Journal of Bodywork & Movement Therapies 21 (2017) 1024–1027

Contents lists available at ScienceDirect

Journal of Bodywork & Movement Therapies

journal homepage: www.elsevier.com/jbmt

PREVENTION & REHABILITATION: ORIGINAL RESEARCH

Immediate effect of mental practice with and without mirror therapy on muscle activation in hemiparetic stroke patients☆

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ARTICLE INFO

Article history:
Received 25 August 2016
Received in revised form
10 December 2016
Accepted 20 December 2016

Keywords:
Stroke
Electromyography
Mental practice
Mirror therapy

ABSTRACT

Mental practice (MP) consists of the repeated mental rehearsal of a physical skill without movement, called motor imagery (MI). Studies show that MP and MI associated mirror therapy (MPMT) may improve muscle control of the upper limbs in hemiparesis. This study aimed to evaluate muscle activation during active flexion of the wrist (MA), MP, and MPMT in patients with history of stroke and hemiparesis. Individuals diagnosed with stroke showing sequelae of upper limb hemiparesis were enrolled. The flexor carpi ulnaris was analyzed using electromyography during tasks (MA, MP, MPMT) involving wrist flexion. Greater electromyographic activity was detected during MP and MPMT techniques compared to active movement ($p = 0.02$). There was no significant difference between MP and MPMT ($p = 0.56$). These results were found in both the affected limb and unaffected limb. Immediate effects on muscle activation are experienced during MP and MPMT, and muscle activity was similar with both therapies.

1. Introduction

Mental practice (MP) and mirror therapy are complementary forms of treatment for some stroke sequelae. “During mental practice an internal representation of the movement is activated and the execution of the movement repeatedly mentally simulated within a chosen context. This mental simulation takes place in absence of bodily activity. It is used for the goal-oriented improvement or stabilization of a given movement” (Braun et al., 2006). MP consists of the repeated mental rehearsal of a physical skill without movement through the mental simulation, called motor imagery. So, motor imagery is “imagining oneself undertaking the skilled movement without actually doing the movement” (Jackson et al., 2001). Motor imagery, is a dynamic representation of the imagined motion, promoting its internal reactivation within the memory. In this way, the individual revives the sensation of a specific action, which promotes greater learning capacity and motor improvement (Pacheco et al., 2007; Gaspar et al., 2011).

Mental practice associated mirror therapy (MPMT) may be able to create an illusion within the brain of motor activation of the affected limb. During MPMT, the patient moves the unaffected limb in front of a mirror, where the reflection appears to the be that of the affected limb moving correctly; this occurs because of the activation of mirror neurons and consequently, increased proprioceptive input (Lamont et al., 2011; Rezende, 2014; Altschuler et al., 1999).

Investigating the literature related to MP, mainly systematic reviews, we found many articles using functional outcomes and Activities of Daily Life measures. The majority of them did not find significant improvement after MP treatment although the use of MP combined with other physical practices has shown functional gains in upper limbs after stroke. The methodological limitations of the studies are the main problem to ensure evidence (Braun et al., 2013; Carrasco and Cantalapiedra, 2013; Barclay-Goddard et al., 2011). In contrast, Mirror Therapy as a complement to conventional rehabilitation may promote improvement in motor function in patients with stroke (Hatem et al., 2016; Thieme et al., 2013; Castelli

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http://dx.doi.org/10.1016/j.jbmt.2016.12.010
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and Corbetta, 2011).

A measure little used to investigate MP and also mirror therapy is electromyography, and we believe in muscle activation during both. The study by Oliveira et al. (2014) used electromyography, and showed that MPMT may be capable of promoting improvement in muscle control of the hemiparetic upper limb. Other studies reporting electromyographic effects of MP are found in the literature (Guillot et al., 2007; Lebon et al., 2008; Sivadasan et al., 2013). Guilliot et al. (2007) and Lebon et al. (2008) used EMG to measure muscle responses during MI in healthy subjects; their results show increased muscle activation when comparing rest to imagined movement. Sivadasan et al. (2013) reported similar findings, but their study was conducted in individuals diagnosed with focal dystonia of the upper limb. Based on this little review the hypothesis of the present study are: (1) MP could promote greater muscle activation when compared to active movement, and (2) MPMT may produce greater muscle activation than that obtained by active movement and MP.

Therefore, this study aimed to determine if there are differences in muscle activation during active movement (AM) of flexion of the wrist, MP, and MPMT in patients who have suffered stroke and subsequent hemiparesis.

