Mental Practice in Chronic Stroke
Results of a Randomized, Placebo-Controlled Trial

Stephen J. Page, PhD; Peter Levine, BA, PTA; Anthony Leonard, PhD

Background and Purpose—Mental practice (MP) of a particular motor skill has repeatedly been shown to activate the same musculature and neural areas as physical practice of the skill. Pilot study results suggest that a rehabilitation program incorporating MP of valued motor skills in chronic stroke patients provides sufficient repetitive practice to increase affected arm use and function. This Phase 2 study compared efficacy of a rehabilitation program incorporating MP of specific arm movements to a placebo condition using randomized controlled methods and an appropriate sample size.

Method—Thirty-two chronic stroke patients (mean age=3.6 years) with moderate motor deficits received 30-minute therapy sessions occurring 2 days/week for 6 weeks, and emphasizing activities of daily living. Subjects randomly assigned to the experimental condition also received 30-minute MP sessions provided directly after therapy requiring daily MP of the activities of daily living; subjects assigned to the control group received the same amount of therapist interaction as the experimental group, and a sham intervention directly after therapy, consisting of relaxation. Outcomes were evaluated by a blinded rater using the Action Research Arm test and the upper extremity section of the Fugl-Meyer Assessment.

Results—No pre-existing group differences were found on any demographic variable or movement scale. Subjects receiving MP showed significant reductions in affected arm impairment and significant increases in daily arm function (both at the P<0.0001 level). Only patients in the group receiving MP exhibited new ability to perform valued activities.

Conclusions—The results support the efficacy of programs incorporating mental practice for rehabilitating affected arm motor function in patients with chronic stroke. These changes are clinically significant. (Stroke. 2007;38:1293-1297.)

Key Words: hemiparesis ■ occupational therapy ■ randomized controlled trials ■ rehabilitation ■ stroke recovery

Although hemiparesis is one of the most pervasive and disabling impairments, evidence supporting stroke rehabilitation efficacy is limited, with 30% to 60% of patients unable to use their more affected arms functionally after discharge. As such, improved rehabilitation strategies are needed, particularly in the chronic (>1 year poststroke) stage, where spontaneous recovery is often slowed or stopped, and patients are discharged from rehabilitation.

Mental practice (MP), sometimes called “motor imagery,” is a technique by which physical skills can be cognitively rehearsed in a safe, repetitive manner. MP increases motor-skill learning and performance in rehabilitative settings, and the same neural and muscular structures are activated when movements are mentally practiced as during physical practice of the same skills. Other similarities between MP and physical practice include: (1) the time taken to mentally and physically perform movements is highly similar; (2) during MP, the speed accuracy tradeoff (ie, Fitts Law) is maintained; and (3) MP produces similar autonomic events as physical practice of the same skills. Pilot data suggest that the addition of MP to motor therapy yields greater motor outcomes than conventional motor therapy in subacute and chronic stroke. The needed next step in this line of research was to perform a randomized controlled study. This randomized, controlled study compared the efficacy of 2 motor rehabilitation regimens: (1) a program in which 5 specific arm motor skills were physically practiced and subjects then listened to a 30-minute tape of relaxation exercises (relaxation plus physical practice [R+PP]); and (2) a program in which 5 specific arm motor skills were both mentally and physically practiced (MP+PP). Based on previous study results, our primary hypothesis was that subjects receiving MP would exhibit significantly greater fine motor function changes, as shown by the Action Research Arm Test (ARA), a measure of distal motor function, than subjects in other groups. We also hypothesized that
MP+PP subjects would exhibit markedly larger score increases on the Fugl-Meyer Impairment Scale. Given the previously stated need for improved rehabilitation strategies, this study was part of a larger program to develop clinically practical, efficacious strategies to improve motor function after stroke.

Subjects and Methods

Power Analysis and Subjects

Based on previous MP studies, our primary outcome measure was the ARA (described later), and our main hypothesis was that subjects receiving the MP+PP intervention would exhibit the greatest increases in scores on the ARA. To reach 80% power (and effect size of 0.36, considered medium-high) using a F test to test the group by time interaction at a 5% significance level, 15 subjects were found to be needed in each group for a total number of 30. A power analysis was also conducted using Sample Power ANOVA model, in which anticipated means for the 2 conditions were entered into the model, as well as average between and within groups variances. Based on aforementioned pilot data, we set the effect size for the interactions to be high (f=0.40). Results were similar to those obtained in the initial power analysis; whereas 80% is the “standard” for power analyses, because the MP effect was high in initial studies, to obtain only 69% power (0.40 effect size) at a 5% significance level, 15 patients were needed/group for a total number of 30.

