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Research Paper

The effect of motor imagery on functionality, pain, kinesiophobia, and quality of life in patients with distal radius fractures: A randomized controlled double-blind study

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A B S T R A C T

Background: Conventional physiotherapy plays a significant role in treating distal radius fractures (DRF), but pain and functional limitations can persist despite treatment. Therefore, additional interventions are needed to improve treatment efficacy. Motor imagery (MI) has been shown to improve pain, function, range of motion (ROM), and muscle strength in musculoskeletal rehabilitation, though studies on its effect on upper extremity injuries are limited.
Purpose: To investigate the effect of MI training applied with the telerehabilitation method on pain, kinesiophobia, and functionality in patients with DRF.
Study Design: This was a double-blind randomized controlled trial with registration number NCT05360836.
Methods: Thirty volunteer patients aged 18-65 years with DRF, who decided to be treated conservatively, were randomly allocated to either the conventional treatment (CT) group (n = 15; 40.28 ± 18.18 years) or the MI group (n = 15; 38.80 ± 14.12 years). The MI group received imagery treatment in addition to traditional rehabilitation, and the CT group received traditional rehabilitation (three times a week for 8 weeks). Disabilities of Arm, Shoulder and Hand was our primary outcome measure, while the secondary outcome measures included the Patient Rated Wrist Evaluation, Visual Analog Scale, Tampa Scale for Kinesiophobia, normal ROM in the wrist joint, grip strength of hand and finger, left-right discrimination, and quality of life.
Results: The pain intensity, wrist functional status, muscle strength, active ROM, and quality of life were improved in both groups. Group comparisons showed statistically significant changes in Patient Rated Wrist Evaluation-function parameter, wrist extension active ROM, and hand grip strength in favor of the MI group (respectively, Δmean = −13.15, p = 0.034, effect size [ES] = 0.76, Δmean = −9.33, p = 0.019, ES = 0.91, Δmean = −10.96, p = 0.008, ES = 0.94).
Conclusions: Adding MI to conservative treatment after DRF improved function, wrist extension, and hand grip strength compared to CT alone.

Introduction

One of the most frequent types of fractures is a distal radius fracture (DRF).[1] In determining the treatment, whether conservative or surgical, the stability and the pattern of the fracture, injury mechanism, soft tissue injury, patient characteristics, and bone healing factors are evaluated.[1] In conservative treatment of DRF, patients are immobilized with a plaster cast for an average of 4-6 weeks.[2] Persistent pain after implementation of the initial management strategy is an important risk factor that affects functionality and recovery.[3] Decreases in muscle strength, wrist range of motion (ROM), and proprioception may occur as a result of the fracture and subsequent immobilization process.[4,5] Severe pain and diminished proprioception may contribute to the development of kinesiophobia in individuals with DRF.[4] Kinesiophobia is defined as a "fear of movement," which involves individuals avoiding movement due to

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the fear that physical activity or exercise will exacerbate pain or worsen injuries.[4] It can reduce the joint ROM in the affected arm and negatively affect functionality.[6] Failure to initiate a rehabilitation program promptly after immobilization in patients with DRF may cause functional impairments and disabilities in the long term.[1,7,8] Additionally, the rehabilitation process becomes more difficult in DRF that is not treated and monitored appropriately.[5,7,8]

In the treatment of DRF, immobilization of the wrist with splinting provides the foundation for subsequent gradual mobilization, ultimately facilitating the restoration of function.[2] However, immobilization can lead to central nervous system reorganization, impairing the central control of movements, and causing a temporary dysfunction in the affected limb.[8-10] This dysfunction can complicate the rehabilitation process after the immobilization period.[8-10] In this context, cognitive therapies such as motor imagery (MI) are being explored.[9] MI refers to the mental representation of a movement without physically executing it, encompassing various cognitive training interventions.[11] It has been shown that MI shares overlapping neural substrates with motor execution, which provides strong rationale for its use in rehabilitation.[12,13] MI has been proven effective in improving clinical outcomes, including pain reduction, increased functionality, and enhanced muscle strength.[11,14] However, the number of studies examining MI for upper extremity injuries, particularly DRF, is limited.[8,9] Additionally, it is seen that no consistent model or framework is used in the design of MI interventions in the literature.[11] The PETTLEP (Physical, Environment, Task, Timing, Learning, Emotion, Perspective) imagery model developed by Holmes and Collins[15] provides a framework for effectively implementing imagery interventions. Several variables must be considered when implementing an MI intervention, including how the imagery is prompted and the specific task the patient is asked to imagine.[11] Many studies on MI also lack sufficient detail in describing the intervention protocols.[11] There is no consensus on the optimal frequency, duration, or content of MI intervention to reduce pain and improve proprioception, ROM, and function after DRF.[8,9] Schuster et al stated that 24 sessions were required to receive positive results in MI training.[16]

After the COVID-19 pandemic, new care paradigms have been developed for DRFs, as in many pathologies, and treatment is now recommended to be non-emergent and conservative.[17] Additionally, difficulties in accessing rehabilitation services due to the pandemic have led to a preference for remotely accessible treatments.[18,19] The World Confederation for Physical Therapy has recommended implementing online rehabilitation services.[19] However, the number of studies conducted on telerehabilitation for the upper extremity is limited in the literature.[17,20] Telerehabilitation-based MI training is an innovative rehabilitation concept that has been shown to be effective in neurological patients.[21]

Upper extremity injuries can significantly impact daily activities, leading to a reduction in quality of life and overall well-being.[22] The ability to discriminate between left and right is crucial for the smooth execution of daily life activities.[23] Previous studies on DRF have focused on only one of the outcome measures of pain, muscle strength, or motor function, but have stayed away from multidimensional assessments.[24,25] According to the International Classification of Functioning, Disability, and Health; World Health Organization, a biopsychosocial approach is recommended in the evaluation.[26]

Although several studies have been conducted with the conservative treatment of DRF, it is still unclear which type of therapy has the most significant impact on wrist function recovery, ROM, and strength.[27,28] The effects of MI on pain, kinesiophobia, and functionality in musculoskeletal injuries have been examined in a limited number of studies.[8,9,13] Further research is needed to explore the effects of MI across different patient populations. Therefore, our study aimed to investigate the effects of MI on pain intensity, kinesiophobia, functionality, wrist ROM, hand grip strength, pinch grip strength, left-right discrimination, and quality of life in patients with conservatively treated DRF via telerehabilitation. We hypothesized that adding MI to conventional treatment (CT) after DRF would show better results across all evaluation parameters.

