Mental Practice Combined With Physical Practice for Upper-Limb Motor Deficit in Subacute Stroke

Background and Purpose. This case report describes a patient with upper-limb hemiparesis (ULH) who received a program combining physical therapy for the affected side with mental practice. **Case Description.** The patient was a 56-year-old man with stable motor deficits, including ULH, on his dominant side resulting from a right parietal infarct that occurred 5 months previously. He received physical therapy for an hour 3 times a week for 6 weeks. In addition, 2 times a week the patient listened to an audiotape instructing him to imagine himself functionally using the affected limb. The patient also listened to the audiotape at home 2 times a week. Pretreatment and posttreatment measures were the upper-extremity scale of the Fugl-Meyer Assessment of Sensorimotor Impairment (Fugl-Meyer Scale), the Action Research Arm Test (ARA), and the Stroke Rehabilitation Assessment of Movement (STREAM). **Outcomes.** The patient exhibited reduction in impairment (Fugl-Meyer Scale) and improvement in arm function, as measured by the ARA and STREAM. **Discussion.** Mental practice may complement physical therapy to improve motor function after stroke. [Page SJ, Levine P, Sisto SA, Johnston MV. Mental practice combined with physical practice for upper-limb motor deficit in subacute stroke. *Phys Ther.* 2001;81:1455–1462.]

Key Words: *Imagery, Impairment, Mental practice, Outcomes, Stroke, Upper limb.*

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Each year, approximately 500,000 people have a first or subsequent stroke. Upper-limb hemiparesis (ULH) is one of the most debilitating effects of stroke, and it is the primary impairment underlying functional disability following stroke.[1–3] Upper-limb hemiparesis is one of the most prevalent conditions treated by physical therapists and occupational therapists.[2–4]

During the subacute phase (<1 year poststroke), patients with stroke learn or relearn competencies necessary to perform activities of daily living (ADL). Frequent practice of skills enhances motor learning and skill acquisition.[2,3,5,6] Traditionally, the practice provided in neurologic rehabilitation has focused on reducing motor impairment and minimizing physical disability. Intensive rehabilitation is expensive, however, and many managed care organizations provide their clients with a limited number of therapy sessions before they stop financing rehabilitation. Furthermore, the limited number of sessions can cover a wide range of services (eg, physical therapy, occupational therapy, speech therapy) and a large number of skills (eg, transfers, use of the affected arm, balance retraining), and, therefore, repetitive practice may not be provided at appropriate frequencies for motor learning to occur. As a result, therapy intended to improve upper-extremity function following a stroke, which may involve less repetitive practice of skills than is needed, is not as effective as it could be.[7] Given these practice limitations, therapists seek strategies that minimize the use of costly resources while maximizing practice opportunities that would enable motor learning to occur.

> *Mental practice may be used as a noninvasive complement to physical therapy to improve motor function after a stroke.*

For decades, authors have reported that mental practice (also known as "imagery"), when combined with physical practice, accelerates motor learning and improves subsequent physical performance.[8–11] Because of its positive effects on strength,[12,13] endurance,[14] and aim and precision,[15,16] mental practice is frequently used by professional and amateur athletes.[17,18] Mental practice has also been suggested to be a viable tool for improving motor learning and performance in rehabilitative settings.[1,19] Some studies[20,21] have demonstrated the effectiveness of mental practice in therapeutic settings in improving motor performance when it is combined with physical practice. Randomized controlled studies by Fansler et al[20] and Linden and colleagues,[22] for example, demonstrated greater improvements on balance tasks (eg, one-legged standing) among elderly women who combined mental practice with physical practice than those who participated only in physical practice. Fairweather and Sidaway[23] reported that a 3-week mental practice program, when combined with physical practice, improved posture of individuals with abnormal curvature of the spine. In addition to using randomized controlled methods, all of these studies had independent evaluators and significant effects.