Volunteers were recruited using advertisements placed in neurology and physical therapy clinics in hospitals in the Midwestern United States. A research team member screened volunteers using the following inclusion criteria from previous MP research: (1) history of no more than one stroke; (2) ability to actively flex at least 10° from neutral at the affected wrist and the metacarpophalangeal and interphalangeal joints of two digits; (3) stroke experienced >12 months before study enrollment; (4) a score ≥69 on the modified Mini Mental Status Examination25; (5) age >18 and <80 years. We also applied the following exclusion criteria: (1) excessive spasticity, defined as a score of ≥2 on the Modified Ashworth Spasticity Scale; (2) excessive pain in the affected upper limb, as measured by a score of ≥4 on a 10-point visual analog scale; (3) still enrolled in any form of physical rehabilitation; (4) participating in any experimental rehabilitation or drug studies.

Using the above inclusion/exclusion criteria, a total of 50 volunteers were screened, with 18 subjects excluded for the following reasons: (1) still enrolled in some form of motor rehabilitation (n=2); insufficient motor function in the more affected arm (n=8); (3) excessive spasticity (n=5); (4) other medical comorbidities (n=1); (5) too much motor function in the more affected arm (n=2). Thus, 32 patients were found eligible and agreed to participate (18 males, 14 females; mean age = 59.5±13.4 years, age range 27 to 81 years; mean time since stroke onset = 42.0 months, range of onset = 12 to 174 months; 19 subjects with right hemiparesis).

Outcome Measures

Instruments used for this study were applied in previous MP studies by Page and colleagues, and were: (1) our primary outcome measure was the 66-point, upper extremity section of the Fugl-Meyer Assessment of Motor Recovery After Stroke (FM)26 which assesses several impairment dimensions using a 3-point ordinal scale (0 = cannot perform; 1 = can perform partially; 2 = can perform fully). The FM has been shown to have impressive test-retest reliability (total = 0.98–0.99; subscales 0.87 to 1.00), interrater reliability, and construct validity.27–29 The FM has been used extensively in studies measuring functional recovery in stroke patients, and is highly recommended for “use in clinical trials designed to evaluate changes in motor impairment following stroke.”20; (2) The ARA,33 our primary outcome measure, is a 19-item test divided into 4 categories (grasp, grip, pinch, and gross movement), with each item graded on a 4-point ordinal scale (0 = cannot perform no part of the test; 1 = performs test partially; 2 = completes test but takes abnormally long time or has great difficulty; 3 = performs test normally) for a total possible score of 57. The test is hierarchical in that if the patient is able to perform the most difficult skill in each category, they will be able to perform the other items within the category and, thus, they need not be tested. The ARA has high intrarater (r = 0.99) and test–retest (r = 0.98) reliability and validity.29,32

In addition to their strong psychometric characteristics, both the FM and ARA are responsive to motor changes in chronic stroke,33 making them ideal outcome measures for this study.

Testing and Intervention

A single-blinded, multiple baseline, randomized, pre- and post-test control group design was applied. After screening and signing consent forms approved by the local institutional review board, the FM and ARA were administered on 2 occasions one week apart. This multiple baseline design had 2 purposes: (1) it was probable that chronic stroke patients would exhibit stable motor deficits. However, given recent findings of improvement years after stroke, multiple administrations of the outcome measures helped us assure that individuals were exhibiting stable motor deficits; (2) our repeated pretesting designto increase the stability of the individual motor estimates, thereby lessening error variance. This will diminish the effect of any pre-existing individual differences.

After the second pretesting session, patients were randomly assigned to one of the below described conditions with equal probability using a computer-generated random numbers table. Therapists hired for this grant (n = 5) underwent extensive inserviceing so that therapy was consistent from subject to subject. This included substantial group review of pertinent stroke and MP literature, hours of cross-validation and videotaping of therapists’ provision of the activities that patients practiced, and information sessions run by the research team.

Relaxation Plus Physical Practice (R+PP)

All subjects practiced activities of daily living during therapy sessions. These sessions occurred on 2 days per week, in 30-minute segments, for 6 weeks. All therapy was administered by the same inserviced therapists in the same fashion and environment. Emphasis was on bimanually performing activities of daily living listed in Table 1 through the entire range of motion and, if necessary, the affected arm supported the less affected hand. This therapy program was consistent with the methods of previous MP work in which positive treatment effects were shown.18–21

Therapists maintained a treatment card for each patient that detailed the sessions so that researchers could monitor compliance with the protocol. Therapists were blinded to group assignment. Random grouping of patients will minimize effects of participant characteristics and be useful in distributing participant characteristics between groups in an unbiased way. All subjects were instructed not to perform additional PP of any of the skills at home.

