RESEARCH ARTICLE

EFFECTIVENESS OF GRADED MOTOR IMAGERY IN PAIN AND DISABILITY AFTER ROTATOR CUFF INJURY

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ABSTRACT

Objective: to determine the effects of graded motor imagery (GMI) on pain and disability in rotator cuff injuries. **Methodology**: A Randomized Control Trial conducted at national institute of rehabilitation medicine (NIRM) after the approval from the executive director. A total n=40 subjects were recruited through non probability convenient sampling technique and allocated randomly in the Conventional physical therapy (CPT) (n=20) and the graded motor imagery (GMI) group (n=20). Patients with age range 25-50 years having history of trauma with positive impingement sign were included and patient with diabetes were excluded from the study. The data was collected through General demographic questionnaire included age, gender, ADLs, Diabetes, Hyper tension etc. Shoulder Pain and Disability Index (SPADI) was used to measure current shoulder pain and disability in an outpatient setting. Data was compared at baseline and after 2[nd] week and 4[th] week. **Results**: The mean age of the study participants was 38.67±7.437 years. Within-group changes showed that both group improved significantly ($p \leq 0.05$) from 0-4[th] week regarding total shoulder pain and disability score. While comparing the both groups, significant improvement ($p \leq 0.05$) was found in as compare to conventional PT group. **Conclusion**: graded motor imagery (GMI) and conventional PT both are effective for management of pain and disability due to rotator cuff injuries. But GMI was found to be more effective than conventional PT.

Keyword: rotator cuff injury, graded motor imagery, pain, disability, phantom limb pain.

INTRODUCTION

The Glenohumeral joint is one of the strongest and mobile ball and socket complex joint and it is supported by static and dynamic components of Musculotendinous cuff and the scapular stabilizers muscles.[1] Musculotendinous/Rotator cuff injuries are most common cause of pain in shoulder area.[2] Repetitive overhead activities, trauma to shoulder joint leads to massive tear or tendinitis of rotator cuff muscles. Repetitive overhead activities or trauma or gradual onset is associated with the rotator cuff injuries[3,4]

Pain in rotator cuff injuries is most common symptom, it may be aggravated by overhead activities or a forward-flexed position which is associated with weakness and limitation of motion presented with clicking, catching, stiffness, and crepitus.[5,6] The severity of injury determine the treatment option, as Complete full thickness tears require surgery followed by rehabilitation and minor breadth tears can be preserved with physical therapy[7,8]

According to recent suggestion the neuromatrix model codes pain characters allowing for mental, passionate, and sensory dimensions. So it offers specific rehab strategy that addresses all these dimensions. [9]

Graded motor imagery (GMI) it is very good method in pain management that organizes cortical activation and gradually decreases cortical disinhibition to prevent from acute pain to chronic pain.[10] Graded motor imagery process from innovation of improved sensory cortex organization to targeted sensory discrimination exercise for clinical benefit has been frequent in complex regional pain syndrome (CRPS). Without eliciting the protective response of pain graded motor imagery slowly involve cortical motor networks. excessively complex nociception system and the interrupted cortical mechanisms is only provided by graded motor imagery. [11,12]

Graded motor imager (GMI) uses have 3 sequential stages for application. left & right judgment which activates premotor cortex without activating primary motor areas is the first stage of graded motor imagery. Fictional movements which trigger motor cortical parts similar to those activated in actual accomplishment of movement is the second stage of graded motor imagery. Mirror therapy triggers not only motor cortex but also provides a strong visual input to the cortex in the third or final stage of graded motor imagery, though activation for each stage of GMI have been supported by brain imaging in healthy subjects.[12,13,14.] It has been shown that treatment methods like visualization approach reduces pain at early stage and motor imagery with proprioception and visualization takes part the same neural mechanisms.[15,16]

Positive effects of motor imagery technique on motor effects and learning in athletes, healthy people as well as people with neurological conditions have many evidences (e.g., stroke, spinal cord injury, Parkinson disease) has been published. But evidence for effective treatment of rotator cuff retraining and rehabilitation with graded motor imagery is limited. Graded motor imagery is the psychological representation of attention doing movement of a part of body, without actually moving that part. Because of this, it was intended to conclude the effects of graded motor imagery (GMI) on pain and disability in rotator cuff injuries.