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Studies have shown that, during mental practice, correlative activations occur at the cortical level as well as in the musculature imagined as being used. For example, Breitling and colleagues reported similar activity in the motor execution cortical areas when subjects imagined finger movements in a relaxed state as when they actually performed the movements.[24] Studies measuring electromyographic (EMG) activity, cortical motor evoked potentials, and cerebral blood flow also have shown that the appropriate neuromotor pathways imagined as being used are actually being used and that metabolic activity of neurons is increased during mental practice as if the activity is actually being performed.[25–28] Mental practice and physical practice also lead to plastic changes in the motor cortex area of the brain.[29] Other authors[30] have determined that identical cerebellar control mechanisms are used in mental practice as are used in actual movement.

Given the evidence relating mental practice, neuromuscular activation, and motor performance and considering the debilitating effects of ULH, Page[21] posited that mental practice could be a noninvasive, useful tool in rehabilitating patients with strokes. To test this belief, he provided 8 patients with chronic stroke (patients who had a stroke more than 1 year previously) with a 3-week program combining mental practice and occupational therapy for the affected side (T+I group). He also provided 8 patients with chronic strokes with an identical therapy regimen, but without mental practice (control group). Prior to intervention, patients in both groups exhibited similar levels of impairment, as measured by the upper-extremity scale of the Fugl-Meyer Assessment of Sensorimotor Impairment (Fugl-Meyer Scale)[31] ($\overline{X}$=22.13 among patients in the T+I group, $\overline{X}$=22.23 among patients in the control group). After the 3-week protocol, patients in the T+I group scored a mean of 29.97 (SD=4.1) on the Fugl-Meyer Scale, whereas patients in the control group scored a mean of 26.89 (SD=5.4). Statistical analyses revealed that the patients in the T+I group exhibited greater reductions in their impairment levels than patients in the control group (F=14.71; df=1,14; P<.05).

Although this therapy appears to be effective for patients with chronic strokes, most patients seen in rehabilitative environments are in the subacute phase of recovery. In a review of stroke rehabilitation and physical therapy, Ernst[32] concluded that the greatest potential for motor recovery is during the first year following a stroke. These facts provided impetus to combine traditional therapy for the affected side with mental practice in patients who have had subacute strokes. Because rehabilitation is increasingly concerned with outcomes, we also wanted to examine the effect of therapy plus mental practice on both impairment and functional outcomes in the wrist and hand. The following data were collected to determine the feasibility of this method with patients with subacute strokes prior to the initiation of a larger study. We also wanted to pilot test the responsiveness of the chosen impairment and outcome measures with a patient with a subacute stroke who had used mental practice as a component of intervention.

Case Description

Patient

Letters of recruitment were sent to patients who experienced a stroke and were discharged from outpatient therapy in a rehabilitation hospital. A research assistant screened an individual who responded to the letter of recruitment for inclusion in the study. Exclusion criteria applied during screening were based on the work of Page.[21] Volunteers were excluded if: (1) the stroke occurred less than 4 weeks or more than 1 year earlier, (2) serious sensory or cognitive deficits existed, as evidenced by a score of less than 20 on the Modified Mini-Mental Status Test,[33] (3) they had hemorrhagic lesions, or a lesion affecting both hemispheres, as determined by computed tomography scans available in the medical record, (4) excessive spasticity or pain at the elbow, wrist, or hand was exhibited, defined as greater than 2 on the Modified Ashworth Spasticity Scale,[34] (5) aphasia was present, and (6) they were unable to image, as evidenced by a score of 25 or less on the Movement Imagery Questionnaire (MIQ).[35] Using these criteria, the first individual tested was admitted to the study and was chosen for this case report because he met inclusion criteria, was motivated, and was willing to follow intervention guidelines.