Directly following each therapy session, each subject randomly assigned to the R+PP group listened to a 30-minute tape in which they were taken through a progressive relaxation program. This regimen asked subjects to flex different muscles in the body, and then relax them. Because the MP+PP subjects also listened to a tape with comparable length and frequency (as described below), provision of the relaxation sequence allowed contact time between the 2

TABLE 1. Sequences on Each Tape, and Where/When Tape Was Used

<table>
<thead>
<tr>
<th>Tape No.</th>
<th>Functional Task Described</th>
<th>Where/When Administered</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Reaching for and grasping a cup or object</td>
<td>Research lab/Weeks 1, 2</td>
</tr>
<tr>
<td>2</td>
<td>Turning a page in a book</td>
<td>Research lab/Weeks 3, 4</td>
</tr>
<tr>
<td>3</td>
<td>Proper use of a writing utensil</td>
<td>Research lab/Weeks 5, 6</td>
</tr>
</tbody>
</table>
groups to remain consistent. R+PP subjects were instructed not to engage in additional relaxation practice at home.

**Mental Practice (MP+PP)**

Subjects randomly assigned to the mental practice plus physical practice (MP+PP) condition participated in the same physical practice regimen, practicing the same activities of daily living in the same environment and with the same therapists as individuals in the R+PP group. However, in addition to participating in the PP regimen, the MP+PP group mentally practiced the activities performed in therapy, as described in Table 1 and administered in previous studies. Specifically, after each PP session, MP+PP subjects received a recorded MP intervention lasting 30 minutes. As with previous MP interventions, the MP was read by a male psychologist, and opened with 5 minutes of relaxation, asking patients to imagine themselves in a warm, relaxing place (eg, a beach) and asking them to contract and relax their muscles (ie, progressive relaxation). This portion of the tape was followed by suggestions for internal, cognitive polysensory images in which the patient was seated (eg, kitchen or therapy gym). The subject was then taken for a cup, the recording first described the setting in which the patient would show greater changes between pre- and post-treatment ARA administrations than would scores of the R+PP group, was tested using the change scores (time 2 minus the mean of the 2 baseline testings). The change scores in the 2 groups were compared using the Wilcoxon rank sum test with exact probability value computation, attributable to assumed, non-normal distributions. Pre-, post-, and change-group means are reported in Table 3. On the ARA the MP+PP group improved an average of 7.81 points, whereas the control group improved on average only 0.44 points (P<0.0001). On the FM, the MP+PP group improved a mean +6.72 points, as compared with 1.0 point changes for the R+PP control group (P=0.0001). All subjects and their caregivers reported not engaging in any additional MP, R, or PP while at their homes.

**Discussion**

Hemiparesis is a disabling, common impairment. Given a paucity of effective, home-based protocols and increased stroke incidence, interventions are needed that reduce hemiparesis and provide opportunities for practice of valued activities. Previous pilot study results suggest that addition of mental practice to affected arm rehabilitation increases outcomes. Using an appropriate sample size and randomized controlled methods, this phase 2 study compared efficacy of interventions combining MP+PP showed large reductions in affected arm impairment as measured by the FM, and large

**Results**

The 2 groups were compared on demographic variables and baseline scores. No subjects exhibited stroke-induced visual impairments (9 subjects wore glasses; 4 wore contact lenses) or sensory impairments. Group differences on dichotomous variables were tested with Fisher exact test, whereas the other variables were compared using the Wilcoxon rank sum test. (These latter variables tended to be distributed in markedly non-normal fashion.) The groups did not differ significantly on any of the interval level baseline measures, which were age, time poststroke, FM score, and ARA score (Table 2). Groups also did not differ on nominal variables before intervention. Seven of 16 patients in the MP+PP group exhibited left-side hemiparesis, as did 6 in the R+PP group (exact P=1.00). Three other nominal variables, sex (exact P=0.29), type of stroke (ischemic versus hemorrhagic; exact P=0.66), and lesion site (cortical, subcortical, or mixed; exact P=0.75), also did not differ between groups at pretesting.