Methods

Study design

This clinical trial was designed as a prospective, single-center, randomized, double-blind investigation. The Department of Physiotherapy and Rehabilitation at Istanbul University-Cerrahpasa carried out the investigation from October 2021 to May 2023. The research protocol was designed according to the Consolidated Standards of Reporting Trials (CONSORT) criteria (refer to the CONSORT checklist, Figure 1). The study protocol was approved by the Clinical Research Ethics Committee of Istanbul University-Cerrahpasa (approval date: July 8, 2021, approval number: A-22). The study was conducted in accordance with the Declaration of Helsinki. The trial was registered on ClinicalTrials.gov under the identifier NCT05360836. Before enrollment, all participants provided informed consent.

Participants

We recruited consecutive patients who applied to the Department of Orthopedics and Traumatology at Istanbul University-Cerrahpasa and underwent conservative treatment at the Faculty of Health Sciences, Department of Physiotherapy and Rehabilitation, due to a diagnosis of DRF. Patients were diagnosed by an orthopedic surgeon (M.F.G.) who specialized in wrist, elbow, and hand-shoulder pathologies. All patients were classified according to the Frykman fracture classification,[29] and DRF cases that were uncomplicated, treated with a cast, and did not require surgical intervention were included in the study. The eligibility criteria were as follows: age between 18 and 65 years, ability to read and write in Turkish, agreeing to participate in the study, having a Standardized Mini-Mental State Test (SMMT) score of more than 24 points, applying within the first 15 days after plaster removal, ability to perform video call, and having no pathology in hearing and vision. The SMMT was used to assess cognitive status.[30] The scale score of less than 24 denotes cognitive impairment, whereas values between 24 and 30 are normal. Individuals who scored 24 or more on the SMMT were selected as participants in this study.

The exclusion criteria were as follows: unstable, segmental, or complicated fractures, bilateral fractures, fractures associated with malignant conditions, presence of nonhealing wound or infection, applying after 15 days following plaster removal, and having previously received physiotherapy for DRF. Since the use of different analgesic drugs may cause changes in the evaluation results, the same drug was prescribed to all patients by the physician and participants were asked not to deviate from this treatment.

MI abilities were assessed using the Kinesthetic and Visual Imagery Questionnaire (KVIQ).[31,32] This scale consists of 10 movements that measure five visual and five kinesthetic visualization skills. All movements were evaluated in a comfortable sitting position. The participant's imagery of the movement and the visual clarity of the imaged movement or the intensity of the sensations were scored with the help of a 5-point ordinal scale. The survey is not a self-report scale administered by an evaluator. Higher scores indicate greater visual clarity or intensity of sensations. Because initial differences in MI ability may alter gains from MI, individuals' MI abilities were assessed only once before treatment via the KVIQ to see if there was a homogeneous distribution across groups.

Sample size

G*Power 3.1 Analysis Program was used to determine the sample size. According to the Disabilities of Arm, Shoulder and Hand (DASH)