The patient was a 56-year-old Caucasian man whose past medical history included diabetes mellitus and hypertension. Five months previously, the patient had experienced sudden onset of slurred speech and left-sided weakness. After being immediately admitted to a local hospital, a computed tomography scan revealed a right parietal infarct, and manual muscle testing revealed grades of 5/5 in the right extremities and 0/5 in the left extremities. He had received 30 days of inpatient rehabilitation, including physical therapy, occupational therapy, and speech therapy. Comparison between our observations at initial screening and medical records, discharge summaries, therapist observations, and physiatrist observations suggested that the patient's affected limb function had not improved since the time of discharge from the hospital.

Instruments

The MIQ[35] was administered as a screening tool to measure the patient's general ability to mentally practice physical movements. The MIQ consists of 6 items

designed specifically to measure mental practice of movements and contains scales for measuring visual and kinesthetic mental practice ability. Each item in the questionnaire represents a unique movement, and every movement is precisely described so that all individuals completing the questionnaire imagine the same movements. The questionnaire incorporates variety of relatively simple arm, leg, and whole-body movements. For each movement, participants are first asked to assume a standard starting position and then execute the movement. After returning to the starting position, the execution of the movement is imagined. Finally, the individual rates the difficulty experienced in imagining the movements on a 7-point Likert scale ranging from 1 (easy to imagine) to 7 (difficult to imagine). The reliability of data obtained with the MIQ is high.[35] Cronbach internal consistency coefficients are $\alpha=.90$ (visual subscale) and $\alpha=.91$ (kinesthetic subscale).[35] Test-retest reliability of data obtained over a 3-week period was $r=.83$ for the visual subscale and $r=.75$ for the kinesthetic subscale.[36] The MIQ has been used in a number of mental practice studies involving rehabilitation of patients who did not have strokes.[25,26]

The Fugl-Meyer Scale[31] assesses several dimensions of impairment, including range of motion, pain, sensation, upper extremity, lower extremity, and balance. The specific items in the upper-extremity subsections were derived from the Brunnström stages of poststroke motor recovery. The data arise from a 3-point ordinal scale (0=cannot perform, 1=can perform partially, 2=can perform fully) applied to each item, and the items are summed to provide a maximum score of 226. The upper-extremity motor component, which consists of 66 points, was used in this study. The Fugl-Meyer Scale has been used extensively as a measure of impairment in studies measuring functional recovery in patients with strokes, including our pilot work.[21] The Fugl-Meyer Scale has been shown in patients 1 to 3 years post–cerebrovascular accident to have high test-retest reliability (total: $r=.98–.99$, subtests: $r=.87–1.00$),[37] interrater reliability,[37] and construct validity.[38] High correlations have been shown between the Fugl-Meyer and DeSouza methods (multiple regression analysis $r=.97$,[39] and .67 to .76 between the Fugl-Meyer Scale and Barthel Index assessments.[40]

The Action Research Arm Test[41] (ARA) is an outcome measure designed specifically for use with patients with strokes. The 19-item test is divided into 4 categories (grasp, grip, pinch, and gross movement), with each item graded on a 4-point scale (0=can 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) and a total possible score of 60. The test is hierarchical because, if patients are able to perform the most difficult item in each category, they will be able to perform the other items within the category and, thus, the other items need not be tested. The test provides ordinal-level scores, can be completed in a short amount of time, and is highly correlated with many well known but less functional measures of stroke outcome, including the Fugl-Meyer Scale ($r=.94$)[42] and the Barthel Index.[42] In a study of the reliability of data obtained with the ARA in patients with stroke,[41] intrarater reliability was $r=.99$ and interrater reliability was $r=.98$. The ARA is also easier to administer than the Fugl-Meyer Scale, taking only 8 to 10 minutes to administer, with no special training required.

