Technique to Improve Chronic Motor Deficit After Stroke

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• The unaffected upper extremity of chronic stroke patients was restrained in a sling during waking hours for 14 days; on ten of those days, these patients were given six hours of practice in using the impaired upper extremity. An attention-comparison group received several procedures designed to focus attention on use of the impaired upper extremity. The restraint subjects improved on each of the laboratory measures of motor function used—in most cases markedly. Extensive improvement, from a multi-year plateau of greatly impaired motor function, was also noted for the restraint group in the life situation and these gains were maintained during a two-year period of follow-up. For the comparison group only one measure showed small to moderate improvement, and this was lost during the follow-up period; there was essentially no overlap between the individuals of the two groups. Thus, prolonged restraint of an unaffected upper extremity and practice of functional movements with the impaired limb proved to be an effective means of restoring substantial motor function in stroke patients with chronic motor impairment identified by the inclusion criteria of this project.

KEY WORDS: Cerebral infarction; Limbs; Motor skills; Rehabilitation

When a single forelimb is deafferented by dorsal rhizotomy in a monkey, the animal does not make use of it in the free situation.[1-4] However, the monkey can be induced to use the deafferented extremity by either (1) restraint of the intact limb,[5,6] or (2) application of training techniques such as operant conditioning.[4,5,7-16] A useless limb is thereby converted into a limb capable of extensive movement. Restraint of an unaffected limb also improves use of the affected limb following unilateral cortical area 4 ablation[17] and unilateral pyramidotomy[18] in monkeys.

Several converging lines of evidence suggested that the nonuse of a single deafferented limb is a learning phenomenon, termed "learned nonuse," involving a suppression of movement.[7,8,10,19] The restraint and training techniques appeared to be effective because they successfully overcame the learned nonuse. It was hypothesized that the nonuse or limited use of an affected upper extremity in humans after stroke could, in some cases, be due to a similar learned suppression phenomenon.[19]

The central premise of this view is that immediately after somatosensory deafferentation a monkey cannot use a single deafferented limb because of the presence of a shock-like condition that follows substantial neurological injury, whether at the level of the spinal cord (spinal shock) or brain (diaschisis).[7-9,19] In monkeys, recovery from this shock-like phenomenon requires weeks or months.[7-9] An animal with one deafferented limb tries to use that extremity in the immediate postoperative situation, but finds that it cannot. It gets along quite well in the laboratory environment on three limbs, and this pattern of behavior is therefore strengthened. Moreover, continued attempts to use the deafferented limb often lead to aversive consequences, such as loss of balance and falling during ambulation or climbing, loss of food objects, and indeed failure of almost any attempted use of the limb. This has the effect of suppressing all behavior with that limb; the monkey thus learns not to try to use it. This tendency persists, becoming stronger with time, and consequently the monkey never learns that, several months after surgery, the spinal shock has passed and the limb has become potentially useful.

The consideration that led to the conduct of the present research with human stroke patients is that, according to this formulation, learned nonuse could develop after any neurological injury resulting in central nervous system (CNS) shock and an initial inability to use an extremity. The operation of the mechanism, as proposed, should be independent of the nature of the lesion that gives rise to the CNS shock and limb nonuse. If there is then a recovery from the initial CNS shock state and if sufficient neural substrate remains intact to provide a basis for movement, then the techniques used for overcoming learned nonuse following somatosensory deafferentation in monkeys should be equally applicable following other types of neurological injury, including stroke in humans, in restoring the

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ability to use the limb. This would be the case even though entirely different lesions are involved, and though stroke in man involves different physical deficits and cognitive defects beyond those produced by somatosensory deafferentation in monkeys.

Preliminary application to human chronic stroke patients of one of the early conditioned response paradigms developed in primate deafferentation research showed promise.[20,21] Other investigators, not operating within a learned nonuse context, have used training techniques to obtain some improvements in limb use in chronic stroke patients whose greatly impaired motor function was presumably not amenable to further recovery.[22,23] Recently, Wolf and coworkers[24,25] working with chronic stroke and traumatic brain injury patients in an impressive experiment used the second main approach to overcoming learning nonuse derived from the primate deafferentation experiments—restraint of the unimpaired upper extremity. The results were very promising. The absence of a control group, though, made the improvement in motor ability following restraint difficult to distinguish conclusively from an improvement observed over a series of baseline (ie, prerestraint) motor testing sessions. Moreover, it is unknown whether the improvement observed in the laboratory transferred to the activities of daily life. Though not in themselves conclusive, these studies raised the possibility that humans can in some cases learn to overcome an inability or reduced ability to use an impaired limb after stroke through the application of one of the techniques designed to overcome learned nonuse.