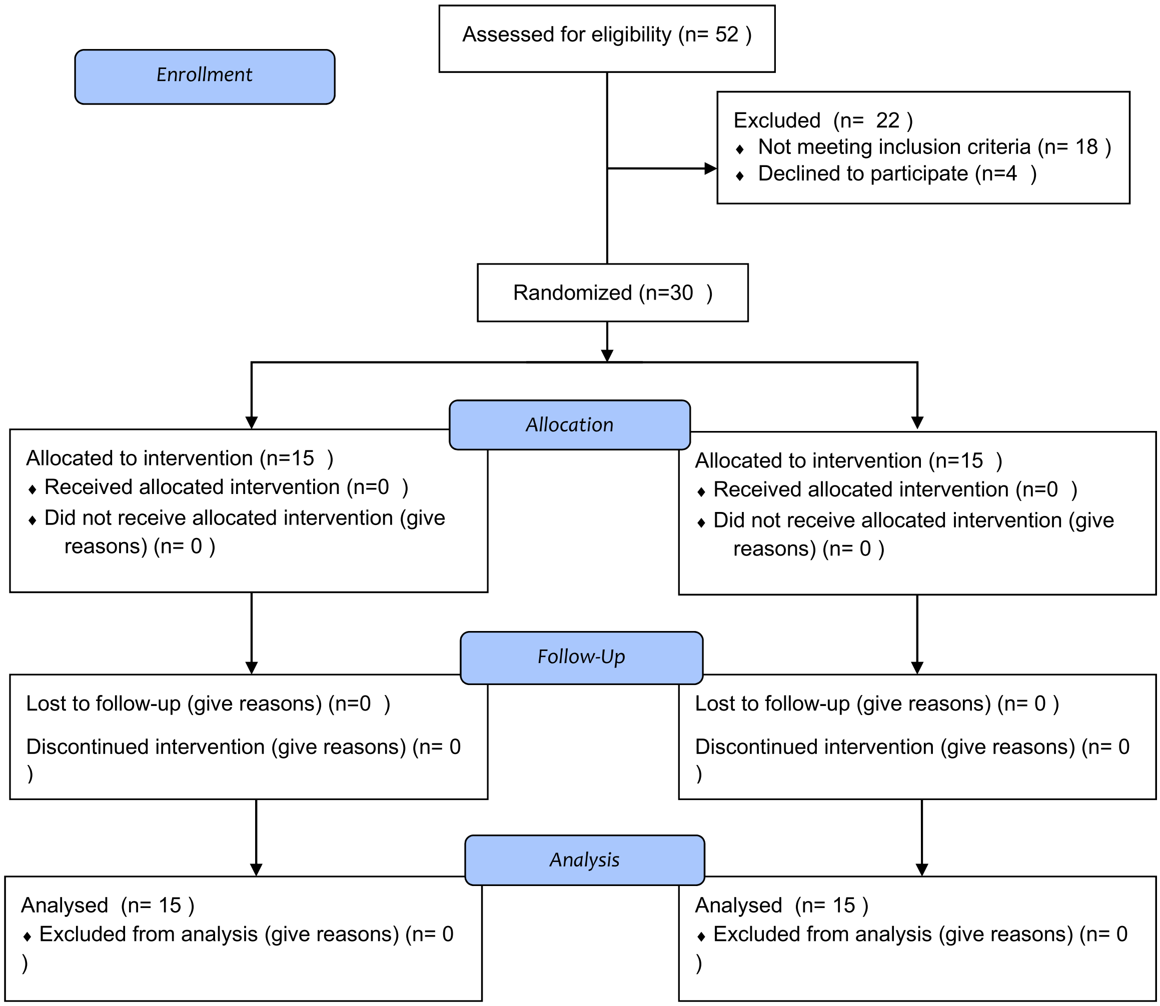

Fig. 1. CONSORT 2010 flow diagram. CONSORT = Consolidated Standards of Reporting Trials.

score results obtained from the research conducted by Tomruk et al[7] (effect size [ES] = 1.159, t test in independent groups), the minimum number of participants was determined as 24, with 85% power and significance level a = 0.05 (type-1 error = 0.05) (12 participants for each group). The minimum necessary sample size was determined to be 15 subjects for each group, with a 25% absence rate.

Randomization and blinding

The online randomization application "Research Randomizer" (https://www.randomizer.org/) was utilized to randomly assign patients to one of two intervention groups: group 1 (CT, n = 15), and group 2 (MI, n = 15) (Fig. 1). Simple randomization procedures (computerized random numbers) were performed, and sequentially, numbered index cards containing the random assignments were prepared by an investigator with no clinical involvement in the study to ensure allocation concealment. Index cards were folded and placed in sealed envelopes. Then, the physiotherapist (M.G.K.) performing the interventions opened each envelope and divided the participants into groups according to the selected index card. Participants and outcome assessors were blinded to group allocation. Outcome assessors were not involved in treatment delivery and were instructed not to inquire about the participants' interventions. The interventions were delivered online through telerehabilitation by the same physical therapist (M.G.K.), while the assessments were conducted face-to-face by another physical therapist (Y.A.A.) at a university research clinic.

Outcome measures

The participants' socio-demographic features were recorded on the Socio-demographic Data Form. Additionally, the participants' functional status, pain intensity, kinesiophobia, wrist ROM, hand grip strength, pinch grip strength, right-left discrimination, and quality of life were evaluated. The evaluations were conducted twice in a face-to-face/in-person clinic, before and after treatment (8 weeks). The average evaluation time conducted for each patient was 30 minutes.

Primary outcome

The primary outcome measure of this study was the functional status of the upper extremity, assessed using the DASH score. The DASH score is derived from responses to a 30-item questionnaire, including questions about physical problems, pain, and daily activities. The maximum DASH score is 100, with higher scores indicating increased disability.[33-35] The established minimum clinically important difference (MCID) for the DASH was 10.83 points.[36]

Secondary outcomes

The secondary outcomes were pain intensity, kinesiophobia, functional level of the wrist, wrist ROM, hand grip strength, pinch grip strength, right-left discrimination, and quality of life.

The pain intensity was measured by the Visual Analog Scale (VAS). Patients were asked about their pain during rest (VAS rest) and daily living activities (VAS activity). Participants were asked to mark the pain intensity on a 10 cm horizontal line between 0 (no pain) and 10 (worst pain felt).[37] The established MCID for the VAS is 20 mm.[38]

The kinesiophobia was assessed by the Tampa Scale of Kinesiophobia (TSK).[39,40] The survey includes 17 questions. The total score varies between 17 and 68 points. The higher scores indicate an increased fear of movement-related pain and re-injury.

The Patient Rated Wrist Evaluation (PRWE) consists of two subsections and 15 questions measuring the severity of wrist pain and the functional level of the wrist. The total score is calculated out of 100. A higher score indicates a worse outcome.[41-43] Furthermore, the outcomes were juxtaposed with the MCID documented in existing literature. The established MCID for the PRWE was 11.5 points.[44]

The wrist ROM was measured in appropriate positions with a universal goniometer.[45] Wrist extension, flexion, ulnar deviation, radial deviation, and forearm pronation and supination values of patients were recorded in degrees. To measure wrist flexion and extension ROM, the patient was seated supported by the edge of a table with the forearm in pronation. For ulnar and radial deviation measurements of the wrist, the patient was positioned with the forearm in pronation and the volar surface of the hand on the table. Forearm supination and pronation measurements were taken with the patient seated, the arm in contact with the body, the elbow flexed at 90°, and the forearm in a neutral position. Each participant was given verbal information about the test before starting. The affected side was assessed three times, with a 30-second interval between tests, and the best value was calculated for analysis.

Grip strength was measured in a seated position with the shoulder adducted, neutrally rotated, and the elbow flexed at 90°, with the wrist in a neutral position, and the ulnar deviation 0-15° using a Jamar hand dynamometer.[45]

Finger grip strength was measured using a pinchmeter (Pinchmeter Baseline). Three types of grips were assessed with a pinchmeter: fingertip grip strength using the distal ends of the first and second fingers, key grip strength involving the tip of the first finger and the lateral aspect of the second finger, and triple grip strength using the distal ends of the first, second, and third fingers.[45,46] To analyze the grip strength of the wrist and finger, each extremity was tested three times, with a 30-second break in between. The mean value was then determined.