METERIAL & METHODS

A Randomized Control Trial conducted at national institute of rehabilitation medicine (NIRM) after the approval from the executive director. A total n=40 subjects were recruited through non probability convenient sampling technique and allocated randomly in the Conventional physical therapy (CPT) (n=20) and the graded motor imagery (GMI) group (n=20) through lottery method. (Figure 1) The duration of the study was 1 year from June 2016 – June 2017. Patients with age range 25-50 years having history of trauma with positive impingement sign were included and patient with diabetes were excluded from the study.

The conventional PT group received total 8 sessions (twice a week for four weeks). Dry Heating pack applied on the shoulder at the start of treatment in side lying position for 15 mins as tolerable. After that Interferential Current Therapy was applied for 10 minutes with 90-130 MHZ frequency. At the end of session therapeutic exercises were incorporated for shoulder joint. Those are passive & active shoulder flexion extension, abduction, adduction and circumduction with and without Thera band. Each exercise was repeated 10-15 times for 3sets. These exercises were also part of home exercise plan in both groups.

The GMI Group was briefed doing three sessions for ***left and right discrimination*** in first week. In the left right discrimination step patient sound and painful shoulders were used. The shoulder images were displayed using multimedia on a power point presentation. The next week three sessions for ***explicit motor imagery*** was conducted in a relaxing environment and maintained temperature. The patients were instructed to calm down, lay on their couch close their eyes, inhale and exhale air deeply and focus on the words from physiotherapist. Physiotherapist made the GMI Group Increase their motor imagery experience with warmth, breezes, textures, smells, sounds, the weight of patients own limb, the space around them, the touch of their clothes, their environment was according to their occupations and routine life style. A total six ***mirror therapy*** was conducted for last two weeks. For treatment purposes physiotherapist chose to use a shoulder as the subject inside the box using a larger mirror box. The patients were made sit comfortably with the involved shoulder in the box, keeping it hidden from view. Depending on the pain and disability state, the on an appropriate activities were performed by the therapist doing same movements sitting opposite to the patient guiding verbally and with actions. After the patient conquered the movement the next progression to a more challenging movement was done by the patient. Overall, all the patients had to repeat movements under therapist's guidance which she accordingly graded from easy to more difficult. Therapist than enriched the movements with different contexts.

The data was collected through General statistical demographic questionnaire included age, gender, ADLs, Diabetes, hypertension etc. Ongoing shoulder pain and disability were measured in an outpatient setting through Shoulder pain and disability index (SPADI). After second week and fourth week Data was compared at standard.

The data was not normally distributed at standard presented through Shapiro–Wilk test, that's why non parametric tests were applied. The results were presented as frequency, percentages, mean±SD, median (IQR), correlation coefficients and p-values. Different tests were used so that Mann Whitney U-test was used for between-group comparison and Friedman Test and Wilcoxon Signed-Rank Test with post hoc analysis was used for within-group changes. Significance level was set at a *p-value<0.05.* SPSS 21 was used to analyze the data.