In the present experiment, an attempt was made to use both types of techniques to accomplish this objective. A separate-groups design was used with an attention-comparison group that made it valid to administer only one baseline prerestraint testing session, thereby avoiding the possible complication of an improvement across baseline days. Data were obtained on whether the procedures used in the clinic had an effect on improving the extent and quality of motor function in activities of daily life.

METHODS

Patients

Potential subjects were identified from physician files at Spain Rehabilitation Center and the Department of Neurology of the University of Alabama at Birmingham. They were screened in preliminary fashion by telephone and potential candidates were given a structured examination at Spain Rehabilitation Center by a physical therapist (JEC); the most promising were given a second structured examination by a physiatrist (WCF or CSN). This study was reviewed and approved by the Institutional Review Board for Human Use of the University of Alabama at Birmingham.

The following exclusion criteria were used: (1) stroke experienced less than one year earlier; (2) lack of ability to extend at least 10° at metacarpophalangeal and interphalangeal joints and 20° at wrist (the focal criterion); (3) balance problems including walking at all times with an assistive device; (4) ability to make extensive use of the involved upper extremity so that significant further improvement could not be expected; (5) serious cognitive deficits (as determined from the medical chart, the two examinations noted above, and the six cognitive tests noted below); (6) excessive spasticity (not found in any subject meeting criterion 2); (7) serious uncontrolled medical problems; (8) more than 75 years of age; and (9) left arm dominance or left hemiplegia (for ease in test administration with the equipment supplied).

To assess cognitive abilities, all potential subjects underwent neuropsychological screening focusing on language skills and visual scanning/sensory neglect, which it was believed could negatively affect participation in the study. The tests administered included the Sentence Repetition and Token Tests of the Multilingual Aphasia Examination,[26] abbreviated Sensory-Perceptual Examination focusing on suppression to double simultaneous stimulation,[27] the Test of Visual Neglect,[28] Letter Cancellation,[29] and the Mini-Mental State Examination.[30] The majority of test scores were within normal limits for control and experimental subjects. The one exception was a subject initially accepted for the experiment based on a promising interview and family report who was later found to be severely impaired in cognitive functioning. This subject was discontinued in the treatment protocol and was not included in any analyses. Remaining subjects exhibited occasional low scores, including some difficulty with the concentration subsection of the Mini-Mental State Examination (three subjects) and the Token Test. On the latter, no subject missed more than three items, and these lower scores were uniformly due to instructions having to be repeated. Two subjects (one experimental, one control) exhibited mild right neglect in the tactile modality, but no visual neglect. There was no indication of expressive or receptive aphasia in any of the subjects.

Nine patients who met the study's inclusion/exclusion criteria were randomly assigned to either an experimental group (four) or an attention-comparison group (five). The subjects in the two groups were closely matched in initial motor ability and did not diverge significantly in such demographic characteristics as age (restraint group: median, 65 years; comparison group: median, 63 years), sex (one male per group), and socioeconomic status. Chronicity ranged from 1.2 to 18 years (restraint group: median, 4.1 years; comparison: median, 4.5 years).

Interventions

For the experimental group, the unaffected limb was secured in a resting hand splint and then placed in a sling closed at both ends. The restraint was to be worn at all times during waking hours except when specific activities were being carried out (eg, excretory functions, naps, situations where balance might be compromised). Each subject agreed to spend well over 90% of waking hours in restraint. The restraint devices were worn for 14 days. On each weekday during this period, patients spent seven hours at the rehabilitation center and were given a variety of tasks to be carried out by the paretic upper extremity for six hours (eg, eating lunch with a fork and spoon, throwing a ball, playing dominoes or Chinese checkers, card games, writing on paper, writing on a chalk board, pushing a broom, Purdue Dexterity Board, Minnesota Rate of Manipulation Test).