The primary hypothesis, that scores in the MP+PP group would show greater changes between pre- and post-treatment ARA administrations than would scores of the R+PP group, was tested using the change scores (time 2 minus the mean of the 2 baseline testings). The change scores in the 2 groups were compared using the Wilcoxon rank sum test with exact probability value computation, attributable to assumed, non-normal distributions. Pre-, post-, and change-group means are reported in Table 3. On the ARA the MP+PP group improved an average of 7.81 points, whereas the control group improved on average only 0.44 points (P<0.0001). On the FM, the MP+PP group improved a mean +6.72 points, as compared with 1.0 point changes for the R+PP control group (P=0.0001). All subjects and their caregivers reported not engaging in any additional MP, R, or PP while at their homes.

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Hemiparesis is a disabling, common impairment. Given a paucity of effective, home-based protocols and increased stroke incidence, interventions are needed that reduce hemiparesis and provide opportunities for practice of valued activities. Previous pilot study results suggest that addition of mental practice to affected arm rehabilitation increases outcomes. Using an appropriate sample size and randomized controlled methods, this phase 2 study compared efficacy of adding mental practice versus a “sham” program of relaxation to affected arm rehabilitation.

As in previous studies, subjects participating in a regimen combining MP+PP showed large reductions in affected arm impairment as measured by the FM, and large

**Results**

The 2 groups were compared on demographic variables and baseline scores. No subjects exhibited stroke-induced visual

<table>
<thead>
<tr>
<th>TABLE 2. Preintervention Demographics and Scores, By Group</th>
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<tbody>
<tr>
<td>Age</td>
</tr>
<tr>
<td>------------------------</td>
</tr>
<tr>
<td>58.69 (12.89)</td>
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<tr>
<td>Months poststroke</td>
</tr>
<tr>
<td>Mean FM score</td>
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<tr>
<td>Mean ARA score</td>
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Note: 2-sided P denotes 2-sided probability value for Wilcoxon nonparametric test. FM and ARA mean scores are means of 2 testings per subject, with SDs taken on those mean scores across subjects, n=16 per group.

<table>
<thead>
<tr>
<th>TABLE 3. Patient Scores on the FM and ARA Before and After Intervention</th>
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<tbody>
<tr>
<td>FM</td>
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<tr>
<td>-------------------------------------------</td>
</tr>
<tr>
<td>MP (n=16)</td>
</tr>
<tr>
<td>PP (n=16)</td>
</tr>
<tr>
<td>ARA</td>
</tr>
<tr>
<td>-------------------------------------------</td>
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Note: PRE indicates mean score obtained during pretesting period; POST, mean score obtained during posttest; Change, Post−[Pre1 + Pre2)/2]. Exact P values for the Wilcoxon test comparing the change scores for the 2 groups are P<=0.0001 for the FM, and P<=0.0001 for the ARA. These significant change scores are denoted by "***".
increases in movement as measured by the ARA. In both cases, MP+PP subjects showed changes significant at the P=0.0001 level. These motor changes transferred to new ability to perform valued activities that MP+PP subjects had not performed in months, such as writing, turning pages in a book, and reaching for and drinking out of a cup.

Mental practice is thought to render its impact by at least 2 independent but interrelated mechanisms. First, stroke patients have been shown for decades to not use their more affected arms, even when capable of doing so35,36; a phenomenon traditionally termed “hemiakinesia.” However, MP use was recently shown to increase affected arm use,21 thus overcoming this movement suppression phenomenon. In “exit interviews” conducted with each subject participating in the current study, all MP+PP subjects similarly reported using the affected arm for valued activities of daily living such as turning on a light, opening a refrigerator door, and putting on clothing items. Subjects participating in R+PP showed no alterations in spontaneous use of the affected arm for valued activities. The current study did not use objective measures of affected arm use, such as activity monitors, to measure arm use, but this limitation is being overcome in current work.

The second hypothesized mental practice mechanism is use-dependent brain reorganization, in which new cortical areas are recruited to assist in movement of the affected arm. Previous study results show that this phenomenon occurs with a variety of task specific protocols, even of a brief duration, including mental practice,38 and that motor changes correlate with cortical changes. This study provides the first randomized controlled, appropriately powered support to the hypothesis that substantive motor changes may be produced through a regimen including mental practice. The current study did not use neuroimaging to confirm the neural substrate; the very rapid period during which MP subjects exhibited motor changes, and the fact that subjects in both groups were matched in their characteristics (including motor scores) before intervention, motor changes exhibited by MP subjects are unlikely to be attributable to chance.

Conclusion
Results of this trial suggest that a traditional rehabilitation program that includes mental practice of tasks practiced during therapy increases outcomes significantly.

Disclosures
None.

References


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