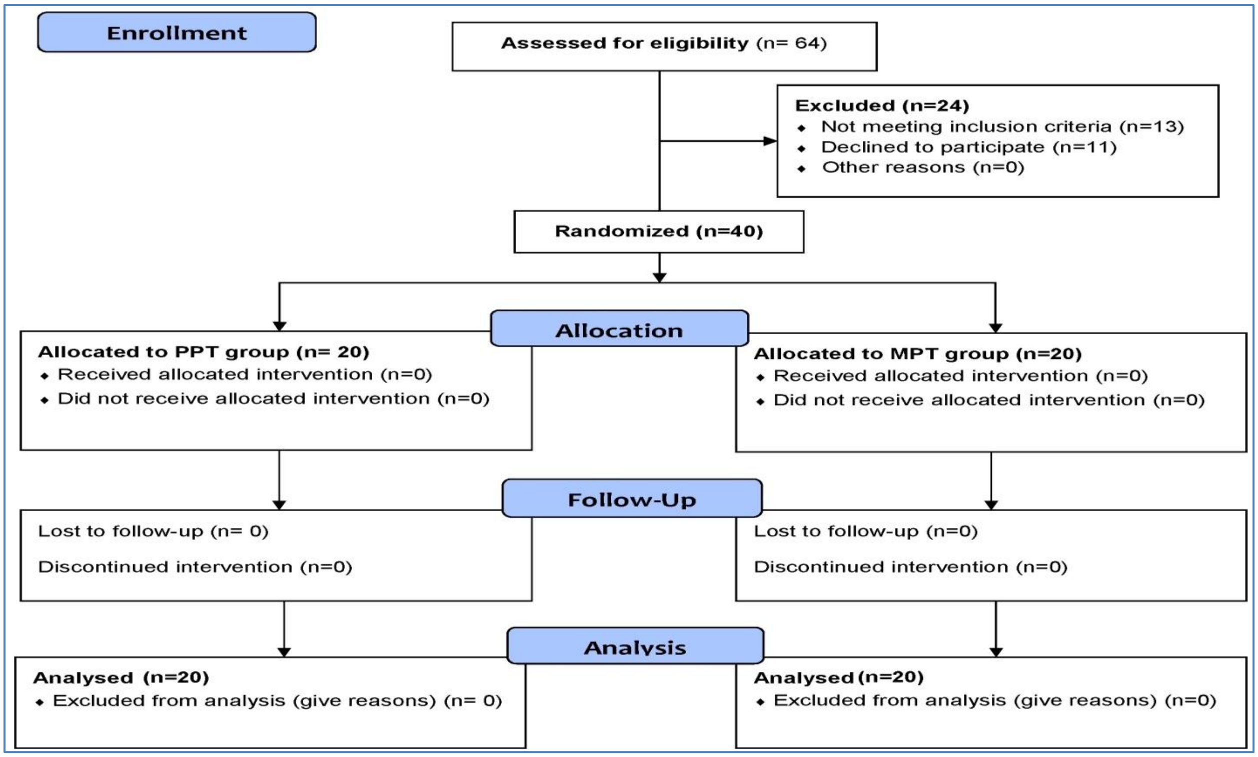

Figure 1: CONSORT diagram

RESULTS

The mean age of participants was 38.67±7.437 years. A total of n=26 males and n=14 female participated in the study. The distribution of different physical activity life styles in current patients, n=18(45%) patients had low physical activity, 8 (20%) had moderate while 14(35%) patients had high physical activity. A total of n=9(22%) participants were having a desk job, 18(45%) having a field job and 13(33%) having a job involving heavy physical activity. While there were 8(20%) patients belong to the 25-30 years' age group, 5(12%) patients belonging to the 30-35 years' age group, 8(20%) patients from the 35-40 years' category, and 11 (28%) patients from the 40-45 years' category and 8(20%) patients from the 45-50 years' category.

Within-group changes showed that both group improved significantly (p≤0.05) from 0-4th week regarding total shoulder pain and disability score. The detail of within-group changes in respect of individual items in both can be seen in table 1. While comparing the both groups, significant improvement was found in severity of pain of GMI group as compare to conventional group. {3(2) ver. 4(3), *p=0.020*}. Pain when lying on involved side {6(1.75) ver. 4(2), *p=0.012*} and difficulty in pulling over undershirt {6(2.50) ver. 4(2.75), *p<0<0.0011*} also significantly improved in GMI group as compare to conventional PT last two weeks. The difficulty while placing an object on high shelf significantly reduced in GMI group as compare to conventional group in initial two weeks {6(1.75) ver. 4(2), *p=0.012*}. the total score of SPADI also showed that GMI group significantly(p≤0.05) better score as compare to conventional group in last two weeks. The table 2 shows detail of remaining items.

Table 1: Within-group changes (SPADI)