2. Methodology

This study was approved and follows all recommendations of the Ethics Committee of the UFTM Protocol (1647). It is characterized as experimental, transversal, and quantitative research, with intra- and interpersonal analysis.

We enrolled individuals diagnosed with stroke (ischemic or hemorrhagic, acute or subacute [up to 1 year post stroke]), with sequelae of upper limb hemiparesis and without disabling cognitive deficits. Individuals were excluded if they were diagnosed with other diseases and were required to have preserved imaginative capacity (as determined by Kinesthetic and Visual Imagery Questionnaire (Gregg et al., 2010) translated and validated for native language (Mendes et al., 2016), reaching a minimum score of 55 points). No patient had cognitive impairment as determined by the Mini Mental State Examination (Folstein et al., 1975), in which, Lourenço and Veras (2006), verify the validity of the criterion of the Portuguese version and participants were required to have a minimum score of 30 points on the Fugl-Meyer scale, with reliability and validity tested in the native language (Maki et al., 2006), only items matching the upper limbs (Scalha et al., 2011). In total, 8 subjects were included irrespective of age, ethnicity, or sex. Table 1 summarizes participants' characteristics.

We used the imagination questionnaire visual and kinesthetic, which evaluates the imaginative capacity of individuals in the visual and kinesthetic areas. Scores range from 1 to 7, considering the most difficult and most easily, respectively. The execution of mental task is determined by specific movements or actions (Gregg et al., 2010).

Physical performance was evaluated using the Fugl-Meyer assessment, which is used to measure sensorimotor recovery of post-stroke patients based on assessment of 5 areas: motor function, sensory function, balance, mobility, and pain. Scores range from 0 to 2, corresponding to complete disability and full capacity to complete the task, respectively (Scalha et al., 2011). For this study, we considered only items related to the upper limb. Total possible score was 128 points, as reported by Scalha et al. (2011).

Electromyographic analysis was performed using EMG System do Brasil®, band pass 20–500 Hz, with common mode rejection >120 dB, input impedance >10 MOhms, gain 100× signal conditioner, and 20× liabilities bipolar electrode, totalizing 2000×. The signal was collected at 1000 Hz, filtered and rectified. Electrodes were attached to the flexor carpi ulnaris, three to four finger widths distal to the midpoint of the medial epicondyle of the connecting line and biceps tendon, following the protocol of Perotto (2011) and later confirmed by palpation and proof of specific muscle function proposed by Mccreary et al. (2007).

EMG data were collected during tasks involving wrist flexion during AM, MP, and MPMT. During the task the individual sat comfortably in a chair facing a table, which allowed the full support of the forearm, keeping the shoulder joint at 0°, elbow at 90° and wrist at the neutral position. During the AM the individual performs the active flexion of the wrist, to perform the MP the subject was instructed to imagine the flexion of the wrist as performed in the previous task and during the MPMT the subject was oriented to position the affected member inside the mirror box, while the healthy one was positioned in front of the mirror, the subject was instructed to perform active flexion of the healthy wrist and to imagine that the reflex of the movement as being his affected member. Five recordings were made with an interval of one minute between each recording.

Data were digitized by conversion board A/D 16 bits resolution and sampling frequency 1 kHz in each channel. WinDaq (DataqInstruments®) software was used. Calculations were based on the EMG activity area, considering the whole area under the curve obtained during the time of flexor carpi ulnaris muscle activation.

Study participant data were analyzed using descriptive statistics (mean and standard deviation) and also the values on the Fugl-Meyer and Kinesthetic and Visual Imagery Questionnaire scales. EMG data were previously tested for normality by the Shapiro-Wilk test. As the data conforms to normality, we used the Student *t*-test with a significance level set at 5%.

3. Results

In the affected upper limb, there were significant differences in the area obtained by EMG between AM and MP ($t = -4.75$, $p = 0.00$) and between AM and MPMT ($t = -4.39$, $p = 0.00$). There was no significant difference between the values recorded for MP and MPMT ($t = -0.33$, $p = 0.75$) (Fig. 1).

Similar results were found for the unaffected upper limb, with significant differences between AM and MP ($t = -4.25$, $p = 0.02$) and between AM and MPMT ($t = -3.05$, $p = 0.03$). There was no significant difference between MP and MPMT ($t = 1.25$, $p = 0.72$) (Fig. 2).

4. Discussion

The aim of this study was to evaluate whether there are differences in muscle activation during AM, MP, and MPMT in post-stroke patients with hemiparesis. The first hypothesis was accepted, because the EMG values were significantly different between MP/MPMT and AM. The second hypothesis was partially

Table 1
Study participant characteristics.