The procedures given to the comparison group were designed to focus attention on the involved extremity. This was accomplished in three ways: (1) Patients were told during four ten-minute periods on separate days that they had much greater motor ability with their affected extremity than they were exhibiting; they were exhorted to focus attention on using the affected extremity at home in as many new activities as possible. Examples were given and record keeping was required and monitored. (2) Patients received two sessions labeled "physical therapy," but involving only activities that required neither active movement nor limbering of the involved limb. The activities consisted of the therapist determining passive range of movement, joint play, muscle tone, and sensory loss. (3) Patients were given self-range-of-movement exercises to carry out at home for 15 minutes a day. In these exercises, the affected extremity was passively moved into a variety of positions by the unaffected extremity. Thus, the involved limb was not given any experience of or training for active movement.

Tests

Each of the tests used was administered to experimental and comparison subjects just before and immediately after their two-week intervention period. The Emory Motor Function test was developed by Wolf and collaborators[25] at Emory University to quantify motor function in stroke and traumatic brain injury patients. At the advice of the Emory group, two of the least reliable tasks were excluded and 19 items were kept. On 16 of the retained items, performance time is measured, on two strength is measured, and one is evaluated by quality of product (ie, signature). Half of the items involve simple limb movements without functional endpoints; only three involve complete tasks that are commonly carried out in the life situation. Consequently, the results from this test, while quantitative, have an unknown relationship to a person's ability to perform the activities of daily life (ADL). The Arm Motor Activity Test (AMAT) was developed to provide this information.[31] It consists of 16 compound tasks composed of one to three component tasks performed continuously without the subject's awareness of the component parcellation. Each of the compound tasks is a complete ADL commonly carried out in the life situation (eg, donning a sweater, picking up a single dried bean on a spoon and bringing it to the mouth, unscrewing a jar cap). Subjects were permitted 60 seconds to complete each task of the Emory test and 120 seconds for the more complex tasks of the AMAT. Performance was videotaped. Breaking the tasks down into component segments and timing each permits the type of quantification possible with simpler actions without interfering with the normal flow of movement characteristic of everyday activity. In the research that led to the development of this instrument, it was found that the rating scales that were used (quality of movement, functional ability) had interrater reliabilities between 0.95 and 0.99.[31] The videotaped test performances on both motor tests were later rated independently by the same three clinicians for whom reliability data had been obtained in the test development research. They were "blind" to group membership and to the preintervention or postintervention order of test administration. Each subject's score on each task was taken as the mean of the clinicians' scores. The median performance time across all tasks was also calculated for each subject for each administration of the test.

A third instrument, the Motor Activity Log, provided information about motor function in the life situation. It consists of 14 common and important ADLs from such functional areas as feeding, dressing, and grooming. For each item the patient must report whether and how well (on a six-point scale) each activity was performed during a specified period. Information was obtained about motor activity in the year prior to the subject's participation in the project, every other day during the intervention period, on a weekly basis for one month afterwards, and again two years after the end of treatment.

Passive range of movement was tested at each joint of the affected limb. In addition, to determine cognitive status the six tests noted above were administered.

The order of testing was the same for all subjects, as follows: Motor Activities Log, passive range of movement, Emory Motor Function Test, 30-minute rest, AMAT, 30-minute rest, cognitive tests.

Data Analysis

Initial statistical tests focused on differences between groups at each assessment occasion. Prior to analysis of posttreatment data, one-way ANOVAs were conducted on pretreatment scores. These tests indicated that there were no preexisting differences between treatment groups on any of the measures. The effects of restraint versus control treatment were assessed with parallel ANCOVA conducted for each measure, with pretreatment scores serving as covariates. In one case (the analysis of number of Motor Ability Log tasks that the subject could complete), the nonparametric Mann-Whitney U statistic was used because serious distribution problems made the ANCOVA inappropriate. Additional follow-up tests took two forms: (1) pretreatment versus posttreatment tests performed separately on each group's data to determine which group(s) improved over the course of treatment, and (2) tests on data for individual subjects to determine how many subjects in each group showed improvement. These tests were generally conducted as paired-difference t-tests, although the nonparametric sign test was used for the motor test performance times because these times could be truncated (as a result of task incompletion during the maximum time allowed); therefore only improvement, but not the precise amount of improvement, could be determined. Because only improvements were considered interpretable, these follow-up tests (but not the original ANCOVAs) were conducted with a one-tailed rejection region. Where not otherwise noted, a $p = .05$ significance criterion was used.

RESULTS

Mean performance times on the two motor ability tests were significantly faster for the restraint group than for the control group following treatment (fig 1). Performance times for the experimental group decreased 30.0% from preintervention to postintervention, whereas the mean performance times of the comparison subjects increased 2.2%. In individual subject tests, all four experimental subjects exhibited significant or near significant improvements in performance time following restraint (all *p*s < .06; median *p* = .002), whereas none of the subjects in the comparison group showed significant improvement (all *p*s > .3).