SPADI		Conventional group (n=20)			GMI group (n=20)		
		Median(IQR)	*Z-score*	*p-value*	Median(IQR)	*Z-score*	*p-value*
How severe is pain at worst?	0 week	7(1)	-3.271	<0.001	6(2.75)	-1.892	.058
	2nd week	6(1.75)	-1.807	.071	5(2.75)	-3.197	<0.001
	4th week	5(1.75)	-3.619	<0.001	4(2.75)	-3.841	<0.001
When lying on the involved side?	0 week	7(2)	-2.549	.011	6(1)	-3.436	<0.001
	2nd week	6(1.75)	-2.075	.038	4(2)	-6.472	.517
	4th week	4(2.75)	-3.691	<0.001	4(2.75)	-3.547	<0.001
Reaching for something on a high shelf?	0 week	7(4)	-3.491	<0.001	6(1.75)	-3.239	<0.001
	2nd week	5(3)	-1.803	.071	4(2.75)	-1.782	.075
	4th week	4(2)	-3.947	<0.001	4(2)	-3.682	<0.001
Touching the back of your neck?	0 week	6(2)	-1.955	.051	7(3)	-2.289	.022
	2nd week	5(3)	-1.375	.169	5(2.75)	-2.177	.030
	4th week	4(3)	-3.021	<0.001	3(2)	-3.455	<0.001
Pushing with the involved arm?	0 week	6(3)	-2.723	<0.001	7(2)	-3.127	<0.001
	2nd week	5(2)	-2.382	.017	5(2)	-3<0.0014	<0.001
	4th week	3(2)	-3.568	<0.001	3(1.75)	-3.847	<0.001
How much difficulty you have in Washing your back?	0 week	7(2.75)	-2.676	<0.001	6(1)	-1.853	.064
	2nd week	5(1.75)	-1.908	.056	5(2.75)	-2.503	.012
	4th week	4(2)	-3.052	<0.001	4(2.75)	-2.875	<0.001
Washing your hair?	0 week	7(2)	-2.210	.027	6(3)	-2.609	<0.001
	2nd week	6(2)	-2.448	.014	5(2.75)	-1.480	.139
	4th week	4(1.75)	-3.767	<0.001	4(2)	-3.479	<0.001
Putting on an undershirt or pullover sweater?	0 week	6(2)	-.888	.375	7(1)	-3.652	<0.001
	2nd week	6(2.50)	-2.692	<0.001	4(2.75)	-.519	.604
	4th week	4(2.75)	-3.289	<0.001	3(2.75)	-3.646	<0.001
Putting on a shirt that buttons down the front?	0 week	6(3)	-2.653	<0.001	6(3)	-2.597	<0.001
	2nd week	5(3.75)	-2.159	.031	5(3.75)	-2.619	<0.001
	4th week	4(2)	-3.475	<0.001	4(1.75)	-3.841	<0.001
Putting on your pants?	0 week	6(3)	-2.084	.037	7(1.75)	-2.415	.016
	2nd week	4(2)	-.407	.684	5(3)	-2.917	<0.001
	4th week	4(2)	-2.164	.030	4(2.75)	-3.736	<0.001
Placing an object on a high shelf?	0 week	5(2)	-0.477	.633	7(1)	-3.257	<0.001
	2nd week	5(3.75)	-1.833	.060	4(2)	-2.099	.036
	4th week	4(1.75)	-3.324	<0.001	4(3)	-3.741	<0.001
Carrying a heavy object of 10 pounds?	0 week	7(2)	-2.860	<0.001	7(2)	-3.358	<0.001
	2nd week	4(2.75)	-2.519	.012	4(3)	-1.556	.120
	4th week	3(2.75)	-3.587	<0.001	4(3)	-3.635	<0.001
Removing something from your back pocket?	0 week	6(2)	-1.838	.066	7(1.75)	-2.721	<0.001
	2nd week	5(2.5)	-1.602	.109	5(3)	-2.032	.042
	4th week	4(3.75)	-2.635	<0.001	5(3)	-3.462	<0.001
SPADI total	0 week	85(7)	-3.922	<0.001	84(7.75)	-3.925	<0.001
	2nd week	66(8.75)	-3.923	<0.001	63(6.75)	-3.926	<0.001
	4th week	53(7.50)	-3.923	<0.001	47(6.50)	-3.922	<0.001

Table 2: Between group Comparison (SPADI)

