage the cortical motor networks without triggering the protective pain response.[15,17]

Chronic pain conditions such as phantom limb pain, chronic low back pain, and complex regional pain syndrome type 1 (CRPS1) are associated with reorganization of the primary somatosensory cortex.[18,19] GMI has recently been used in the treatment of chronic pain in various orthopedic and neurologic conditions.[13,17,20] Few randomized controlled trials exist that demonstrate the effectiveness of GMI on pain or function. A systematic review supported the claim that GMI is effective in the treatment of chronic pain conditions, especially in CRPS.[21] It has also been shown that GMI can control phantom pain in upper and lower limb amputees.[22] As pain is a major obstacle to recovery of motion and function after DRFx, pain management is an important goal throughout the rehabilitation process.[4,8,9] Although evidence supports the view that GMI is appropriate for chronic pain, as far as we know, there is no study revealing the effectiveness of GMI in pain control in the early phase of rehabilitation. However, many studies have shown that therapy methods including visualization approaches help to reduce pain relief at the early stage.[23-25] It was also proposed that motor imagery and motor intention related with proprioception and vision share the same neural mechanisms.[26,27] Because GMI provided a multitude of visualization approaches, including mirror therapy, motor imagery, and lateralization, we hypothesized that applying visualization approaches at the acute stages may lead to better pain control and functional outcome. Furthermore, GMI is seen as a cost-effective and noninvasive treatment with limited adverse effects and complications.[22] To our knowledge, the effectiveness of GMI on pain and functional status in patients with DRFx has not yet been investigated. Thus, the objective of this study was to determine the effectiveness of GMI on pain control and functional status in patients with DRFx. It was hypothesized that GMI may be an effective rehabilitation strategy to control pain and improve upper limb function.

Methods

Selection and description of participants

Thirty-six participants diagnosed with DRFx were included in this study. Patients with unilateral DRFx who were between 18 and 65 years, who had undergone closed fracture reduction or open reduction internal fixation with a volar locking plate after DRFx, and who had the intellectual capacity to give informed consent for the treatment were included in the study. Patients were excluded from the study for any of the following reasons: If they were unwilling or unable to participate, had bilateral fracture, had intra-articular or unstable DRFx, had associated bone and soft tissue injury, had fractures due to malignancy, had neurologic or rheumatologic diseases, or had insufficient cognitive functioning. All participants were screened for CRPS1 using Budapest criteria by a medical doctor and an experienced physiotherapist (the second author, CA).

Participants were randomly allocated to either the GMI group or the control group using simple randomization technique using sequentially numbered and opaque sealed envelopes. The envelopes containing the paper sheet with the name of the group and a sheet of carbon paper were obscured with aluminum foil, shuffled, then numbered sequentially, and placed in a plastic container, in numerical order, ready to use for the allocation. Envelopes were opened before the treatment. Allocation was performed by the last author (YY) of this study.

The GMI group received traditional rehabilitation and the GMI program, whereas the control group received the traditional rehabilitation program only. Both groups were treated for a period of 8 weeks. All participants performed a home exercise program. Participants in the control and GMI groups attended two, 1-hour-long supervised physiotherapy sessions each week. The appointments were organized to prevent the 2 groups from encountering each other.

Technical assessments

All participants received a written and verbal explanation of the purposes and procedures of the study. If they agreed to participate, they signed the informed consent form, which was approved by the university ethics committee. Treatments were performed by the first author (BD), whereas assessments were completed by the second author (CA), who was blind to the group allocation.

Demographic characteristics regarding gender, age, weight, height, and dominant and injured sides were recorded at the baseline. Participants were instructed not to take any medical treatments providing pain relief such as acupuncture or use any pain medications or substances throughout the study period.

Visual analog scale was used to evaluate pain intensity.[28] The scale consists of a standard ruler marked 0 mm on the left and 100 mm on the right. Participants were instructed to place a mark on the line with regard to their pain intensity while resting and during activity. The scale was labeled 0 (no pain) and 10 (the worst pain), and participants were asked the following 2 questions: "What is your pain level while you are not doing any activities with your hand?" and "What is your pain level during activities that require wrist and forearm motion?".