Quality of movement and functional ability were significantly improved among experimental subjects relative to control subjects on both the Emory Test and the AMAT at the end of treatment (fig 2; all *p*s < .003). Improvement from pretreatment levels for the experimental group was significant for the two motor ability tests. The comparison group did not improve on either scale on either test. On an individual basis, each subject in the experimental group showed a significant improvement on both of the scales on both tests. None of the comparison subjects exhibited a significant improvement on either scale on either test.

The Emory Motor Function Test has two tasks that assess strength. One task involves lifting progressively increasing weights strapped to the forearm from the surface of a table to the top of a 9-inch box. A second task involves measuring grip strength with a dynamometer. The comparison group patients showed a preintervention to postintervention improvement of 10.0% in the lifting task and an 8.8% decrement in the grip task. Of the three experimental subjects for whom data are available on the weight-to-box task (subject 4's data were excluded because he exerted test maximum force during pretreatment testing and could therefore not improve further), the first two exhibited a larger preintervention to postintervention increase in lifting ability (83.3%) than the comparison subjects, but for grip strength (data from subject 4 was available for this task) there was little change (+9.3%). For the last experimental subject (no. 1), an attempt was made to improve strength by providing brief periods of exercise with pulley weights. This was followed by an 808.9% improvement in the lifting task. No specific training was given in grip; nevertheless, it increased in strength substantially (275%).

During and after the restraint intervention, the Motor Activity Log (fig 3) indicated that the experimental subjects exhibited a marked increase in their ability to use their affected upper extremity in a wide range of everyday activities, improving from a rating of 1.5 ("very little"/"slight use") to a rating of nearly 4 ("almost normal use"). Most of the improvement was made during the treatment period. However, these gains were retained during the entire two-year follow-up period and they even increased somewhat during that time. The subject who improved most between one month and two years after treatment (no. 1) is the only one who complied with instructions to keep practicing at home the manual dexterity tasks they each had been assigned. Improvement from baseline for the restraint group was significant at all times beginning at the second measurement point (Day 4) of the first week of treatment. The rate of improvement for the group and for each subject individually describes a typical negatively accelerated learning curve. The restraint subjects performed significantly better than the comparison subjects at each point after the begin-

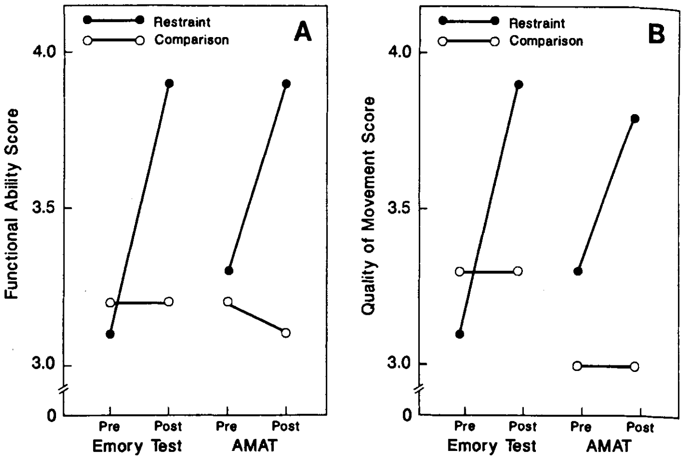

Fig 2—Mean functional ability (A) and quality of movement (B) on two motor ability tests.