		Conventional Median(IQR)	GMI Median(IQR)	U-stats	p-value
How severe is pain at worst?	0 week	7(1)	6(2.75)	163.5	.311
	2nd week	6(1.75)	5(2.75)	187.5	.729
	4th week	4(3)	3(2)	115.5	.020
When lying on the involved side?	0 week	7(2)	6(1)	165	.329
	2nd week	6(1.75)	4(2)	109	.012
	4th week	4(2.75)	5(2.75)	164	.322
Reaching for something on a high shelf?	0 week	7(1)	6(1.75)	147.5	.144
	2nd week	5(3)	5(2.75)	157.5	.240
	4th week	4(2)	4(2.75)	162.5	.298
Touching the back of your neck?	0 week	6(2)	7(3)	175	.489
	2nd week	5(3.75)	5(2.75)	197	.934
	4th week	4(3)	4(2)	184	.654
Pushing with the involved arm?	0 week	6(3)	7(2)	183	.638
	2nd week	5(2)	5(2)	182.5	.630
	4th week	3(2)	3(2)	156.5	.225
How much difficulty you have in Washing your back?	0 week	7(2.75)	6(1)	163	.303
	2nd week	5(1.75)	5(2.75)	180	.577
	4th week	4(2.75)	3(1.75)	159.5	.264
Washing your hair?	0 week	7(2)	6(3)	165	.327
	2nd week	6(2)	5(2.75)	157	.238
	4th week	4(1.75)	4(2.75)	178.5	.552
Putting on an undershirt or pullover sweater?	0 week	6(2)	7(1)	162	.285
	2nd week	6(2.50)	4(2.75)	98.5	<0.001
	4th week	4(2.75)	4(2)	196	.912
Putting on a shirt that buttons down the front?	0 week	6(3)	6(2)	195	.889
	2nd week	5(3.75)	5(3.75)	198.5	.967
	4th week	4(2)	3(2.75)	164	.317
Putting on your pants?	0 week	6(3	7(1.75)	182.5	.628
	2nd week	4(2)	5(3)	165	.335
	4th week	4(2.75)	4(1.75)	132.5	.062
Placing an object on a high shelf?	0 week	5(2.50)	7(1)	117	.021
	2nd week	5(3.75)	4(2)	184.5	.670
	4th week	4(1.75)	4(2.75)	193	.846
Carrying a heavy object of 10 pounds?	0 week	7(2)	7(2)	195.5	.900
	2nd week	5(2.75)	5(3)	173.5	.465
	4th week	3(2.75)	4(3)	176.5	.518
Removing something from your back pocket?	0 week	6(2)	7(1.75)	150.5	.169
	2nd week	5(2.50)	5(3)	195.5	.901
	4th week	4(3.75)	4(3)	177	.523
SPADI total	0 week	85(7)	84(7.75)	171.5	.439
	2nd week	66(8.75)	63(6.75)	107.5	.011
	4th week	53(7.50)	47(6.50)	97.5	<0.001

DISCUSSION

The purpose of this research study was to determine the effectiveness of graded motor imagery (GMI) in pain and disability after rotator cuff injury. The null hypothesis was rejected as graded motor imagery

(GMI) group showed significant progress in pain and disability score on SPADI as compare to conservative treatment.

Visual-motor imagery anticipated to improve motor behavior according to mental practice. Motor deficits can be rehabilitating by graded motor imagery in several neurological conditions. Balance in individuals with multiple sclerosis and elderly women can also be improved by graded motor imagery. In combination with actual practice, a motor deficit in patients of subacute stroke has been used to rehabilitate through mental practice. It has been reported by various studies that progress in strength, function and use of both upper and lower extremities.[17,18,19,34].

Motor imagery is associated with the specific activation of the neural circuits involved in the early stage of motor control it has been proved by research and large number of functional neuro imaging studies. The supplementary motor area, the primary motor cortex, the inferior parietal cortex, the basal ganglia, and the cerebellum included in neural circuits. Common neural mechanisms of imagery and motor preparation has strong support by physiological data.[20,21,22] To reduce the cortical disruption after injury GMI was developed that directly targets the cortex. Focusing attention on the affected limb may cause decline of the limb and chronic pain may result in changes at level of cortex shown by different studies. Reports suggest that pain relief changes the activation of the related neuromotor networks. [17,23].

The effectiveness of graded motor imagery on pain or function has been studied in several studies.[24,25,35] Effectiveness of the motor imagery trainings and the mirror therapy in patients with chronic complex regional pain syndrome (CRPS) was compered by Moseley GL and pain and edema was found reduced in motor imagery subjects.[24] Moseley GL in his study done in 2004 reported that GMI resulted in decrease in Neuropathic pain ($p<0.01$) in patients of complex regional pain syndrome (CRPS) with replicated results in the cross over control group. The study concluded that there is cortical involvement in the development of CPRS and GMI is an effective modality for its treatment.[35] These results can be compared to the results of current study where the mean SPADI score in GMI group was significantly reduced to 47(6.50) as compare to 53(7.50) in conventional group.

