Use of Mental Imagery to Limit Strength Loss After Immobilization

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Objective: To assess whether mental imagery of gripping prevents the loss of grip strength associated with forearm immobilization. Design: Pretest–posttest randomized-group design. Setting: Laboratory. Participants: 13 female and 5 male university students, age between 17 and 30 years, randomly assigned into 2 groups—1 control and 1 experimental. Interventions: Both groups had their nondominant forearms immobilized for 10 days. The experimental group undertook three 5-min mental-imagery sessions daily, during which they imagined they were squeezing a rubber ball. Main Outcome Measures: Wrist-flexion and -extension and grip strength before and after immobilization. Results: There was no significant change in wrist-flexion or -extension strength in the mental-imagery group. The control group experienced a significant decrease in wrist-flexion and -extension strength during the period of immobilization (P < .05). Conclusions: Despite study limitations, the results suggest that mental imagery might be useful in preventing the strength loss associated with short-term muscle immobilization. Key Words: cortical activity, motor planning, motor programming

A decrease in the ability to maximally activate a muscle is a well-known complication of therapeutic immobilization. Studies have shown that strength was lost rapidly in the first week of immobilization, after which there was little additional strength loss. The strength loss occurring during the first week of immobilization has been attributed to central neuromotor adaptations, specifically, a decrease in the ability to activate muscles by voluntary command. If central neuromotor adaptations could be limited, it is possible that the strength loss occurring during immobilization could be decreased.

The observation that training involving imagined muscle contraction can result in increases in strength comparable to those elicited by physical training has been interpreted as indicating that mental imagery can influence the construction, planning, or maintenance of the motor programs involved in maximal contractions. Studies using positron emission tomography and regional cerebral-blood-flow data have shown that mental
imagery activates the motor-output system.\textsuperscript{7,8} Imagined motor activity has also been shown to increase cortical motor evoked potentials in the absence of any changes in EMG activity.\textsuperscript{9}

Mental imagery might limit strength losses in immobilized muscles by stimulating the central pathways responsible for motor control and preventing neuromotor adaptations. The purpose of this study was to make a preliminary assessment of the effects of mental imagery on the loss of grip strength and wrist-flexion and -extension strength induced by 10 days of immobilization of the forearm, to assess whether mental imagery had an impact on the development of fatigue, and to assess whether imagery ability affected the magnitude of any responses observed.

**Methods**

**Design**

A pretest-posttest randomized-group design was used in this study. The dependent variables were wrist-flexion and -extension strength and grip strength after immobilization. The independent variable was mental-imagery training.

**Participants**

Seventeen participants, 13 women and 4 men between 18 and 30 years old, were recruited for the study. Participants were ineligible to participate if they were undertaking weight or other upper-limb training, had suffered an injury to either arm within the preceding year, suffered from myopathy or any other condition that might influence strength, reported any skin condition that would be adversely affected by casting, or lacked an understanding of the requirements for performing mental imagery.

All participants gave their informed consent to participate. The Human Ethics Committee of the University of Sydney approved the experiment.

**Instrumentation**

Grip-strength measurements were made using a Jamar dynamometer (Preston, Clifton, NJ), calibrated using the method of Fess.\textsuperscript{10} Flexion and extension strength were measured with a handheld dynamometer (Nicholas Manual Muscle Tester, Lafayette Instruments, Lafayette, Ind), using standardized body and dynamometer positioning.\textsuperscript{11}

**Testing Procedures**

Grip strength and isometric wrist-flexion and -extension strength were tested before immobilization. One tester (JN) performed all tests. In each test, participants performed 3 maximal voluntary contractions.\textsuperscript{12,13} The mean
of the 3 trials was recorded as the strength, because this has been shown to improve the reliability of measurement.\textsuperscript{14}

The sequence of all measurements was randomized to minimize order and fatigue effects. All measurements in the preimmobilization and post-immobilization trials were made at the same time of day.

**Interventions**

Immediately on completion of the preimmobilization tests, all participants had their nondominant forearms immobilized for 10 days in a short-arm cast that extended from the metacarpal heads to just below the elbow.\textsuperscript{15} The participants were immobilized with their wrists in 15° to 30° of extension, which had the effect of shortening the extensor muscles. The same person applied all casts. Participants in both groups were asked to refrain from using their immobilized arm and to regard it as having an actual injury.