Recognise (NOI, Adelaide, Australia) is an application designed to assess the speed and accuracy of discriminatory judgments made with the left and right hands. It was used to determine left-right discrimination.[47] Recognise hand applications were used for assessment. Two aspects of recognizing the laterality of the hand and implicit imagery capacity were evaluated, and the participants were shown images of the right and left hands from different angles on a phone screen. The participants were seated comfortably in a chair. The phone was placed on the table, at the center of their bodies, positioned at a distance that allowed them to easily see and reach it. A total of 20 images were shown to the patients at 5-second intervals, and response times and accuracy percentages were calculated and recorded.[48] Patients were instructed to react as quickly as possible without guessing whether the image showed their left or right hand. The test was conducted twice, with a 1-minute break between each attempt. The results of the second measurement were examined. Left-right discrimination accuracy of roughly 80% and a response time of 2.0 ± 0.5 seconds for hands, which are considered normative data, were observed.[49]

The quality of life was evaluated by the Short Form 12 Health Survey (SF-12) general health survey, which consists of 12 Likert-type questions and evaluates the mental and physical components of health separately.[50,51]

Interventions

A supervised, synchronized, and person-centered individual telerehabilitation program was applied to both groups by an experienced physiotherapist via WhatsApp or Zoom, 3 days a week for 8 weeks. A home program was not recommended for the treatment to avoid intensity differences and incorrect applications. The treatment duration for the CT group was approximately 20 minutes, whereas the MI group required approximately 35 minutes, including relaxation time.

Conventional treatment

The participants in both groups received individual CT programs after 4-6 weeks of immobilization with a plaster. The CT program included hot application 15 minutes before exercise, massage, passive and active exercises, tendon gliding, cold application after each exercise, and contrast bath during the day. The patients were taught passive, active-assisted, and active ROM exercises to the proximal interphalangeal, distal interphalangeal, and metacarpophalangeal joints within the pain limits. Once the pain was under control, active or active-assistive exercises were started and the exercises were gradually adjusted as needed. Finally, cold application was requested for 15 minutes after each session to prevent pain and edema. Between the fourth and eighth weeks, self-stretching exercises detailed below were applied in addition to previous practices[7,8,5] (Table 1).

Motor imagery

In the second group, MI training was applied in addition to the conventional physiotherapy exercises. The planning of MI training was based on a program demonstrated to be effective in previous studies.[11,21] The PETTLEP model, which includes seven key components (Physical, Environment, Task, Timing, Learning, Emotion, and Perspective), was used to standardize the MI training. The “Physical” component of PETTLEP emphasizes the importance of making the imagery experience as physically engaging as possible. The “Environment” component pertains to the context in which the imagery is performed. The “Task” component underscores that the content of the imagery should align with the individual’s skill level and personal preferences. The “Timing” component refers to the speed at which the imagery is executed. The “Learning” component accounts for the skill level of the individual, suggesting that the imagery content should be adjusted as the individual’s proficiency increases. The “Emotion” component involves the mental recreation of the imagery during the task to enhance its realism. The “Perspective” component refers to the individual’s internal perspective (from the athlete’s viewpoint) or external perspective (as if watching oneself perform, akin to watching on television) during the imagery.[52] This model emphasizes maximizing functional equivalence, defined as stimulating the same brain areas during MI as during actual movement, thus reinforcing the motor task’s memory trace. It emphasizes maximizing functional equivalence, defined as stimulating the same brain areas during MI as in actual movement, thereby reinforcing the motor task’s memory trace.[15] According to the observations and evaluations made by the physiotherapist before the treatment, the functional inadequacies of patients were analyzed and determined.

Table 1
Treatment protocol

	Conventional treatment	CT + MI
Week 1	Passive, active-assistive, or active range of motion exercises for Proximal Interphalangeal Joint (PIP), Distal Interphalangeal Joint (DIP), and Metacarpophalangeal Joint (MCP) Shoulder and elbow joint range of motion exercises	Passive, active-assistive, or active range of motion exercises for PIP, DIP, and MCP joints Shoulder and elbow joint range of motion exercises MI: reaching out and grasping a cup or an object
Weeks 2-4	Active or active-assistive exercises (wrist flexion, forearm pronation-supination, extension, thumb flexion-extension, adduction, abduction, opposition, repositioning, active blocking to other fingers, abduction, adduction, and tendon gliding exercises. Passive flexion, extension, radial, ulnar deviation, supination, and pronation exercises for the wrist	Active or active-assistive exercises (wrist flexion, forearm pronation-supination, extension, thumb flexion-extension, adduction, abduction, opposition, repositioning, active blocking to other fingers, abduction, adduction, and tendon gliding exercises. Passive flexion, extension, radial, ulnar deviation, supination, and pronation exercises for the wrist MI: reaching out and grasping a cup or an object
Weeks 4-6	In addition to the exercises from previous weeks, self-stretching exercises.	In addition to the exercises from previous weeks, self-stretching exercises. MI: using cutlery
Weeks 6-8	In addition to the exercises from the previous week, isometric wrist flexion-extension exercises and exercises aimed at increasing grip strength using a sponge or towel.	In addition to the exercises from the previous week, isometric wrist flexion-extension exercises and exercises aimed at increasing grip strength using a sponge or towel. MI: using cutlery

CT = conventional treatment, MI = motor imagery.

According to the results of the analysis, patients were given task-oriented functional movements in which they could improve their functional deficiencies in MI scenarios. MI application started with 5-minute relaxation breathing exercises. Then patients were asked to visualize sample tasks from a first-person perspective (seeing their limbs) in their minds, with polysensory instructions (ie, kinesthetic and visual cues) selected from functional movements performed by the weeks they were in. Then, patients ended up with instructions that would make them refocused on the room they were in for 3-5 minutes. In the following sessions, different activities or different environments were included in the imagination scenarios in line with the patient's progress, expectations, and wishes. While performing the visualizations, patients were requested to only visualize in their minds and not put them into action. Patients were asked to stop the practice when they felt pain during MI and start again when they were ready.[49,53]

Data analysis

For all statistical studies, SPSS, version 20.0 (IBM, Armonk, NY) for Windows software was utilized. Before doing a statistical analysis, the data distribution was assessed using the Kolmogorov-Smirnov test. The number of samples, percentage, mean, and standard deviation values were included in the descriptive statistics. Additionally, the demographic and clinical characteristics between groups were analyzed using the Chi-square test.