Characteristic	n or mean (±standard deviation)
Sex, F/M	4/4
Age (years)	60.75 ± 10.26
Affected side, Right/Left	4/4
Stroke type, Ischemic/Hemorrhagic	5/3
Time since stroke (months)	7.29 ± 4.50
MMSE results	23.25 ± 2.69
Fugl Meyer results	110.375 ± 11.63
KVIQ results	68.87 ± 17.68

Label: F, female; M, male; MMSE, Mini Mental State Examination; KVIQ, Kinesthetic and Visual Imagery Questionnaire.

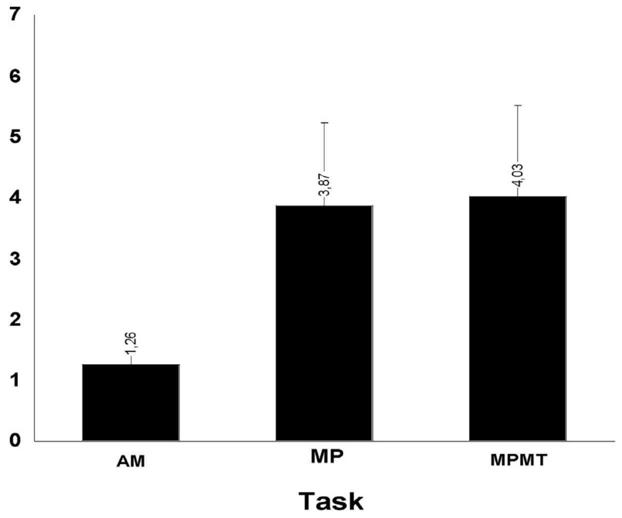

Fig. 1. Mean and standard deviation of flexor carpi ulnaris EMG area in affected upper limb.

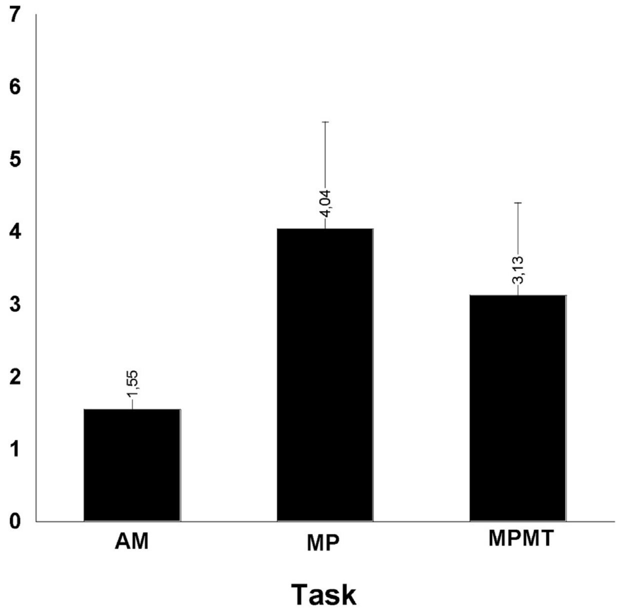

Fig. 2. Mean and standard deviation of flexor carpi ulnaris EMG area in unaffected upper limb.

accepted, because MPMT also generated greater muscle activation. However, the second part of the hypothesis was not accepted, since the inclusion of MT did not cause changes in muscle activation when compared to the use of MP alone.

Studies have demonstrated the use of EMG to indicate muscle activation during motor MI in the absence of motion, both in healthy subjects and in subjects with motor deficits (Guillot et al., 2007; Lebon et al., 2008; Sivadasan et al., 2013), thus revealing the methodological validity of this study. Guilliot et al. (2007) conducted a study in healthy subjects to determine muscle responses during lifting a dumbbell and imagination of the same movement using EMG, which showed increased activity during motor imagery (MI) when compared to idle status (Guillot et al., 2007). Corroborating these findings, Lebon et al. (2008) found similar results in a study of healthy subjects investigating the effect of various types of muscle contraction on the median frequency of the electromyographic signal during MI (Lebon et al., 2008).

Although the current study was performed on individuals with stroke, our results showed a similar pattern of activity between the affected limb and the healthy limb, leading to the assumption that the techniques used here were able to produce a similar activation pattern in both the affected and healthy limb. Thus, we demonstrated similar results in post-stroke patients as reported in two previously published studies involving healthy subjects.