The mirror therapy found to be effective for controlling pain in acute CRPS than in chronic pain[25]. During rest and activity graded motor imagery showed its effectiveness in reducing pain due to changes in cortex patients experiencing phantom limb pain sensory discrimination.[26] Graded motor imagery provide gradual activation of the cortical networks during movement without eliciting pain.[27,28] At early stages after injury may contribute in pain control by non-stimulating primary cortex. Altered proprioception can be caused by immobilization period. Kinematic parameters and clinical symptoms from orthopedic conditions were shown improvement by mental and imagery exercises.[29,30] Mental practice was effective in increasing the Range of motion measurement during the immobilization period by Frenkel et al.[31] Neuroscience education tactile discrimination and limb laterality and graded motor imagery in patient with frozen shoulder and pain at rest, decreased functional status, and shoulder range was increased by Sawyer et al.[33]

More pain relief is contributing factor in increasing movement and pain level contribute to functional status proposed by Metha et al. Approached should target to precise the gap between motor output and sensory feedback suggested by cortical model of pathologic.[34] These procedures lead to diminished pain with better recovery by cortical proprioceptive depiction.[32,33,34,35] Muscle training is associated with morphological changes and neural adaptation required for strength gain. Greater activation in primary cortical areas along with more muscle unit activation result of neural adaptation.[36] Some study contradicts any relationship between GMI[37] and muscle strength, while other prove the efficacy of motor imagery on muscle strength.[38]

Continuing and progressive nature of graded motor imagery is clinically important as suggested by a systemic review. Right and left discrimination which in the statistics provided drift towards pain increase rather than pain relief, only Motor imagery demands attention as it gave no significant benefits. Graded motor imagery technique is very effective in encouraging in complex regional pain syndrome (CRPS) and phantom limb pain (PLP).[14]

The results of current study can also be compared to the results described by Polli A et. al when they compared GMI with conventional rehabilitation in patients of stroke as compared to patients with rotator cuff injuries. Primary outcomes in their study were Wolf Motor Function Test (WMFT) and Fugl-Meyer Assessment (FMA) as compared to (SPADI) score. With 14 patients in each group were included out of 28 patients in research study. Graded motor imagery group having 10 patients and control group having 4 patients reached the minimal clinically important difference in that study while the mean improvement was significantly more in GMI group as compared to the conventional group with the mean difference in WMFT being 0.72 in GMI group and 0.21 in the conventional group ($p<0.001$), and the mean difference in the pain section of the FMA being 10.3 in GMI group and 2.7 in the conventional group ($p=0<0.0016$). While in current study patients who underwent GMI did improve significantly more than conventional group after 4 weeks of therapy ($p<0.001$).[39]

The similar improvements in both GMI and conventional groups in current study can be compared to the results of S Johnson et.al in the UK, where they assessed the effectiveness of GMI in 2 centers for patients of CPRS.[10] There was improvement at one center while no in the second center. The study conducted by Bahram Jam suggested use of Electromyography and Ultrasonography to measure the nerve activity in the region being treated and there was a significant improvement through conventional therapy and through GMI.[41] Scores on SPADI improved with GMI than Conventional therapy. There were patients which due to being conscious and lacking the ability to discriminate switching of body sides during treatment, could not understand and benefit from it as compared to patients who understood the therapy and cooperated more during sessions [42,43]

A female patient reported a strange feeling about having a delusion and unintentionally doing the lifting of effected arm during her sleep and semi-conscious state while going into the sleep just like she was performing during exercise session. It may be due to unintentional nerve firing of same neurons which stimulate the muscle and nerves during the exercise sessions[44] or it may be due to her concern towards her treatment, conscious alertness and dedication towards the therapy. All the three steps of the procedure including the right and left judgement, explicit motor imagery and mirror therapy were difficult to understood and adapted by the subjects. Those who opted willingly for the procedure were also not much confident and sure about it may be due to short duration of GMI. This study also has limitations of assessment sources, like electromyography or ultrasonography.

CONCLUSION

It was concluded that graded motor imagery (GMI) and conventional PT both are effective for management of pain and disability due to rotator cuff injuries. But GMI was found to be more effective than conventional PT. Graded motor Imagery is a novel technique which can be used alone or as an adjunct to standard physical therapy