Wilcoxon Signed Rank test was used to compare pre-and post-treatment changes within groups, and the Mann-Whitney U test was used to compare post-treatment changes in all measurements between CT and MI groups. The significance level was set at $p < 0.05$. Additionally, ES was calculated for statistically significant variables using the following formula: absolute difference between measurements/standard deviation of the first measurement value. An ES between 0.20 to 0.50 was considered "low," between 0.51 and 0.80 was considered "moderate," and 0.81 and above was considered "high."[54]

Results

Fifty-two subjects were screened for eligibility; 22 did not meet the inclusion, therefore 30 were enrolled and evaluated. As described in the CONSORT flowchart, 15 subjects were randomized to the CT group, and 15 subjects were randomized to the MI group (mean ± SD age, 39.51 ± 15.93 years; 57 [50%] females) (Fig. 1). For every person, the interval between randomization and the start of the intervention was between 3 and 5 days. None of the patients experienced negative side effects or problems during the intervention.

At baseline, no significant differences were observed between groups for any of the demographic and clinical variables ($p > 0.05$) (Tables 2-4). A comparison of primary and secondary outcome measures between groups and within-group score changes is shown in Tables 5-7. Within-group score changes were significant in terms of primary and secondary outcome measures, except for TSK in both groups ($p < 0.05$). Group comparisons showed statistically significant changes in PRWE function parameter, wrist extension active ROM, and hand grip strength in favor of the MI group (respectively, Δmean = −13.15, $p = 0.034$, ES = 0.76, Δmean = −9.33, $p = 0.019$, ES = 0.91, Δmean = −10.96, $p = 0.008$, ES = 0.94).

The group differences for the PRWE function subscale showed a medium effect, while the group differences for wrist extension ROM and hand grip strength exhibited large effects. When comparing subjective outcomes with objective measures, somewhat larger effects were observed in the subjective outcomes.

Discussion

The findings disclose that the incorporation of MI into CT via the telerehabilitation method may lead to greater improvements in PRWE function subscales, wrist extension ROM, and hand grip strength, compared to CT via telerehabilitation alone. In addition, our study reveals that significant improvement in both pain and function (objective/subjective) parameters can be observed with both treatment methods.

The similarity in the demographic characteristics and baseline values of our groups contributed to the formation of homogeneous groups. We did not have any patients who discontinued the

Table 2
Baseline demographic and clinical characteristics of the groups

Parameters	CT	MI	p
	Mean ± SD	Mean ± SD	χ^2
Age (y)	40.3 ± 18.2	38.8 ± 14.1	0.776
Height (cm)	168.0 ± 9.7	168.8 ± 10.5	0.895
Weight (kg)	70.6 ± 10.7	75.4 ± 12.4	0.393
BMI (kg/m^2)	25.0 ± 3.2	26.5 ± 3.8	0.295
Education, y, mean (SD)	12.7 ± 5.1	14.1 ± 3.6	0.368

CT = conventional treatment; MI = motor imagery; BMI = body mass index; kg = kilograms; m = meters; SD = standard deviation; y = year; % = percent; χ2 = Chi-square test.

Table 3
Demographic and clinical characteristics of the groups

Parameters		CT	MI	p
		n (%)	n (%)	χ^2
Sex (n)	Female	9 (64.3%)	6 (40%)	0.175
	Male	5 (35.7%)	9 (60%)	
Dominant hand (n)	Right	13 (92.9%)	14 (93.3%)	0.741
	Left	2 (7.1%)	1 (6.7%)	
Injured hand (n)	Right	11 (78.6%)	10 (66.7%)	0.383
	Left	4 (21.4%)	5 (33.3%)	
Dominant side injured (yes/no)	Yes	10 (66.7%)	11 (73.3%)	0.500
	No	5 (33.3%)	4 (26.7%)	
Frykman classification	Type I	4 (26.7%	3 (20%)	0.746
	Type II	2 (13.3%)	1 (6.7%)	
	Type III	2 (13.3%)	2 (13.3%)	
	Type IV	-	1 (6.7%)	
	Type V	4 (26.7%)	3 (20%)	
	Type VI	1 (6.7%)	2 (13.3%)	
	Type VII	2 (13.3%)	1 (6.7%)	
	Type VIII	-	2 (13.3%)	

CT = conventional treatment; MI = motor imagery; n = number of people; % = percentage; χ^2 = Chi-square test.

Table 4
Comparison of baseline characteristics before treatment

Parameters	CT	MI	p*
	Mean ± SD	Mean ± SD	
KVIQ-visual	20.9 ± 4.1	21.1 ± 3.5	0.949
KVIQ-kinesthetic	21.4 ± 4.0	21.1 ± 3.4	0.715
DASH (0-100)	65.1 ± 25.0	59.9 ± 10.7	0.132
PRWE pain (0-50)	28.5 ± 12.8	30.5 ± 7.8	0.431
PRWE function (0-50)	34.9 ± 13.7	34.2 ± 9.6	0.631
PRWE total (0-100)	63.1 ± 26.4	62.9 ± 15.6	0.743
VAS rest (cm)	3.2 ± 2.4	2.3 ± 2.0	0.346
VAS activity (cm)	6.4 ± 1.9	5.9 ± 1.3	0.372
TSK (17-68)	39.8 ± 4.2	36.1 ± 11.7	0.483
Flexion (°)	43.5 ± 16.1	47.3 ± 11.9	0.166
Extension (°)	20.1 ± 14.1	21.5 ± 14.7	0.947
Radial deviation (°)	16.9 ± 11.9	16.3 ± 5.8	0.626
Ulnar deviation (°)	18.6 ± 9.3	22.7 ± 8.7	0.211
Supination (°)	53.6 ± 21.9	62.5 ± 24.8	0.220
Pronation (°)	51.7 ± 21.6	69.7 ± 19.3	0.033
Hand grip strength (kg)	9.3 ± 13.0	4 ± 4.5	0.774
Fingertip grip strength (kg)	4.9 ± 3.0	3.0 ± 2.6	0.087
Key grip strength (kg)	8.5 ± 4.1	5.7 ± 3.2	0.028
Triple grip strength (kg)	6.7 ± 4.0	4.1 ± 3.2	0.044
Speed right (s)	2.1 ± 0.5	2.0 ± 0.5	0.809
Speed left (s)	2.2 ± 0.8	2.0 ± 0.6	0.776
Accuracy right (%)	80.7 ± 12.1	80 ± 22.4	0.574
Accuracy left (%)	85 ± 14.0	78 ± 27.0	0.720
SF-12 physical (0-50)	34.0 ± 4.3	34.7 ± 6.4	0.550
SF-12 mental (0-50)	38.7 ± 9.3	41.1 ± 9.3	0.462