The Stroke Rehabilitation Assessment of Movement (STREAM) is a new clinical outcome measure for evaluating the recovery of voluntary movement and basic mobility following stroke.[43] Data arise from a 5-point ordinal scale assessing movement quality (0=unable to perform the movement, 1a=able to complete only part of the movement and with marked deviation from the normal pattern, 1b=able to perform only part of the movement but in a manner that is comparable to the unaffected side, 1c=able to complete the movement but only with a marked deviation from the normal pattern, 2=fully able to complete the movement in a manner comparable to the unaffected side) on 3 scales: upper extremity, lower extremity, and basic mobility. The STREAM has been shown to be a reliable measure of motor recovery following stroke (intrarater reliability using direct observation=.995, intrarater reliability using videotaped observation=.999, internal consistency=.984).[43,44] We used the upper-extremity scale for the patient described in this case report.

Screening, Testing, and Intervention

Screening and baseline testing (pretests 1 and 2). After signing 2 consent forms (approved by the institutional review boards of Kessler Medical Rehabilitation Research and Education Corporation and The University of Medicine and Dentistry of New Jersey), the patient was tested on 2 separate occasions during the baseline phase by the research assistant. The Fugl-Meyer Scale, ARA, and STREAM were administered at the first baseline period (pretest 1) and 2 weeks later (pretest 2). All scores were recorded on a cover sheet to which the researchers were blinded. The 2 baseline measurements were intended to capture the rate of natural recovery that occurs after a cerebrovascular accident.

Physical therapy intervention. The participant received physical therapy 3 times per week, in 1-hour segments, for 6 weeks. The exercises were concentrated on the upper limbs for half an hour and on the lower limbs for half an hour. All therapy was provided according to the

neurodevelopmental treatment (NDT) method[45] because it was consistent with therapy that the patient had received during inpatient therapy and NDT has never been proven to be more effective than other modalities in stroke.[46] The patient performed all activities, such as working on transfers, balance/walking training, and ADL training (eg, putting on clothes, working on a computer), bimanually and, if necessary, with the affected arm with support of the unaffected side. The therapist had 10½ years of experience and was blinded to the mental practice treatment that the patient was receiving to ensure that no positive or negative biases could occur. The therapist was blinded to the fact that the patient was receiving mental practice in addition to therapy using the following methods: (1) the therapist was told that, after therapy, the patient was participating in a noninvasive research program, and no other specifics were given, (2) the therapist was asked not to ask the patient specific questions about the research program until the intervention period was over, and (3) the patient was instructed (and reminded) not to divulge to the therapist what was occurring during mental practice sessions.

The patient was treated using the NDT method. Functional activities (eg, walking, reaching, hanging clothes, pouring water) were performed integrating both limbs, and, when needed, the affected upper limb was supported using the unaffected hand. Symmetry of posture and inhibition of inappropriate synergistic movements were emphasized during therapy sessions.

About 20 minutes after therapy and after the patient had been transported to the research department, the patient listened to a tape-recorded mental practice intervention lasting approximately 10 minutes in a quiet examination room away from the therapy department. The patient was positioned supine on a padded treatment table. During the first 2 sessions, a member of the research team accompanied the patient; during the remainder of the mental practice sessions, the patient was alone. The intervention first consisted of 2 to 3 minutes of relaxation, asking the patient to imagine himself in a warm, relaxing place (such as a beach) and asking him to contract and relax his muscles (progressive relaxation). The patient was asked first to tighten the muscles in his feet and then relax them; the same procedure was followed in his legs, arms, and hands. This portion of the audiotape was followed by 5 to 7 minutes of suggestions for internal, cognitive visual images[47] related to using the affected arm in functional tasks (to maintain interest, 3 scripts were provided during the 6-week intervention: 1 during the first 2 weeks, 1 during the second 2 weeks, and 1 during the third 2 weeks). Internal, cognitive images were used in which the patient received audiotaped commands to

imagine himself from a third-person perspective executing the tasks specified on the mental practice audiotapes. The intervention was intended to target—and improve—functional use of the patient's affected wrist and fingers as well as to secondarily improve his ability to move out of synergy with the affected arm. During the first 2 weeks, the audiotaped functional task was reaching for and grasping a cup. During the second 2 weeks, the functional task practiced was turning pages in a large reference book. During the third 2 weeks, the task practiced was reaching for and grasping an item on a high shelf and then bringing the item to himself. For each of these tasks, the patient was urged to use all of his senses (eg, "feel your fingers grasp around the edge of the cup," "see your arm extend forward and upward toward the item on the shelf").