After casting, participants were randomly balloted into 1 of 2 groups. The first group, comprising 8 women, was designated immobilization—control (I-C). Participants in the I-C group did not perform any mental imagery during the period of immobilization. The group designated immobilization—mental imagery (I-MI) consisted of 5 women and 4 men. On each day of the immobilization period, participants in the I-MI group performed 3 mental-imagery sessions, each of 5 minutes duration. The participants completed the imagery sessions alone, at times convenient to them.

The mental imagery required the participants to imagine that they were squeezing a rubber ball as tightly as possible. Squeezing was selected because it is an activity that requires a strong effort from the flexor muscles of the fingers.

Before the mental-imagery sessions began, one of the experimenters (JN) described to members of the I-MI group how the imagery was to be performed and emphasized the fact that actual muscle contraction was to be avoided. The mental imagery was guided by instructions recorded on an audiocassette. The participants were instructed to “imagine squeezing a rubber ball as tightly as possible. You should imagine the feel of the movement, but your muscles must stay relaxed. Do not perform the movement, but try to imagine the sensation of it occurring.” Participants in the I-MI group recorded each imagery session on a diary sheet. The number of sessions completed by each participant was calculated at the end of the immobilization period.

On the day after the completion of the 10-day immobilization period, all strength measurements were repeated using a protocol identical to the preimmobilization tests.

In order to assess the relationship between imagery ability and changes in strength after mental-imagery training, each participant’s imagery ability was determined using a validated questionnaire—the shortened form
of Bett's Questionnaire Upon Mental Imagery.\textsuperscript{16,17} Participants completed this questionnaire at the time of the initial strength testing. The questionnaire contains 35 questions designed to measure an individual's ability to generate images in the visual, auditory, cutaneous, kinesthetic, gustatory, and olfactory modalities. In scoring the questionnaire, both a total score and a score in the kinesthetic modality were calculated.

At the postimmobilization testing session, participants in the I-MI group were asked to report any physical sensations they had experienced during the mental-imagery sessions.

\textbf{Statistical Analysis}

Independent $t$ tests were used to identify between-group differences in preimmobilization grip strength and wrist-flexion and -extension strength. In order to remove the effects of the baseline differences in strength, ANCOVAs were used to analyze between-group differences in the effects of immobilization on the 3 strength measures. An alpha level of $P < .05$ was used to determine significance. Partial eta-squared values were calculated to determine the percentage of variation in the data that could be attributed to treatment differences.

Linear trends (to assess fatigue or endurance effects) and quadratic trends (to identify skill or learning changes) were calculated to investigate the relationship between the results of sequential trials conducted in measurement sessions. Correlation analyses were performed to examine the relationship between initial strength and strength changes after immobilization and changes in strength and imagery ability in the I-MI group. A Pearson correlation coefficient was calculated for each pair of variables, and a 2-tailed test of significance performed. Between-group differences in imagery ability were compared using a $t$ test. All statistical procedures were performed using the Statistical Package for the Social Sciences (SPSS 7.5) for Windows.

\textbf{Results}

\textbf{Effects of Mental Imagery on Strength Loss During Immobilization}

Details of the effects of mental imagery on immobilization-related changes in isometric wrist-flexion and -extension strength and grip strength are presented in Table 1. There was no significant difference in preimmobilization grip or wrist-flexion or -extension strength between groups. Preimmobilization and postimmobilization grip and wrist-flexion and -extension strength values for participants in each group were normally distributed.
Table 1 Preimmobilization and Postimmobilization Means for Grip and Wrist Flexion and Extension*