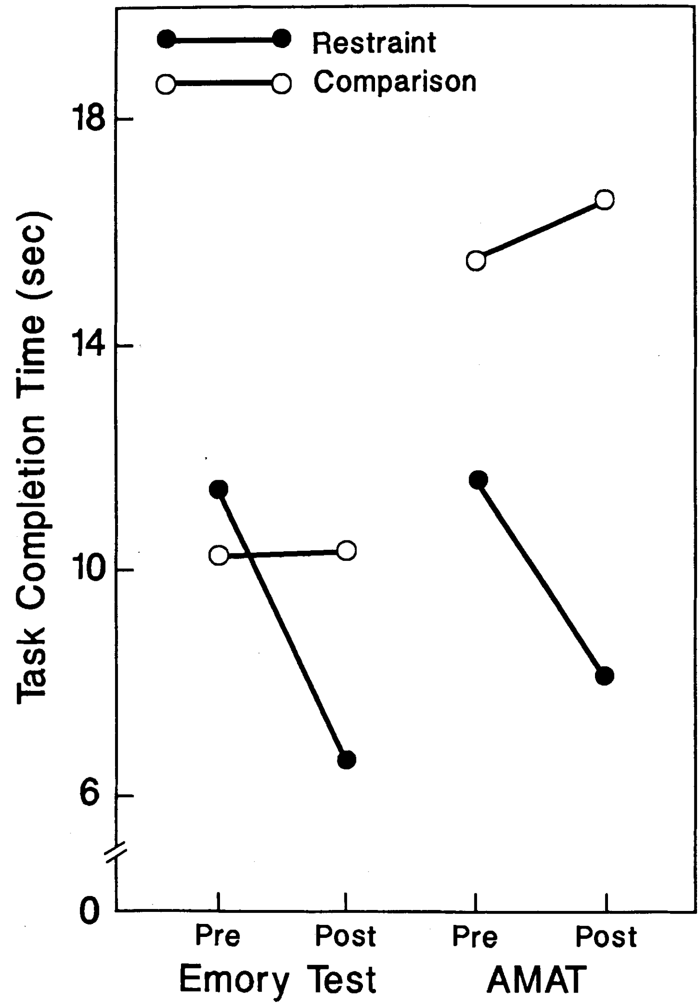

Fig 1—Mean task completion time (seconds) on two motor ability tests.

ning of the interventions. In addition, as may be seen from fig 4, there was no overlap in the Motor Activity Log scores of the individuals in the two groups after the first week of treatment. Three of the comparison subjects exhibited a small to moderate improvement in motor function that was significant at all data points until the end of the first month after treatment in one case (no. 13) and during treatment (but not the first month of follow-up) in another (no. 12). On a group basis, motor improvement approached significance at the end of treatment and for each of the first two weeks after treatment (p = 0.08, 0.1, 0.08, respectively). However, two years after the end of treatment the motor ability of the two most improved subjects had regressed: slightly below the baseline value in one case (no. 12) and halfway back to the baseline value in the other (no. 13). On a group basis the earlier motor gains had been lost (mean = −.2 unit).

The improvement of the restraint patients in Motor Activity Log scores in part reflects better quality of movement, and in part the fact that these patients were able to translate the improvements in the nature of their movements measured in the laboratory into mastery of a large range of ADLs that they had not been able to carry out with the affected arm since experiencing their stroke. The new activities engaged in included brushing teeth, combing hair, picking up a glass of water and drinking, eating with a fork or spoon, and writing, among others. Determination on a simple binary basis of whether a subject made no attempt to carry out a given motor activity in contrast with any attempt at all, at whatever level of ability, is a more clear-cut, reliable measure than a multistep rating scale. The table shows that there was a mean increase of 97.1% in the number of activities on the Motor Activity Log that the patients could carry out one month after restraint compared to the period before treatment. The comparable change for the comparison subjects was 14.5%. The difference between groups on this measure was significant after the interventions (U test, $p < 0.01$) but not before. The robustness of the effect is indicated by the fact that differences between groups were statistically significant despite the fact that the sample size was small. Two years after treatment there was no decrease in the restraint group's ability to perform the new tasks, but the comparison group, as above, had lost all its gains. The fact that all four restraint subjects performed at the 14-item maximum for the log at both four weeks and two years after intervention imposed an artificial ceiling on the improvement that could be recorded for the restraint group on this instrument. Consequently, the data presented in the table probably understate the true improvement of the restraint subjects in ADLs.

Each of the three experimental subjects for whom data are available showed at least some increase in passive range of movement. The comparison subjects showed no clear change. Though the differences in the experimental group