This was followed by 2 minutes of refocusing into the room. During refocusing, the patient was reoriented to his surroundings and to his body. After being told that it was time to "return to the room," refocusing began with concentration on feelings in the patient's own body. Then, he was asked to reconcentrate on his surroundings (eg, the buzz of the lights, becoming aware of voices or other noises that he may be able to hear outside), and the narrator counted down from 10 to 1. At 1, the patient was told to open his eyes. The patient received an audiotape identical to the one used in the laboratory for use at home. The patient was then asked by the research team member to use this audiotape 2 times per week. Informal interviews revealed that adherence to the home listening regimen was not an issue. The format for the mental practice audiotape used in this study was consistent with the protocols of reported mental practice studies in rehabilitation.[20,21]

After the 6-week intervention, the patient returned to the laboratory and was again administered the Fugl-Meyer Scale, ARA, and STREAM by the same research assistant who had performed the pretesting.

Outcomes

Comparisons of scores obtained prior to intervention (pretests 1 and 2) and after intervention (posttest) on the Fugl-Meyer Scale, ARA, and STREAM were used to determine whether changes occurred in the patient's upper-limb function. The patient had Fugl-Meyer Scale scores of 46 at pretest 1, 38 at pretest 2, and 53 at the posttest. Improvements were noted on the wrist and finger items of the Fugl-Meyer Scale in particular. Scores on the ARA were 15 at pretest 1, 17 at pretest 2, and 40 at the posttest. He improved on the grip and grasp items of the ARA, with slight improvements on the pinch scale as well. On the STREAM, the patient had the same scores at pretests 1 and 2. At the posttest, he improved

Table.
Pretest and Posttest Scores on the Upper-Extremity Scale of the Stroke Rehabilitation Assessment of Movement (STREAM)

Category	Pretest 1	Pretest 2	Posttest
Protracts scapula in spine	2	2	2
Extends elbow in supine	1c	1c	1c
Shrugs shoulders	1a	1a	2
Raises hand to touch top of head	1a	1a	1c
Places hand in sacrum	1a	1a	1b
Raises arm overhead to fullest elevation	1a	1a	1a
Supinates and pronates forearm	1a	1a	1b
Closes hand from fully opened position	2	2	2
Opens hand from fully closed position	1a	1a	1c
Opposes thumb to index finger	1a	1a	1c

on 6 of the 10 items of the upper-extremity scale (Table).

Discussion

Following a regimen combining therapy with mental practice, a patient 5 months poststroke and exhibiting stable motor deficits had reductions in upper-limb impairment as well as substantial functional gains. Our finding that upper-limb impairment level was reduced was consistent with the findings of Page.[21] It should be noted that our patient's initial impairment level ($\overline{X}$=42.0), as measured by the Fugl-Meyer Scale, was greater than the mean impairment level of patients in the Page[21] study ($\overline{X}$=22.1). Furthermore, our patient exhibited a relatively unstable baseline on the Fugl-Meyer Scale, which we believe was attributable to illness during the second pretesting session. Functional improvements on the ARA and STREAM, however, support improvement. Although functional outcome in the affected arm has not been previously tested, these functional improvements were also consistent with the speculations of Page,[21] who suggested that functional outcome could be enhanced by mental practice, and they were consistent with functional improvements observed in other mental practice studies.[22,23]