<table>
<thead>
<tr>
<th>Group</th>
<th>Preimmobilization mean</th>
<th>Postimmobilization mean</th>
<th>Difference in means</th>
<th>$P$</th>
<th>Partial $\eta^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grip</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I-C</td>
<td>29.6 ± 7.8</td>
<td>24.8 ± 8.3</td>
<td></td>
<td>.149</td>
<td>.13</td>
</tr>
<tr>
<td>I-MI</td>
<td>37.4 ± 5.2</td>
<td>36.9 ± 8.0</td>
<td>12.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wrist flexion</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I-C</td>
<td>12.6 ± 3.2</td>
<td>10.0 ± 2.3</td>
<td></td>
<td>.002</td>
<td>.50</td>
</tr>
<tr>
<td>I-MI</td>
<td>15.6 ± 2.5</td>
<td>15.4 ± 1.8</td>
<td>5.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wrist extension</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I-C</td>
<td>13.3 ± 2.1</td>
<td>10.0 ± 2.0</td>
<td></td>
<td>.001</td>
<td>.54</td>
</tr>
<tr>
<td>I-MI</td>
<td>17.1 ± 3.1</td>
<td>15.7 ± 1.8</td>
<td>5.7</td>
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</tr>
</tbody>
</table>

*I-C indicates immobilization—control, and I-MI, immobilization—mental imagery.
Participants in both the I-C and the I-MI group experienced a nonsignificant decrease in mean grip strength as a result of immobilization. The decrease in mean grip strength in the I-C group approached significance ($F_{1,7} = 3.62$, $P = .09$). There was no significant difference in the adjusted mean postimmobilization grip-strength scores between the I-C and I-MI groups ($F_{15} = 2.31$, $P = .149$).

Immobilization did not result in a significant change in wrist-flexion or -extension strength of participants in the I-MI group, whereas significant decreases were observed for wrist-flexion strength ($F_{1,7} = 11.71$, $P = .011$) and wrist-extension strength ($F_{1,7} = 12.07$, $P = .010$) in the I-C group after immobilization.

The adjusted mean postimmobilization wrist-flexion strength was significantly lower in the I-C group than in the I-MI group ($F_{15} = 14.90$, $P = .02$, $\eta^2 = .498$). The adjusted mean postimmobilization wrist-extension strength was also significantly lower in the I-C group than in the I-MI group ($F_{15} = 17.25$, $P < .001$, $\eta^2 = .535$).

There was no difference between the 2 groups in linear or quadratic strength trends over 3 trials in any of the preimmobilization tests. After immobilization, there was a significant difference in linear effect between the groups for wrist-flexion strength ($P = .02$). The I-C group got progressively weaker across trials, whereas the I-MI group did not. The linear trend for wrist-extension strength after immobilization followed a similar pattern but did not reach a significant difference between groups ($P = .07$).

Participants with higher initial strength tended to lose more flexion strength during immobilization. The correlation between initial strength and loss of flexion strength was $-70$ in the I-C group ($P = .06$) and $-83$ in the I-MI group ($P = .005$). Similar results were observed for wrist-extension strength, with a correlation of $-68$ in the I-C group ($P = .06$) and $-84$ ($P = .004$) in the I-M group.

Weak negative correlations between strength changes and imagery ability were found for changes in both wrist-flexion strength ($r = -.31$, $P = .26$) and wrist-extension strength ($r = -.33$, $P = .23$) with immobilization.

**Mental-Imagery Ability**

Possible scores for the Questionnaire Upon Mental Imagery range from 35 (highest imagery ability) to 245 (lowest ability). The range of scores for the I-C group was 49–148 (mean 98.5 ± 33.76). Scores in the I-MI group ranged from 77 to 146 (mean 113.89 ± 27.04). The mean scores for the 2 groups were not statistically different.

**Compliance With the Imagery Regime**

The number of mental-imagery sessions recorded as completed by participants in the I-MI group ranged from 26 to 30 (out of a possible total of 30). The mean number of sessions was $28 \pm 1.7$. 
Individual Experiences

Six of the participants in the mental-imagery group reported muscle twitches in their hands during the imagery session. Two participants reported sensations of warmth in the immobilized arm, and 2 felt that their heart rate had increased during imagery.

Comments

The purpose of this study was to examine the effects of mental imagery on strength loss associated with immobilization.

There was no significant effect of mental imagery on the loss of grip strength resulting from immobilization. Gripping was the activity practiced by participants in the I-MI group. The absolute loss of grip strength in the I-C group (4.83 kg), however, was larger than that in the I-MI group (0.56 kg). In percentage terms, these results represented a loss of 16.3% in the I-C group and 1.5% in the I-MI, suggesting that mental imagery might be of benefit in limiting the losses in grip strength associated with short-term immobilization of the wrist.