REFERENCES

1. Terry GC, Chopp TM. Functional anatomy of the shoulder. Journal of athletic training. 2000 Jul;35(3):248.
2. Neer CS, 2nd, Welsh RP. The shoulder in sports. Orthop Clin North Am. 1977;8(3):583-91.
3. Herrmann SJ, Izadpanah K, Sudkamp NP, Strohm PC. Tears of the rotator cuff. Causes--diagnosis--treatment. Acta Chir Orthop Traumatol Cech. 2014;81(4):256-66.
4. Maffulli N, Longo UG, Berton A, Loppini M, Denaro V. Biological factors in the pathogenesis of rotator cuff tears. Sports Med Arthrosc. 2011;19(3):194-201.
5. Bishay V, Gallo RA. The evaluation and treatment of rotator cuff pathology. Prim Care. 2013;40(4):889-910, viii.
6. Boorman RS, More KD, Hollinshead RM, Wiley JP, Brett K, Mohtadi NG, et al. The rotator cuff quality-of-life index predicts the outcome of nonoperative treatment of patients with a chronic rotator cuff tear. J Bone Joint Surg Am. 2014;96(22):1883-8.
7. Haering D, Blache Y, Raison M, Begon M. Mechanical risk of rotator cuff repair failure during passive movements: A simulation-based study. Clin Biomech (Bristol, Avon). 2015;30(10):1181-8.
8. Baumgarten KM, Osborn R, Schweinle WE, Jr., Zens MJ, Helsper EA. Are Pulley Exercises Initiated 6 Weeks After Rotator Cuff Repair a Safe and Effective Rehabilitative Treatment? A Randomized Controlled Trial. Am J Sports Med. 2016;44(7):1844-51.