CT= conventional treatment; MI = motor imagery; SD = standard deviation; DASH = Disabilities of the Arm, Shoulder and Hand; VAS = visual analog scale; TSK = Tampa Scale of Kinesiophobia; PRWE = Patient Rated Wrist Evaluation; KVIQ = Kinesthetic and Visual Imagery Questionnaire; SF-12 = Short Form 12 Health Survey.
* Mann-Whitney U test, statistical significance $p < 0.05$.

treatment or did not participate in the evaluations. This may be due to the fact that there was no obligation to physically participate in the sessions and each session was performed simultaneously.

Pain following DRFs constitutes a significant risk factor that impedes recovery.[7,8,14] A systematic review investigating the effectiveness of MI in musculoskeletal pain conditions showed that the use of MI is very effective, especially in reducing chronic pain, but is not superior to standard rehabilitation in acute pain.[13] Previous studies have shown that MI training is effective in reducing pain in CRPS-I following hand fractures.[55,56] Dilek et al, similar to our study, compared CT with CT combined with GMI in patients with DRF and found that the group with GMI added showed a greater reduction in pain at the end of the study.[8] In our study, post-treatment evaluations revealed a reduction of more than 20 mm in the intra-group change averages of both the VAS-rest and VAS-activity scores, respectively (CT: 2.13, 4.21; MI: 2.13, 4.4). This decrease exceeds the MCID value accepted for the VAS.[32] However, when the changes in pain levels were compared between groups, no superiority of the two treatment approaches was found. However, when the changes in pain levels were compared between groups, no superiority of the two treatment approaches was found. Considering the causes of pain, it is likely that the effect of MI is less in acute pain cases. For these reasons, there may not have been an advantage in the group in which we applied MI in addition to CT.

A review of the literature reveals a lack of consensus regarding the effects of muscle strength and MI on patients with DRF.[8,9,57,58] Dilek et al did not find an increase in grip strength in their study, in which they applied GMI after DRF.[8] Korbus and Schott observed an increase in grip strength in the MI group after DRF in women aged 65 and over.[9] Our study revealed that MI may be more effective in improving hand grip strength in the group compared to the conventional group alone. The discrepancy in the findings of the studies in the literature may be attributed to the fact that the variables under investigation are distinct. We recommended exercises that focus on activities of daily life to motivate participants to regain wrist function.

Remaining in plaster immobilization after DRF, especially the presence of pain during activity, makes activities difficult, and this causes a decrease in ROM in patients.[1,8] In our study, as expected patients in both groups reached a joint ROM of 40°-40° flexion-extension and 50°-50° supination-pronation, which are defined as functional wrist range in the literature.[59] Hoyek et al, in their study with patients diagnosed with shoulder impingement syndrome, concluded that MI increased shoulder mobility.[53] It was found that MI had an effect solely on the abduction movement in patients with frozen shoulder.[60] In our study, the MI group showed a significantly greater improvement in ROM only in active wrist extension. It is well known that wrist extension ROM plays a crucial role in activities such as grasping.[61] Therefore, the higher grip strength values observed in the MI group may be related to increased wrist extension.

Although the focus throughout the rehabilitation process is on enhancing muscle strength and joint ROM, what is ultimately important for patients is their level of independence during functional activities. It has been reported that the major advantage of using patient-rated outcome measures is that they provide important information about the patient's condition.[13,57] Considering the functional results of our study, significant improvements were noted in both groups in DASH scores and all parameters of the PRWE questionnaire. The MCID for the DASH was reported as 10.83 points,[36] while the MI group showed a difference of 30.83 points (CT: 27.82). Similarly, for the PRWE,[44] with an MCID of 11.5 points, the MI group demonstrated a difference of 41.26 points (CT: 32.86). These findings actually suggest that motor performance has improved to a greater extent in the MI group. However, the literature highlights that the PRWE questionnaire is particularly sensitive to changes in functional status in individuals with DRF.[41,62,63] DASH has the advantage of being a standard outcome measure; however, it also has the disadvantage of being less representative of the patient's individual abilities.[64] We attribute the significant difference we found in the MI group to the PRWE being more sensitive in representing individual abilities. Furthermore, a strong relationship between PRWE score, grip strength, and wrist extension was found in a previous study.[65] Consistent with the literature, we observed a significant difference in favor of the MI group in all three parameters.

Table 5
Comparison of function, pain intensity, kinesiophobia, active range of motion, measures between pre- and post-treatment