Active range of motion (ROM) measurements regarding wrist flexion, extension, ulnar and radial deviation, and forearm supination and pronation were evaluated with a universal goniometer and recorded in degrees.[29]

Grip strength was measured in kilograms using a calibrated hand dynamometer (Jamar; Bolingbrook, IL). The measurements were performed as defined by the American Hand Therapist Assosiation.[30] The average of 3 measurements was recorded. The unaffected side was tested first, followed by the affected side.

Disability of the Arm, Shoulder and Hand (DASH) is the gold-standard questionnaire used to assess upper extremity function.[31] The Turkish version was used.[32] DASH includes a 30-item self-report questionnaire to assess the upper extremity disability level. Of the 30 questions, 21 are regarding daily life activities, 5 relate to symptoms (pain, activity-related pain, tingling, stiffness,

and weakness), and 4 are concerned with social function, working status, sleeping, and self-confidence. Item responses range from 1 (no difficulty) to 5 (unable). Total scores range from 0 to 100. Higher DASH scores indicate increased disability.

Michigan Hand Questionnaire (MHQ) Turkish version was used to evaluate daily life activities and functional levels.[33] MHQ has 63 questions and evaluates 6 domains: overall hand function, activities of daily living, work performance, pain, esthetics, and patient satisfaction with hand function (12 questions). The domains of function and pain refer to symptoms (15 questions) and those of work and activities of daily living refer to disability and handicap (22 questions). Scores on MHQ range from 0 to 100, with a lower score indicating higher degree of disability.[34]

Most assessments were performed at the baseline and end of the eighth week of treatment. Grip strength was assessed at the eighth week, once. Initial assessments took place at the first or second physiotherapy session and took approximately 40 minutes. The noninjured side was tested first, followed by the injured side.

Interventions

Traditional rehabilitation program

All participants in both groups received traditional rehabilitation services for 8 weeks (2 days, per week). Traditional rehabilitation program received by both groups for the 8-week period is given in Appendix A. Therapy started immediately after fracture reduction and stabilization; digital, elbow, and shoulder motion was encouraged. Therapy goals were to control edema and pain, restore ROM, and promote the use of the involved extremity for grip and weight-bearing activity.[35] The therapy program was arranged based on principles of fracture healing and fixation technique.[35] It was reported that volar plating allowed early ROM at 7-10 days postoperatively in stable, whereas mobilization after closed treatment in a cast began after the immobilization period lasting up to 6 weeks.[36] Home exercise program was included in the rehabilitation program for all participants. Home exercises were prescribed 4 times a day.

GMI program

The GMI protocol consisted of 3 stages that required 3 weeks of lateralization, 3 weeks of motor imagery, and 2 weeks of mirror therapy. Each stage was applied as described by Moseley.[13] Forty pictures of the right hand were selected using Recognise (Noigroup, Adelaide, Australia).[37] These pictures, matched to gender and in various positions and alignments, were digitally mirrored to create a picture bank, including 80 images with right and left hands. These images were supplied to the participants by using a web-based program. Rather than a software program, SurveyMonkey (Retrieved from http://www.surveymonkey.com), which is an online survey tool, was used to present the images to the participants on the screen. It was convenient for the participants to access the task by using this tool. The images selected from Recognise application were uploaded to this survey tool. Detailed instructions were given to the participants about how to use the program, and a practice session was inserted before the experimental session to ensure that they understood the procedure. Throughout the study period, participants did not have any problems at the first and second stages while using this online survey tool. For the third stage, they were given a mirror box to use at home.

The first stage was identification of hand laterality. Pictures of hands were displayed in random order on a screen. According to the test protocol, participants were advised not to focus on their hands during the test. They were asked to choose the correct hand (right or left) from the image on the screen. The participants performed this stage 3 times (approximately 10 minutes) each waking hour. Reaction times and accuracy of performance were recorded to establish an outcome measure required to pass the next stage. Accuracy and reaction times of responses were recorded using a software program (E-prime Psychology Software Tools, Sharpsburg, VA).

The second stage was motor imagery. At this stage, participants visualized the hand postures without moving their hand. Twenty-eight pictures of the affected hand were randomly selected from the picture bank. Participants were requested to imagine moving their own hand to adopt the posture shown in the picture. Participants were instructed to perform this task for approximately 15 minutes 3 times every waking hour.