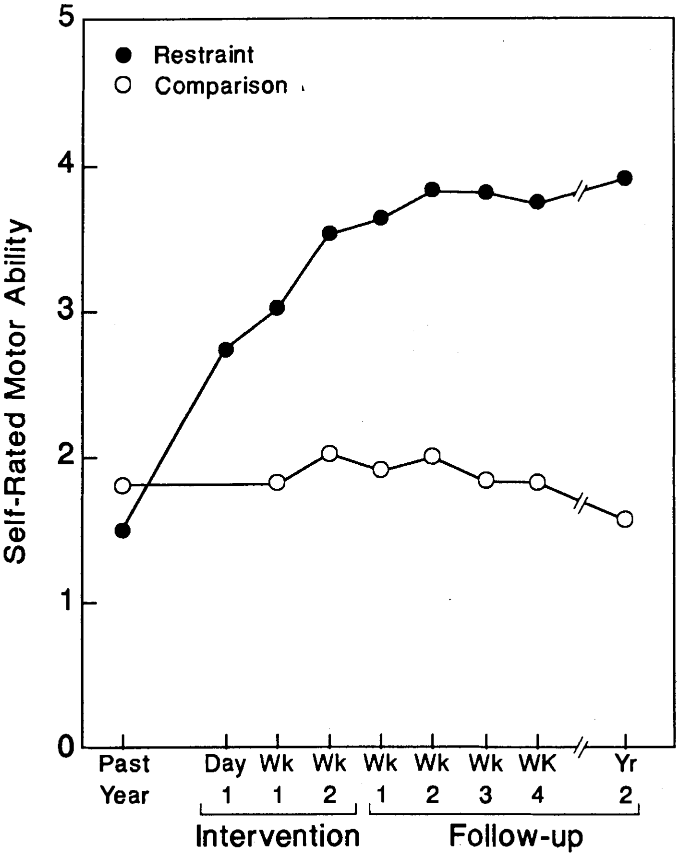

Fig 3—Group data on Motor Activity Logs.

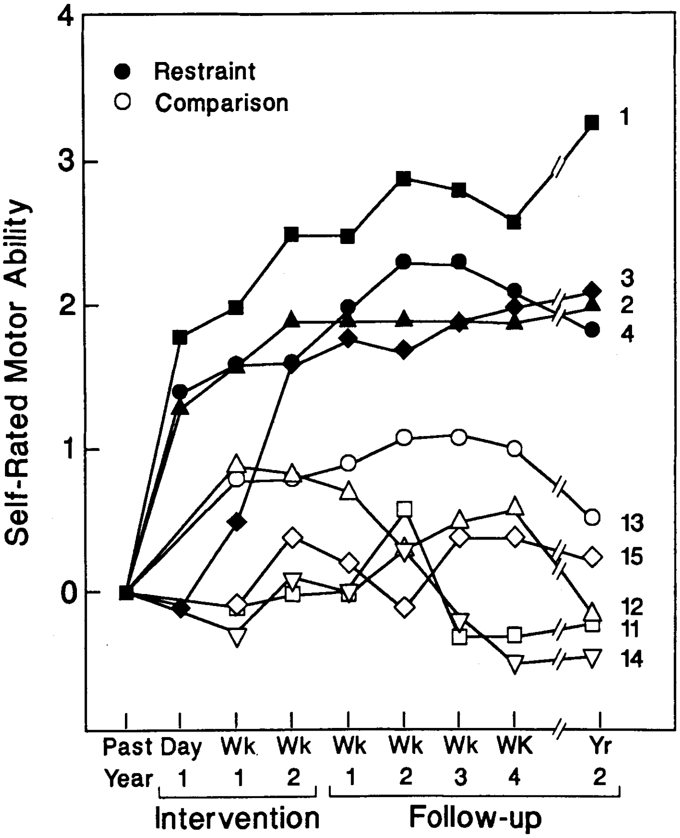

Fig 4—Individual data on Motor Activity Logs. The data are ipsitized so that each subject's pretreatment score is set to zero.

Motor Activity Log: Number of Activities of Daily Life that Could be Performed Before and After Interventions[*]

Subject	Pretreatment	One Month Posttreatment	One Month % Change	Two Years Posttreatment	Two Years % Change
Restraint Group					
1	5	14	180.0[†]	14	180.0[†]
2	14[†]	14	—	14	—
3	9	14	+55.6	14	55.6[†]
4	9	14	+55.6	14	55.6[†]
Mean			+97.1[‡]		+97.1[‡]
Comparison Group					
11	3	4	33.3[†]	3	0.0
12	12	14	16.7[†]	11	−8.3
13	5	9	80.0[†]	8	60.0[†]
14	14	7	−50.0	7	−50.0
15	13	12	−7.7	11	−15.4
Mean			14.5[†]		−2.7

[*] 14 is maximum score possible.

[†] Ceiling effect in pretreatment performance renders this aspect of H.D.'s data uninterpretable (though her quality of movement improved substantially —see fig 1).