The absence of any significant effect on grip strength might result from the fact that participants were immobilized in such a way as to permit opposition of their thumb and third finger, allowing the participants to perform some gripping actions.

Mental imagery was of benefit in preventing the loss of wrist-flexion and -extension strength that occur as the result of immobilization. Although there was no significant decrease in the wrist-flexion or -extension strength of participants in the I-MI group after immobilization, both variables were significantly decreased in participants in the I-C group after immobilization.

Both groups exhibited greater strength loss in the wrist-extensor muscles than in the flexors. Participants were immobilized with their wrists in 15° to 30° of extension, which had the effect of shortening the extensor muscles. Muscles that are fixed in a shortened position exhibit greater strength loss as a result of immobilization. The contribution of flexor-muscle activity to the gripping action is greater than that of the extensors, which are limited to a stabilizing role. The differences in roles of the 2 muscle groups might have had an influence on the changes observed.

This study did not attempt to explain the mechanisms underlying the observed effects on strength. Because mental imagery involves only cortical activation, however, any protection against strength loss is likely to be caused by central processes.

There is considerable evidence supporting the importance of central processes in the strength changes observed with mental imagery and immobilization. Central factors have been implicated in the strength gains occurring in response to mental imagery. Imagined activity results in cortical activity that is specific to the areas associated with the muscle being mentally
exercised.\textsuperscript{19} Strength gains resulting from motor imagery might involve improved representation of motor-force generation in the cortex and improved programming and planning in the motor system.\textsuperscript{24-29} Yue and Cole compared strength gains produced by training programs involving actual or imagined muscle contractions.\textsuperscript{6} The strength gains early in the 2 programs were identical and were associated with increases in EMG activity. Muscles were quiescent during imagined training, meaning that changes in motoneurons, interneurons, and reflex pathways were unlikely to have contributed to the strength gains observed in the imagery group. Yue and Cole hypothesized that changes in central programming were responsible for the strength gains observed and that such changes did not require repetitive muscle activation.\textsuperscript{6}

It is likely that the strength losses that occur as a result of immobilization are also associated with changes in central programming and planning of muscle contractions. Immobilization has been found to lower EMG activity during a maximal voluntary contraction, suggesting that central activation of muscles is reduced.\textsuperscript{19-21}

If mental imagery has a significant role in limiting strength loss during immobilization, it seems reasonable to expect that strength loss would correlate with the imagery ability of the participants. No such correlations were found in this study. One possible explanation for this observation is that the range of imagery ability among the participants was not large enough to produce measurable differences in the rate of strength loss.

The difference between groups in the linear trend for wrist-flexion strength suggests that mental imagery might help maintain the endurance capacity of muscles during immobilization. An increase in endurance after mental imagery has been reported previously in the abdominal muscles and in participants performing bench presses.\textsuperscript{22,23}

This study had several limitations that must be considered when drawing conclusions from it. Foremost is the inability to eliminate the possibility that participants contracted their muscles during mental-imagery sessions. Given the difficulty of refraining from contracting muscles during mental-imagery sessions, it is possible that some gripping movement occurred, and if so, this might have affected the results obtained. Many of the muscles involved in finger movement are also involved in wrist-extension and -flexion. Consequently, unintended finger movement during imagery sessions might have helped maintain flexion and extension strength.

Although it is impossible to be certain that participants in the I-MI group did not actively contract their muscles during practice sessions, it seems reasonable to assume that the magnitude of such contractions would have been small. The effect of such small movements on strength during a maximal contraction cannot be ascertained.

Although immobilization was incomplete, the fact that the casts applied to both groups were identical is likely to limit the impact of any nonspecific muscle contraction that occurred during the immobilization period.
The small number of participants in each group and differences between groups in preimmobilization strength might also have had an impact on the results. These limitations make it impossible to firmly conclude that mental imagery has an effect on strength loss resulting from immobilization.

Conclusions

The results of this study, despite its limitations, suggest that mental imagery might be of benefit in preventing the strength losses that occur during immobilization. Because of the clinical benefits of preventing strength loss during immobilization and the low cost of the intervention, the effects of mental imagery warrant further study.

Acknowledgment

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References