The third stage was the mirror therapy performed using a vertical mirror box ($300 \times 300 \times 300$ mm^3). Twenty images of the unaffected side were selected from the picture bank. Participants were asked to adopt the posture shown in each image with both hands using a smooth and pain-free movement, 10 times each waking hour.

When the participants were instructed about the entire procedure, it was emphasized that they adhere to the therapy appointments and the prescribed home exercises. Attendance at scheduled therapy appointments was used as a measure of adherence and was expressed as a percentage of scheduled sessions attended. Most participants were adherent during their appointments (Table 1). Home exercise adherence was normally distributed, and there was wide variability in the level of completion of the prescribed exercise (Table 1). The question "Did you perform your exercise for 1 hour daily?" inquired about adherence to a given exercise.

Statistical analyses

Statistical power analyses were used to determine the optimum sample size by using DASH score.[38] The minimum necessary sample size was determined to be 15 subjects for each group, with a 20% absence rate. The alpha level used in determining the sample size was 0.05, and the ideal power was considered to be 80%. The primary outcome was DASH score, whereas the secondary outcomes were pain at rest and activity, ROM degrees of wrist and forearm, grip strength, and MHQ score. Descriptive statistics were reported for continuous variables using mean and standard deviations (SDs) and for categorical variables using counts. For all data sets, the Kolmogorov-Smirnov test of normality was used to determine whether the distribution of values was normal ($P > .05$) or not normal ($P < .05$) and to indicate whether parametric or nonparametric statistical analysis should be used to analyze test results. According to the Kolmogorov-Smirnov test results, there was not a normal distribution of data. Wilcoxon signed rank test was used to test the mean differences between at the beginning and at the end of the treatment. Mann-Whitney *U* test was used to examine if the differences between the scores in the control and GMI groups were statistically significant. Data analysis was carried out using the Statistical Package for the Social Sciences (SPSS), version 16.0, for Windows (SPSS Inc, Chicago, IL). The alpha level for determining statistical significance was set at 0.05.

Table 1
Distribution of adherence variables

Adherence to appointments	GMI group ($n = 17$)	Control group ($n = 19$)
Adherence variables (% of scheduled appointments)	90	100
Home exercise (% of prescribed exercises)	100	90

GMI = graded motor imagery.