Parameters	CT Mean ± SD				MI Mean ± SD				Δ Group I-II		Effect size
	BT	AT (8 week)	z	*p**	BT	AT (8 week)	z	*p**	z	*p*†	
Primary outcomes											
DASH	65.1 ± 25.0	37.3 ± 20.2	−3.297	0.001*	59.8 ± 10.7	29.0 ± 11.3	−3.409	0.001*	−0.109	0.913	-
Secondary outcomes											
VAS rest (cm)	3.2 ± 2.4	0.5 ± 0.0	−2.97	0.003*	2.3 ± 2.0	0.2 ± 0.6	−2.816	0.005*	−0.806	0.420	-
VAS activity(cm)	6.4 ± 1.9	2.2 ± 1.0	−3.317	0.001*	5.9 ± 1.2	1.5 ± 1.2	−3.422	0.001*	−0.266	0.790	-
TSK	39.8 ± 4.2	37.4 ± 5.7	−1.619	0.105	36.1 ± 11.7	38.1 ± 4.3	−0.245	0.807	−1.588	0.112	-
PRWE pain	28.5 ± 12.8	11.6 ± 5.4	−3.171	0.002*	30.5 ± 7.8	11.1 ± 11	−3.352	0.001*	−0.961	0.337	-
PRWE function	34.9 ± 13.7	17.7 ± 7.2	−3.297	0.001*	34.2 ± 9.6	10.3 ± 7.7	−3.409	0.001*	−2.118	0.034†	0.76
PRWE total	63.1 ± 26.4	30.3 ± 12.2	−3.297	0.001*	62.9 ± 15.6	21.6 ± 18.5	−3.413	0.001*	−1.224	0.221	-
Flexion (°)	43.5 ± 16.1	62.5 ± 11.5	−3.189	0.001*	47.3 ± 11.9	71.5 ± 12.5	−3.412	0.001*	−1.823	0.068	-
Extension (°)	20.1 ± 14.1	40.2 ± 10.7	−3.301	0.001*	21.5 ± 14.7	50.9 ± 11.9	−3.448	0.001*	−2.354	0.019†	0.91
Radial deviation (°)	16.9 ± 11.9	21.4 ± 9.7	−2.692	0.007*	16.3 ± 5.8	21.4 ± 3.9	−3.237	0.001*	−0.747	0.455	-
Ulnar deviation (°)	18.6 ± 9.3	24.1 ± 7.7	−2.963	0.003*	22.7 ± 8.7	35.1 ± 9.4	−3.302	0.001*	−1.884	0.060	-
Supination (°)	53.6 ± 21.9	73.6 ± 12.6	−3.065	0.002*	62.5 ± 24.8	80.5 ± 14.2	−3.189	0.001*	−0.308	0.758	-
Pronation (°)	51.7 ± 21.6	72.4 ± 15.1	−3.072	0.002*	65.7 ± 15.9	88 ± 4.1	−3.425	0.001*	−0.552	0.591	-

CT = conventional treatment; MI = motor imagery; SD = standard deviation; BT = before treatment; AT = after treatment; DASH = Disabilities of the Arm, Shoulder and Hand; VAS = visual analog scale; TSK = Tampa Scale of Kinesiophobia; PRWE = Patient Rated Wrist Evaluation.
* Wilcoxon Signed Rank Test, statistical significance $p < 0.05$.
† Mann-Whitney U test, statistical significance $p < 0.05$.

Table 6
Comparison of grip strength, lateralization, and quality of life measures between pre- and post-treatment

Parameters	CT Mean ± SD				MI Mean ± SD				Δ Group I-II		Effect size
	BT	AT (8 week)	z	*p* WSRT	BT	AT (8 week)	z	*p* WSRT	z	*p* MWU	
Hand grip strength (kg)	9.3 ± 13.0	22.9 ± 12.9	−3.306	0.001*	4.0 ± 4.5	24.3 ± 10.0	−3.409	0.001*	−3.302	0.008*	0.94
Fingertip grip strength (kg)	4.9 ± 3.0	13 ± 4.0	−3.304	0.001*	3.0 ± 2.6	10.7 ± 4.2	−3.417	0.001*	−0.132	0.895	-
Key grip strength (kg)	7.4 ± 3.4	14.7 ± 2.8	−3.329	0.001*	5.7 ± 3.2	14.8 ± 6.9	−3.298	0.001*	−1.261	0.207	-
Triple drip strength (kg)	6.0 ± 3.2	13.4 ± 4.0	−3.301	0.001*	4.1 ± 3.2	13.3 ± 4.3	−3.410	0.001*	−1.292	.201	-
Left-right discrimination											
Speed right (s)	2.1 ± 0.5	1.8 ± 0.3	−2.422	0.015*	2.0 ± 0.5	1.8 ± 0.4	−2.18	0.029*	−0.245	.807	-
Speed left (s)	2.2 ± 0.8	2.0 ± 0.6	−1.326	0.185	2.0 ± 0.6	1.7 ± 0.4	−1.993	0.046*	−1.213	.225	-
Accuracy right (%)	80.7 ± 12.1	87.1 ± 8.3	−2.714	0.075	80 ± 22.4	89.3 ± 8.8	−1.93	0.054	−0.265	.791	-
Accuracy left (%)	85 ± 14	88.5 ± 12.1	−1.508	0.132	78 ± 27.0	91 ± 8.0	−2.263	0.024*	−0.022	.983	-
Quality of life											
SF-12 physical	34.0 ± 4.3	41.0 ± 6.6	−2.982	0.003*	34.7 ± 6.4	42.5 ± 8.7	−2.982	0.003*	−0.505	0.613	-
SF-12 mental	38.7 ± 11.3	42.2 ± 12.2	−1.099	0.272	41.1 ± 9.3	43.5 ± 8.1	−0.691	0.490	−0.046	0.963	-

CT = conventional treatment; MI = motor imagery; SD = standard deviation; BT = before treatment; AT = after treatment; s = second; kg = kilogram; WSRT = Wilcoxon test was applied; MWU = Mann-Whitney U test; SF-12 = Short Form 12 Health Survey.
* Significance was accepted as $p < 0.05$.

It is known that the speed of discrimination between right- and left-hand images in people with upper extremity pain is slower than in a healthy control group.[66] In our study, after 8 weeks of treatment, hand left-right discrimination test results showed improvement in speed right, speed left, and accuracy left in the MI group, while only speed right improved in the CT group. There was no significant difference between the groups. Pain reduction levels after 8 weeks of treatment did not differ between groups, so left-right discrimination impaired by pain may have decreased in both groups after treatment and did not make a difference between these groups. Furthermore, the increase in the speed-right parameter in both groups may be because most of the individuals in the group were injured in their dominant right hand.

In patients with musculoskeletal injuries, there has been a substantial correlation identified between thoughts of catastrophic pain and anxiety and the severity or impairment of the pain experienced.[6,67] The process of remaining in immobilization with a plaster cast after DRF and the presence of pain during activity after the plaster cast is removed may cause fear of movement. In our study, the TSK values were high before treatment. Neither group showed a significant difference in TSK values before and after treatment. Due to our study being conducted during the pandemic, factors such as social isolation, reduced physical activity, and the increased mortality rates during this period may have caused the lack of decrease in kinesiophobia values in both groups.