Sivadasan et al. (2013) observed the onset of electromyographic activity during the phase of MI in his study of individuals diagnosed with focal dystonia of the upper limb, where they analyzed the pattern of time to muscle activation and EMG activity in distal muscle groups, intermediate versus proximal, in both upper limbs (Sivadasan et al., 2013). Although their findings are similar to the presently reported data, the pattern of muscle activation caused by dystonia compared to stroke is different.

The results reported here provide evidence that neuronal mechanisms may influence the motor system, as EMG captures action potentials generated by various brain areas in different motor units (Lebon et al., 2008; Helm et al., 2015; Decety, 1996). Guilliot et al. (2007) stated that electromyographic activity generated during MI provides evidence that both, MI and motor activity share common neural mechanisms (Guillot et al., 2007). Lebon et al. (2008) report that there is a structural relationship between MI and physical execution, corroborating the study cited above. However, Sivadasan et al. (2013) suggest that electromyographic activity picked up during the phase of imagery can be attributed to anticipation and pre-learned behavior, and that both effects ultimately increase activation of the central motor command (Gregg et al., 2010).

The fact that MP and MPMT showed significant differences from MA in both the healthy and the affected limb is very interesting; first, because there is no active movement during the technique application and second, because both MP and MPMT were able to promote a similar effect to what is considered normal, even in a paretic limb. Rienzo et al. (2015) showed increased muscle activation when performing MI after a resistance training session in healthy subjects. The authors believe that these results are due to central processing that occurs during the application of MI, causing neuronal excitability within somatic ways of specific tasks (Rienzo et al., 2015). The present study was carried out using MI of wrist bending, which occurs as a specific task. The results showed an increase in muscle activation during the technique, as reported by Rienzo et al. (2015), but this activation did not occur with the imagination of a resistance movement, but during active movement, only.

Another important finding in this study was greater activation in MP and MPMT compared to AM. To Guillot et al. (2007), the result of electromyographic activation can be linked to the implicit knowledge of the study participants regarding the level of difficulty of the tasks (Guillot et al., 2007). Thus, the imagination of a movement is considered more difficult than its motor execution, and thus the EMG signal tends to be higher during imagination. Since all the subjects of the present study reported greater difficulty in performing the imagination of the proposed task, this may explain the higher activation recorded during MP and MPMT.

Bonnet, Decety and Requin reported another study substantiating these same results (1997). The authors compared electromyographic data between mental simulation and motor practice related to an isometric pressure from the lower limbs platform; results showed increased electromyographic activity during motor practice as well as during imagery, with a smaller effect reported during imagery (Bonnet et al., 1997). According to the authors, mental simulation has a blocking effect on the peripheral motor system, with only a weak portion of the motor neuron beta activated, explaining the intensification of electromyographic data (Bonnet et al., 1997).

From the results found in this study and studies by Guillot et al. (2007) and Bonnet et al. (1997), it can be said that the physiological responses caused by MI appear to be consistent with a central origin and the occurrence of an EMG activation pattern during MP can be interpreted as comprehensive engine control inhibition.

MT is viewed as a learning process that causes changes in the cortical representation of the motor homunculus, thanks to the plasticity of the central nervous system (Gaspar et al., 2011; Rezende, 2014; Oliveira et al., 2014). The fact that MPMT had no significant effect can be explained because of the difficulty of the task, as for the development of MPMT, the subject must view through the hand imagination to be evaluated in the mirror reflection. Another reason for this result can be found in the study by Rozand et al. (2016). The authors point out that the onset of mental fatigue might occur while performing the proposed task when it exceeds 20 min in length, resulting in no measured change in EMG activity (Rozand et al., 2016).

A systematic review by Thieme et al. (2013) demonstrated significant results when compared to other MT techniques, with respect to motor function, but results are influenced by the type of control intervention (Thieme et al., 2013). This analysis aimed to analyze whether there are differences in muscle activation during flexion grip when performing MA, MP, and MTMP, without the presence of a training protocol. Our focus was not related to the application of interventions as other studies, so, it can justify the negation of our last hypothesis.

5. Limitations

As limitations of the present study or suggestion to future studies we can consider the small sample, the lack of a control group and the necessity of the inclusion of other muscles as extensor carpi ulnaris and also other tasks. The evaluation of the effects of such techniques in a longer period is also a good point to be investigated.

6. Conclusion

This study showed an immediate effect on muscle activation during MP and MPMT in post-stroke individuals. Moreover, it showed that muscle activity was similar during MP and MPMT.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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