9. Main CJ. The importance of psychosocial influences on chronic pain. Pain management. 2013 Nov;3(6):455-66.
10. Johnson S, Hall J, Barnett SA, Draper M, Derbyshire G, Haynes L, Rooney C, et al. Using graded motor imagery for complex regional pain syndrome in clinical practice: failure to improve pain. Eur J Pain.. 2012 Apr;16(4):550-61.
11. Maihöfner C, Peltz E. CRPS, the parietal cortex and neurocognitive dysfunction: An Emerging Triad. Pain. 2011;152(7):1453-4.
12. Bowering KJ, O'Connell NE, Tabor A, Catley MJ, Leake HB, Moseley GL, Stanton TR. The effects of graded motor imagery and its components on chronic pain: a systematic review and meta-analysis. J Pain. 2013;14(1):3-13.
13. Dickstein R, Deutsch JE. Motor imagery in physical therapist practice. Phys Ther. 2007;87(7):942-53.
14. Walz AD1, Usichenko T, Moseley GL, Lotze M. Graded motor imagery and the impact on pain processing in a case of CRPS.Clin J Pain. 2013;29(3):276-9.
15. Munzert J, Lorey B, Zentgraf K. Cognitive motor processes: the role of motor imagery in the study of motor representations. Brain Res Rev. 2009;60(2):306-26.
16. Ramachandran VS, Altschuler EL. The use of visual feedback, in particular mirror visual feedback, in restoring brain function. Brain. 2009;132(7):1693-710.
17. Jackson PL, Lafleur MF, Malouin F, Richards C, Doyon J. Potential role of mental practice using motor imagery in neurologic rehabilitation. Arch Phys Med Rehabil. 2001;82(8):1133-41.
18. Barbarulo AM, Lus G, Signoriello E, Trojano L, Grossi D, Esposito M, et al. Integrated Cognitive and Neuromotor Rehabilitation in Multiple Sclerosis: A Pragmatic Study. Front Behav Neurosci. 2018;12:196
19. Page SJ, Peters H. Mental practice: applying motor Practice and neuroplasticity principles to increase upper extremity function. Stroke. 2014;45(11):3454-60.
20. Guillot A, Di Rienzo F, MacIntyre T, Moran A, Collet C. Imagining is not doing but involves specific motor commands: a review of experimental data related to motor inhibition. Front Hum Neurosci. 2012; 6: 247.
21. Chu RM, Black KL. Current surgical management of high-grade gliomas. InSchmidek and Sweet Operative Neurosurgical Techniques 2012;105-110. WB Saunders.
22. Decety J. The neurophysiological basis of motor imagery. Behav Brain Res. 1996;77(1-2):45-52.
23. Davis KD, Taylor SJ, Crawley AP, Wood ML, Mikulis DJ. Functional MRI of pain-and attention-related activations in the human cingulate cortex. J Neurophysiol. 1997;77(6):3370-80..
24. Moseley GL. Graded motor imagery for pathologic pain: a randomized controlled trial. Neurolo. 2006;67(12):2129-34.
25. Engebretsen K, Grotle M, Bautz-Holter E, Ekeberg OM, Brox JI. Predictors of Shoulder Pain and Disability Index (SPADI) and work status after 1 year in patients with subacromial shoulder pain. BMC Musculoskelet Disord. 2010;11(1):218.
26. Flor H, Denke C, Schaefer M, Grüsser S. Effect of sensory discrimination training on cortical reorganisation and phantom limb pain. Lancet. 2001;357(9270):1763-4.
27. Ortiz-Catalan M. The stochastic entanglement and phantom motor execution hypotheses: a theoretical framework for the origin and treatment of PLP. Front Neurol. 2018;9:748.
28. Roland PE, Larsen B, Lassen NA, Skinhoj E. Supplementary motor area and other cortical areas in organization of voluntary movements in man. J Neurophysiol. 1980;43(1):118-36..
29. Viaro R, Budri M, Parmiani P, Franchi G. Adaptive changes in the motor cortex during and after longterm forelimb immobilization in adult rats. J Physiol . 2014;592(10):2137-52.
30. dos Santos GL, da Silva ES, Desloovere K, Russo TL. Effects of elastic tape on kinematic parameters during a functional task in chronic hemiparetic subjects: A randomized sham-controlled crossover trial. PloS one. 2019;14(1):
31. Frenkel MO, Herzig DS, Gebhard F, Mayer J, Becker C, Einsiedel T. Mental practice maintains range of motion despite forearm immobilization: a pilot study in healthy persons. J Rehabil Med. 2014;46(3):225-32..
32. Anderson B, Meyster V. Treatment of a Patient With Central Pain Sensitization Using Graded Motor Imagery Principles: A Case Report. Jour Chiro Med. 20181;17(4):264-7.
33. Sawyer EE, McDevitt AW, Louw A, Puentedura EJ, Mintken PE. Use of Pain Neuroscience Education, Tactile Discrimination, and Graded Motor Imagery in an Individual With Frozen Shoulder. J Orthop Sports Phys Ther. 2018;48(3):174-184
34. Mehta S, McIntyre A, Guy S, Teasell RW, Loh E. Effectiveness of transcranial direct current stimulation for the management of neuropathic pain after spinal cord injury: a meta-analysis. Spinal Cord. 2015;53(11):780.
35. Moseley GL, Flor H. Targeting cortical representations in the treatment of chronic pain: a review. Neurorehabil Neural Repair. 2012;26(6):646-52.
36. Folland JP, Williams AG. Morphological and neurological contributions to increased strength. Sports medicine. 2007;37(2):145-68.
37. Hortobágyi T, Maffiuletti NA. Neural adaptations to electrical stimulation strength training. Eur J Appl Physiol. 2011;111(10):2439-49.
38. Slimani M, Tod D, Chaabene H, Miarka B, Chamari K. Effects of mental imagery on muscular strength in healthy and patient participants: A systematic review. J Sports Sci Med. 2016; 15(3): 434–450.
39. Polli A, Moseley GL, Gioia E, Beames T, Baba A, Agostini M, Tonin P, et al. Graded motor imagery for patients with stroke: a non-randomized controlled trial of a new approach. Eur J Phys Rehabil Med. 2017;53(1):14-23.
40. Baumer TG, Chan D, Mende V, Dischler J, Zauel R, van Holsbeeck M, et al. Effects of rotator cuff pathology and physical therapy on in vivo shoulder motion and clinical outcomes in patients with a symptomatic full-thickness rotator cuff tear. Orthop J Sports Med. 2016;4(9).
41. Jam B, MPhty B. New Paradigms in Rotator Cuff Retraining.
42. Domkundwar S, Autkar G, Khadilkar SV, Virarkar M. Ultrasound and EMG–NCV study (electromyography and nerve conduction velocity) correlation in diagnosis of nerve pathologies. J Ultrasound. 2017;20(2):111-122.
43. Thoomes-de Graaf M, Scholten-Peeters W, Karel Y, Verwoerd A, Koes B, Verhagen A. One question might be capable of replacing the Shoulder Pain and Disability Index (SPADI) when measuring disability: a prospective cohort study. Qual Life Res. 2018;27(2):401-410
44. Kaur J, Ghosh S, Sahani AK, Sinha JK. Mental imagery training for treatment of central neuropathic pain: a narrative review. Acta Neurologica Belgica. 2019 Apr 15:1-2.

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