This study had several strengths. It was a double-blind, randomized controlled trial. To our knowledge, this is the first study to examine the effects of MI on many parameters such as pain, function, kinesiophobia, and quality of life in individuals with DRF. However, our study had some limitations. First, the long-term results of treatments after DRF were not examined. Second, participants' compliance was not checked. Further investigations could explore the potential additional benefits of increasing the number of MI sessions. Moreover, studies with a larger sample size could provide more robust insights into the treatment's effectiveness. Additionally, assessing activity levels in future studies may facilitate the advancement of the existing literature.

Table 7
Comparison of post-treatment changes in function, pain intensity, kinesiophobia, active range of motion, grip strength, lateralization, and quality of life measures among the groups

Parameters	CT Mean ± SD	MI Mean ± SD	*p*	Mean difference CI
Primary outcomes				
DASH	27.8 ± 13.1	30.8 ± 8.7	0.913	−3.01 ± 8.34 [−11.35, 5.33]
Secondary outcomes				
VAS rest (cm)	2.7 ± 1.8	2.1 ± 1.9	0.420	0.58 ± 1.37 [−0.79, 1.95]
VAS activity(cm)	4.2 ± 1.5	4.4 ± 1.8	0.790	−0.19 ± 1.23 [−1.42, 1.04]
TSK	3.4 ± 4.6	4.4 ± 3.2	0.112	−1 ± 2.95 [−3.95, 1.95]
PRWE pain	17.2 ± 10.4	19.5 ± 8.4	0.337	−2.29 ± 7.05 [−9.34, 4.76]
PRWE function	17.2 ± 8.7	23.8 ± 8.8	0.034*	−6.66 ± 6.54[−13.2, −0.12]
PRWE total	32.9 ± 19.6	41.3 ± 15.0	0.221	−8.44 ± 13.04 [−21.48, 4.6]
SF-12 physical	7.3 ± 5.2	8.9 ± 5.1	0.613	−1.6 ± 3.84 [−5.44, 2.24]
SF-12 mental	5.9 ± 8.5	5.0 ± 4.5	0.963	0.93 ± 5.08 [−4.15, 6.01]
Flexion (°)	19 ± 9.0	24.2 ± 7.8	0.068	−5 ± 6.25 [−11.25, 1.25]
Extension (°)	20.1 ± 11.7	29.4 ± 8.3	0.019*	−9.33 ± 7.61 [−16.94, −1.72]
Radial deviation (°)	4.5 ± 5.3	5.1 ± 4.3	0.455	−0.63 ± 3.62 [−4.25, 2.99]
Ulnar deviation (°)	5.4 ± 3.9	12.4 ± 11.6	0.060	−6.97 ± 6.48 [−13.45, −0.49]
Supination (°)	20 ± 14.9	18.1 ± 15.2	0.758	1.9 ± 11.27 [−9.37, 13.17]
Pronation (°)	20.6 ± 17.3	22.3 ± 19.7	0.674	2.31 ± 13.88 [−11.57, 16.19]
Hand grip strength (kg)	13.5 ± 5.4	20.3 ± 8.7	0.008*	−10.96 ± 5.79 [−16.75, −5.17]
Fingertip grip strength (kg)	8.1 ± 3.8	7.8 ± 3.6	0.895	0.31 ± 2.74 [−2.43, 3.05]
Lateral grip strength (kg)	7.3 ± 3.0	9.1 ± 5.0	0.207	−1.84 ± 3.08 [−4.92, 1.24]
Triple grip strength (kg)	6.7 ± 2.7	9.2 ± 4.4	0.084	−2.49 ± 2.73 [−5.22, 0.24]
Speed right (s)	0.4 ± 0.4	0.4 ± 0.3	0.807	0 ± 0.27 [−0.27, 0.27]
Speed left (s)	0.4 ± 0.4	0.5 ± 0.4	0.225	−0.12 ± 0.31 [−0.43, 0.19]
Accuracy right (%)	6.4 ± 6.3	10.7 ± 19.4	0.791	−4.23 ± 10.81 [−15.04, 6.58]
Accuracy left (%)	3.8 ± 8.7	12.7 ± 24.0	0.983	−8.82 ± 13.52 [−22.34, 4.7]

CT = conventional treatment; MI = motor imagery; SD = standard deviation; s = second; kg = kilogram; MWU = Mann-Whitney U test; CI: confidence interval; SF-12 = Short Form 12 Health Survey.
* Significance was accepted as $p < 0.05$.

Conclusion

Performing MI of daily activities after virtual CT may be effective in increasing the PRWE function subscale, wrist extension, and hand grip strength.

Ethics and Clinical Trial Codes

The approval of the Clinical Research Ethics Committee of Istanbul University-Cerrahpasa was obtained (approval date: July 8, 2021, approval number: A-22). Additionally, this trial was registered at ClinicalTrials.gov under the identifier NCT05360836.

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CRediT authorship contribution statement

Melike Gizem Kalaycı: Writing – review & editing, Writing – original draft, Methodology, Investigation, Conceptualization. **Yildiz Analay Akbaba:** Writing – review & editing, Writing – original draft, Supervision, Methodology, Conceptualization. **Mehmet Fatih Güven:** Supervision, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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JHT Read for Credit

Quiz: # C17

Record your answers on the Return Answer Form found on the tear-out coupon at the back of this issue. There is only one best answer for each question.

#1. The study design was
  a. qualitative
  b. RCTs
  c. case series
  d. n = 1

#2. MI abilities were assessed using the
  a. Kasch Inventory
  b. Kensington Muscle Index
  c. Kelvar Scale
  d. KVIQ

#3. The primary outcome measure was the
  a. Mayo Clinic Wrist Fracture PROM
  b. Moberg Pick Up Test
  c. DASH
  d. modified Quick DASH

#4. Essentially all outcome results were
  a. improved in the experimental group
  b. improved in both groups
  c. improved in the control group
  d. unimproved in both groups

#5. To standardize the MI training the PETTLEP model was followed
  a. true
  b. false