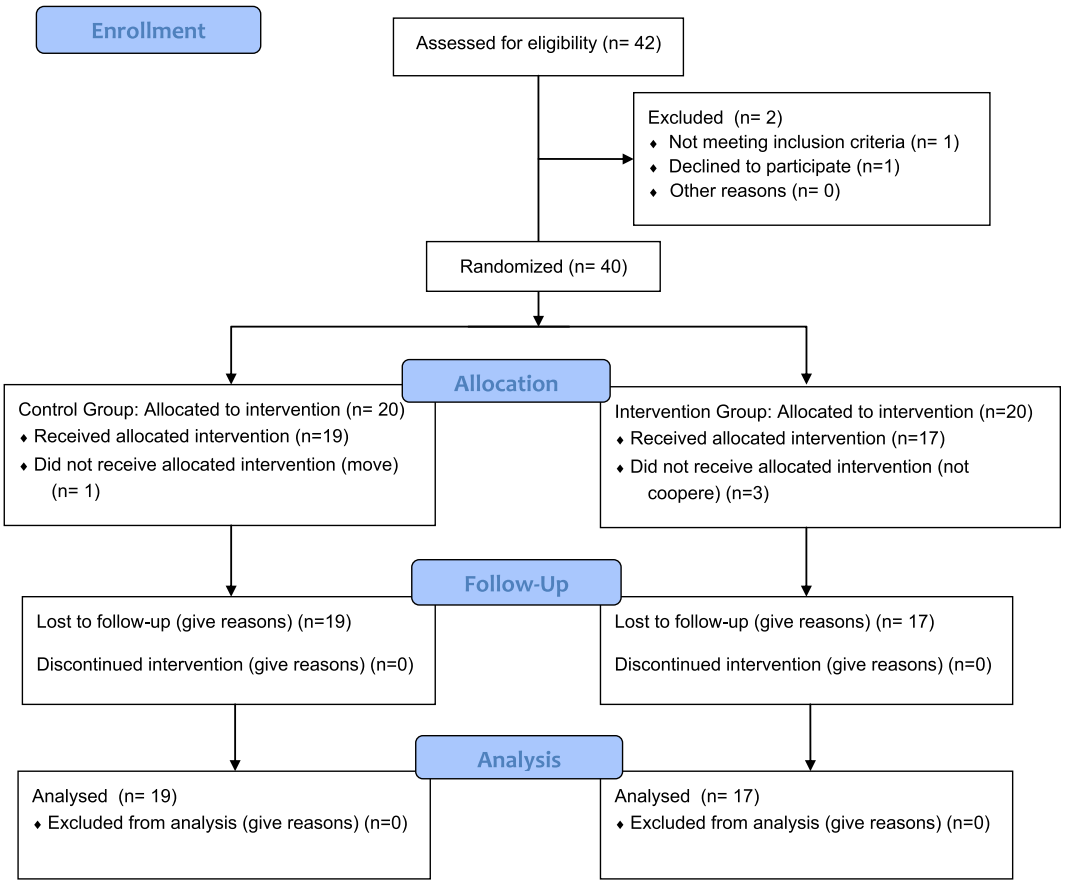

Fig. 1. Consort diagram.

Results

Although 42 participants were recruited in the study, 1 declined to participate and 1 did not meet the inclusion criteria. Therefore, 40 participants were included in the study. Twenty participants were randomly assigned to each group. Of these 40, 4 did not complete the treatment (1 moved to another city and 3 could not follow the instructions as directed); therefore, a total of 36 subjects (12 males and 24 females) completed the treatment (17 in the GMI group and 19 in the control group).

A diagram of the procedural flow of the study is shown in Figure 1. No between-group differences regarding the baseline characteristics were seen ($P > .05$) (Table 2). Mean (SD) age was 52.59 (9.8) years for the GMI group and 47.16 (10.5) years for the control group. Further descriptive data of demographics and baseline scores are reported in Tables 2 and 3, respectively.

No differences between the groups were observed at the baseline ($P > .05$) (Tables 2 and 3). Within-group analysis showed a significant decrease in pain (P values for pain in rest and pain in activity, respectively: in GMI group, .003 and $< .001$; and in control group, $< .001$ and $< .001$), increase in ROM (P values for flexion, extension, radial and ulnar deviation, supination, and pronation in both groups were $< .001$), and improvement in functional status in both groups (P values for DASH and MHQ scores in both groups were $< .001$). Between-group analysis showed a significant decrease in pain (P values for pain in rest and pain in activity, respectively: .05, .01), increase in ROM (P values for flexion, extension, radial and ulnar deviation, supination, and pronation, respectively: .001, .003, .001, .004, .008, and .066), and improvement in functional status in both groups (P values for DASH and MHQ scores, respectively: .048, .038) (Table 3). Although participants in both groups experienced a decrease in pain and an increase in ROM and functional status, between-group analysis showed that there was significantly more improvement in the GMI group compared with the control group.

Between-group comparison revealed significantly greater improvements in pain at rest and during activity in the GMI group than in the control group ($P < .05$). The mean reduction (SD) in pain level scores during rest between pre- and post-treatment was 2.24 (2.08) in the GMI group and 1.11 (1.24) in the control group. Similarly, the mean reduction in pain level scores during activity

Table 2
General characteristics of the participants

Characteristics	GMI group ($n = 17$)	Control group ($n = 19$)	P
Gender (M/F)	5/12	7/12	—
Age (y)	52.59 (9.8)	47.16 (10.5)	.055
BMI (kg/cm^2)	26.93 (4.1)	25.79 (6.6)	.216
Dominant side (R/L)	16/1	16/3	—
Affected side (R/L)	10/7	8/11	—
Orthopedic intervention (conservative/volar fixation)	12/5	11/8	—
Immobilized time (d)	18.7 (11.7)	21.7 (11.1)	.471
Initial treatment (d)	19.8 (11.6)	22.4 (11.5)	.661

GMI = graded motor imagery; M/F = male/female; BMI = body mass index; R/L = right/left.
Values are frequency or mean (standard deviation).