Magill[48] suggested that mental practice is effective because it augments existing motor schema. At the pretest, the patient had limited ability to use the affected wrist and fingers but a greater ability to perform gross movements with the affected arm, as indicated by his scores on items on the Fugl-Meyer Scale and on the gross movement scale of the ARA. After participating in a mental practice intervention targeting grasping, reaching, and gripping behaviors, the patient maintained his gross motor scores while improving on the fine motor components of the Fugl-Meyer Scale, ARA, and STREAM at the posttest. The specificity of the changes in the areas targeted suggests enhancement of the existing motor plan as a possible mechanism.[48,49]

Because our intervention targets the wrist and fingers, the ARA may be the most suitable instrument for measuring change, as it is most sensitive to subtle change in the wrist and fingers. In mental practice research with patients exhibiting less motor return, however, the Fugl-Meyer Scale may be the instrument of choice. Indeed, Page[21] found the Fugl-Meyer Scale to be adequate for measuring changes in patients with less motor return who were primarily capable of gross movements, whereas only 3 of the items of the ARA test gross function. Until researchers determine how much function is necessary for mental practice to be optimally effective, both instruments should continue to be used. We also suggest that future researchers ascertain to what extent combining mental practice and physical therapy results in changes that affect quality of life.

Frequent practice of a skill causes improved motor performance. Mental practice, when combined with physical practice, has been shown to be even more effective in improving motor performance than physical practice alone. One viable hypothesis for this effect is that, during mental practice, concurrent activity occurs in the musculature and in the appropriate neuromotor pathways.[25–28,30] This correlative neuromotor activity is similar to the activity that we hypothesize occurs with repetitive physical practice and is responsible for the motor performance improvements that individuals exhibit after mental practice. We also believe that the patient's improvements between the pretests and the posttest occurred because the patient, through mental practice, was provided with additional practice of functional tasks using the affected arm. On a physiological level, we believe that this practice caused priming of the motor cortex and appropriate activation of the neuromotor pathways, which resulted in the patient's improvements. We are currently attempting to substantiate this claim by monitoring EMG activity to determine whether greater changes occur in motor recruitment patterns and in EMG amplitudes in the limbs of patients receiving mental practice and physical therapy than in a cohort group receiving therapy alone. We believe that correlating changes in motor behavior with changes in cortical organization using functional magnetic resonance imaging might substantiate this claim.

A possible alternative explanation for the effect observed could be natural recovery. We controlled for this possi-

bility, however, by using 2 baseline measurements so that any pattern of natural recovery could be documented. We also controlled this possibility by comparing discharge summaries with our screening data collected 5 months postdischarge and by speaking with the patient's former therapists and physiatrist. All of these data substantiated the existence of a stable motor deficit, and the patient had negligible differences in scores between pretest 1 and pretest 2. Furthermore, some authors[50,51] have argued that, after the first 6 months poststroke, little additional neural reorganization occurs. The short duration of the treatment and the rapid improvement of the patient, combined with data indicating that the patient was exhibiting a stable motor deficit, make natural recovery less probable.

It is also plausible that the therapy alone caused the changes observed. However, this seems unlikely considering: (1) comparison between our observations at initial screening and medical records, discharge summaries, and physiatrist observations indicated that the patient had not exhibited improvement since time of discharge from therapy, suggesting a stable motor deficit, and (2) the regimen of therapy provided during our intervention was nearly identical to that provided during the patient's outpatient therapy. If he showed nominal gains toward the end of outpatient therapy (as reported by the patient and his therapist), it seems unlikely that the same therapy, provided several weeks later and during a shorter time period, would have had an effect, particularly on areas of function that the therapy did not previously improve.

Our experiences with this patient and with a randomized controlled study of patients with chronic stroke[21] suggest that mental practice is a potentially useful method of practicing motor skills. In the current health care environment, therapies that require less direct supervision but that convey improved outcomes are needed. Mental practice may be a cost-effective, noninvasive tool with which patients with stroke can receive additional practice of functional skills, and realize greater outcomes, than if therapy alone were used.

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