Table 3
Main outcome measures by group at the pre- and post-treatment assessments

Outcomes	Pretreatment			Post-treatment		Actual mean difference		
	GMI	Control	*P*	GMI	Control	GMI	Control	*P*
	Mean (SD)			Mean (SD)		Mean (SD)		
Pain (VAS)								
Rest	2.29 (2.08)	2.26 (2.56)	.817	**0.06 (0.24)**[a]	**1.16 (1.57)**[a]	**2.24 (2.08)**[b]	1.11 (1.24)	**.005**[b]
Activity	6.94 (1.34)	5.84 (2.17)	.065	**0.77 (1.09)**[a]	**3.74 (2.13)**[a]	**6.18 (1.43)**[b]	2.11 (0.81)	**.001**[b]
ROM (°)								
Flexion	27.94 (13.24)	32.90 (19.32)	.502	**68.53 (12.09)**[a]	**53.42 (13.44)**[a]	**−40.59 (13.22)**[b]	−20.53 (10.92)	**.001**[b]
Extension	12.65 (8.50)	18.16 (16.77)	.607	**18.16 (16.77)**[a]	**38.95 (17.53)**[a]	**−45.59 (16.19)**[b]	−20.79 (9.32)	**.003**[b]
Radial deviation	12.65 (7.31)	12.63 (8.72)	.779	**12.63 (8.72)**[a]	**26.32 (9.55)**[a]	**−25.59 (7.88)**[b]	−13.68 (6.20)	**.001**[b]
Ulnar deviation	11.76 (5.85)	14.21 (9.90)	.569	**14.21 (9.90)**[a]	**30.53 (8.80)**[a]	**−26.77 (8.83)**[b]	−16.32 (7.97)	**.004**[b]
Supination	19.12 (15.13)	23.16 (22.44)	.822	**23.16 (22.44)**[a]	**42.90 (23.11)**[a]	**−43.82 (14.63)**[b]	−19.74 (11.12)	**.008**[b]
Pronation	50.29 (30.34)	50.53 (28.03)	.974	50.53 (28.03)	72.90 (18.36)	−32.06 (24.69)	−22.37 (16.95)	.066
Grip strength (kg)	—	—	—	2.68 (1.86)	2.16 (1.17)	—	—	.341
DASH score	70.65 (16.76)	70.47 (16.15)	.835	**32.65 (12.96)**[a]	**43.90 (18.55)**[a]	**38.00 (14.33)**[b]	26.58 (16.82)	**.048**[b]
MHQ score	29.71 (7.25)	34.79 (8.70)	.073	**62.24 (9.28)**[a]	**54.47 (10.81)**[a]	**−32.53 (11.09)**[b]	−19.68 (10.40)	**.038**[b]

GMI = graded motor imagery; SD = standard deviation; VAS = visual analog scale; ROM = range of motion; DASH = Disability of the Arm, Shoulder and Hand Questionnaire; MHQ = Michigan Hand Questionnaire.
Change values are expressed for mean (SD).
Bold values indicate statistical significance $P < .05$.
[a] $P < .05$ within-group differences.
[b] $P < .05$ between-group differences.

between pre- and post-treatments was 6.18 (1.43) in the GMI group and 2.11 (0.81) in the control group (Table 3).

Active ROM of wrist flexion, extension, radial and ulnar deviation, and forearm supination in the GMI group improved significantly ($P < .05$) (Table 3). The mean change (SD) in the degree of wrist flexion between pre- and post-treatments was an improvement of −40.59 (13.22) in the GMI group and −20.53 (10.92) in the control group; for wrist extension, an improvement of −45.59 (16.19) in the GMI group and −20.79 (9.32) in the control group; for radial deviation, an improvement of −25.59 (7.88) in the GMI group and −13.68 (6.20) in the control group; for ulnar deviation, an improvement of −26.77 (8.83) in the GMI group and −16.32 (7.97) in the control group; and for supination, an improvement of −43.82 (14.63) in the GMI group and −19.74 (11.12) in the control group.

The grip strength of the injured side was 2.68 (1.86) kg in the GMI group and 2.16 (1.17) kg in the control group.

Between-group analysis showed that the GMI group had better DASH scores than the control group ($P < .05$) (Table 3). The mean change (SD) in DASH scores between pre- and post-treatments was a reduction of 38.00 (14.33) in the GMI group and 26.58 (16.82) in the control group. The GMI group also showed significantly greater improvements in the MHQ scores than the control group ($P < .05$) (Table 3). The mean change (SD) in MHQ scores between pre- and post-treatments was improvement of −32.53 (11.09) in the GMI group and −19.68 (10.40) in the control group.

Discussion

GMI is used increasingly in the treatment of chronic pain. This study investigated the effectiveness of GMI therapy on pain and upper extremity function in patients with DRFx. It was found that GMI provides beneficial effects to control pain, improve grip strength, and increase upper extremity functions at the early stages in DRFx rehabilitation. This is the first study, to our knowledge, investigating the effects of the GMI treatment strategy in the early stage of the DRFx rehabilitation.

GMI was developed to directly target reduction of the cortical disruptions after injury.[17] It has been shown that focusing attention on the affected limb might cause disuse of the limb, and persistent pain may lead to changes at the cortical level.[14,16] Reports suggest that pain relief changes the activation of the related neuromotor networks.[14,16] Several studies investigated the effectiveness of GMI components alone on pain or function. Moseley[16] compared the effectiveness of the motor imagery exercises and the mirror therapy in patients with chronic CRPS1. The motor imagery subjects were found to experience reduction in pain and edema.[16] Mirror therapy alone was found to be more effective in controlling pain in acute CRPS1 than in chronic CRPS1.[39] Similarly, it was found that GMI is an effective treatment in decreasing pain levels both during rest and activity. In patients experiencing phantom limb pain, sensory discrimination training provided improvements in the symptoms, which were found to be due to changes in cortical organization.[19] Although the underlying mechanisms of GMI therapy are not well understood, GMI is hypothesized to provide gradual activation of the cortical networks during movement without eliciting pain.[40]

No consensus exists about which stage of GMI has more ameliorative potential, but the sequence of the program is essential for the cortical network organization.[17] The first stage of GMI leads to increased blood flow in the limb-specific supplementary motor area, inferior premotor cortex, dominant left supplementary motor area, and superior premotor area; no alterations were found in the primary motor or primary somatosensory cortices.[18] Therefore, it was concluded that not stimulating primary cortices at the early stages after injury may contribute to pain control.

The immobilization period might cause altered proprioception.[41] Mental and imagery exercises were shown to improve kinematic parameters and clinical symptoms from orthopedic conditions.[42,43] Frenkel et al[42] showed that mental practice was effective in increasing the ROM measurement during the immobilization period. Mayer et al[43] demonstrated that mental imagery exercises have positive effects on gait parameters in total hip arthroplasty. Mintken et al[20] assessed a top-down treatment approach, including neuroscience education, tactile discrimination, limb laterality, and GMI in a patient with frozen shoulder. According to their results, pain at rest decreased, functional status improved, and shoulder ROM was greater.[20] In the present study, greater ROM degrees were found in the GMI group. Mehta et al[8] proposed that pain level contributes to functional status in patients with DRFx. Therefore, greater pain relief may contribute to improvement in wrist motion.

The cortical model of pathologic pain suggests that strategies should aim to correct the mismatch between motor output and

sensory feedback.[44,45] These strategies lead to reduced pain and normalization of cortical proprioceptive representation and correlates with recovery.[19,44,45] Muscle training is associated with morphologic changes and with neural adaptation for strength gain.[46,47] For instance, a strength task combined with motor imagery changes the central programming process via motor planning and motor learning.[47,48] As a result of neural adaptation, there is more contribution to motor units from muscles, along with greater activation on cortical areas in the primary motor cortex.[49,50] However, the relationship between muscle strength and motor imagery is controversial in the literature. Although some studies underline the efficacy of motor imagery on muscle strength,[51,52] others report no increase in muscle strength.[53,54] In the present study, grip strength was found in similar degrees in both groups at the end of the eighth week. These results could be due to lack of practice or performance of strengthening exercises at the early stage of rehabilitation. Long-term studies are warranted to investigate the effectiveness of GMI on muscle strength.

A successful clinical outcome after DRFx has been based on objective measures, such as improved radiographic parameters, wrist ROM, and grip strength.[5] However, reports indicate that patients are more interested in their ability to complete everyday functional activities.[5,55] Recently, patient-rated outcome measurement systems have been preferred to indicate the psychosocial effects of injury.[55] It was reported that the main advantage of using this kind of questionnaires is providing important information regarding the patient's status at a time that physical measurements cannot be assessed.[56] DASH and MHQ scales are used for self-evaluation of the patient's perspective on his and/or her upper extremity function, and both are used for evaluating functional status. However, there are some differences in the way that the functional status is questioned. Both the DASH and MHQ are specific measures of upper extremity function, whereas the DASH addresses global upper-extremity disability and symptoms, including physical, social, and psychological items.[31,57] DASH is also more sensitive to short-term changes than impairment-level physical measures of strength, sensibility, and motion.[56,57] However, MHQ includes esthetics and satisfaction aspects differently than DASH, and also the domains of MHQ are further subdivided into right and left hand-specific questions.[58] As a result, both questionnaires provide crucial information about the functional status in different ways. In this study, both DASH and MHQ scores were found to be better in the GMI group. The clinically significant change for DASH was reported as 10.83 points[59]; the GMI group showed a difference of 38 points. These findings verify the improvements in motor performance.[13,16,60,61]

There are some limitations to this study. First, although we found a significant effect of GMI in our relatively homogenous population, these results may not generalize across other groups with more variability in age and socioeconomic status. Second, abilities of the participants to engage in imagery could have been evaluated with validated instruments. Finally, the effect of each component could have been assessed with more objective tools, such as functional magnetic resonance imaging. Future long-term follow-up studies are warranted to address these questions.

Conclusion

GMI appears to provide beneficial effects to control pain, improve grip strength, and increase upper extremity functional status in patients with DRFx. Our results suggest that further studies with larger sample sizes are needed that investigate the long-term effects of GMI on pain control in patients with DRFx.

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Appendix A

Traditional rehabilitation program for both groups

Rehabilitation program was planned as shown later (adapted from Ref. 35).

First week

1. Education: All patients were informed about:
   - Healing process and their status and daily life requirements.
   - Compliance and its importance in the rehabilitation.
   - Home instructions for symptom management (elevation of the hand and wrist above heart level to control pain and edema).
2. Active ROM: digits, elbow, and shoulder (and wrist and forearm, if permitted) and over fisting (several times).
3. Retrograde massage and coban wraps were used for edema control.

Second to fourth weeks (each exercise was repeated 5-10 times for each session)

1. Posture exercises.
2. Active and active assistive ROM exercises for shoulder, elbow, forearm, wrist, and digits.
3. Gentle passive ROM exercises: forearm, wrist, and digits (sustained for 10 seconds).
4. Tendon gliding exercises for the superficialis and profundus tendons.
5. Intrinsic muscle stretching exercises (metacarpophalangeal joints extended and proximal interphalangeal joints flexed) (sustained for 10 seconds).
6. Joint mobilization grades 3 and 4 glides; traction grade 3.
7. Ball exercises
   - Wrist roll exercise: gentle wrist flexion and extension exercises with the ball.
   - Table roll exercise: rolling the ball from the tip of the fingers to the palm.
   - Wall roll exercise: rolling the ball on the wall (pain free).

Fourth to sixth weeks (each exercise was repeated 5-10 times)

1. Putty exercises.
2. Strengthening exercises for wrist and forearm with weight and exercise band.
3. Strengthening exercises for intrinsic muscles.
4. Weight-bearing exercises on the table.
5. Weight-bearing exercises on the wall.
6. Weight-bearing exercises on the wobble board.
7. Grip exercises.

Sixth to eigth weeks (each exercise was repeated at least 10 times)

1. Putty exercises.
2. Grip exercises.
3. Strengthening exercises for the wrist and forearm with weight and exercise band.
4. Strengthening exercises for intrinsic muscles.
5. Wobble board exercises.
6. Multiplanar upper extremity exercises.