[‡] $p < 0.01$ for the comparison between the restraint and comparison groups, Mann-Whitney *U* test.

were relatively small, they occurred even though no attempt had been made to train for improved range of motion.

Neither group showed any preintervention to postintervention cognitive change. The lack of change in the restraint group suggests that the improvement on the motor ability measures was not due to some nonspecific effect, such as increased motivation to do well generally or elevated mood, that might have resulted from contact with the project.

Three of the four experimental subjects reported they wore their restraint outside the clinic all the time that had been stipulated. The fourth subject (no. 3) stated she wore the restraint approximately 70% of the agreed-upon time. All four restraint subjects reported they enjoyed wearing the restraint (three of them very much) even when they were on the street or with friends. Two of the subjects made strenuous efforts to convince the project to give them their restraining devices at the end of their two-week intervention. They had come to depend on it because they said it overcame their very strong tendency to use the good limb; the restraint fostered use of the paretic limb, which had been dominant before the stroke and was greatly preferred.

The first three restraint patients reported stiffness and discomfort on the involved side midway through the two-week restraint period. It was clear clinically and from patients' self report that the reason for the muscle soreness was that the patients were making movements of greater excursion with the impaired limb than at any time since their CVA. As a result, they were experiencing the typical consequence of overuse. Consequently, the intervention procedures were modified with the fourth restraint patient so that motor demands were increased slowly, in graded fashion. She reported no muscle soreness.

In interviews, each of the restraint patients stated they were capable of a greatly expanded range of activities in the life situation. They reported they had made major gains in what was, in effect, functional independence. This is consistent with the results for the Motor Activity Log. For example, subject no. 2, while her uninvolved arm was in restraint, baked a cake, brought it into the center, cut it into pieces, placed them on plates with a cake server and then served them to project members using only the affected extremity throughout. When two of the experimental patients (nos. 1 and 4) were asked to sign their names with the involved hand, they said they could not do this and had not been able to since experiencing their stroke. They were asked to try; it was perfectly all right if they could not do the task. Both subjects, to their great surprise, were able to sign their names. The movements were slow, but the signatures were of reasonably good quality (and both speed and quality improved later with practice). Both of these patients began signing checks and writing notes in the life situation with the affected hand (which, as noted, had been dominant before they had experienced CVA). This led to part-time clerical employment for one of these subjects, answering the phone and taking messages with the affected hand, thereby relieving a self-reported depressed state because she previously "had nothing to do except spend most of my days staring at the four walls of my apartment." Though the comparison subjects also expanded somewhat the extent of the activities carried out by their impaired limb in the life situation, in no case did this have significance for functional independence.

DISCUSSION

The results indicate that in stroke patients identified by the inclusion criteria of this study, motor ability can be significantly increased by interventions that are effective in overcoming learned nonuse. The data are characterized by their consistency; there was virtually no overlap between the two groups in any of the parameters measured. Though the sample size was small, the effects were large and they were maintained and even increased somewhat over a two-year follow-up period. In addition, the improvement in the restraint group was superimposed on a median poststroke period of 4.1 years and a median baseline of more than three years during which patients had reached a largely unvarying plateau of greatly impaired motor function. Because of these long baselines and the long follow-up period, the results for each subject are rendered of increased therapeutic significance. Moreover, the maintenance of gains by restraint subjects over a two-year posttreatment period and the dissipation of a much more modest effect over the same time interval in comparison subjects argues against a significant contribution from attention/placebo factors to the motor improvement of the restraint group. These findings are consistent with the work of other investigators.[17,18,24,25]

It is of interest to note that when all exclusion criteria except the third (because balance problems may not be a bar to effective therapy by a modified procedure) were applied, 8.7% of the original complement of patients remained. However, if left hemiplegics and left dominant individuals (excluded here for convenience in testing) had been left in the sample, this value would have more than doubled, becoming 18.2%. This may be an underestimate of the amount of patient inclusion that can generally be expected from the application of these criteria because the study subjects were derived primarily from the patient pool of a tertiary care facility that tends to see patients who are more involved than individuals experiencing CVA in the general stroke population. Moreover, additional patients (eg, robust individuals more than 75 years old and persons with serious but not incapacitating cognitive deficits) who could not meet the inclusion criteria for this experimental study might be suitable for application of the study interventions for treatment purposes.

An informal test used by Wolf based on his previous research[32] for determining a patient's appropriateness for interventions for overcoming learned nonuse involves having a seated person project the affected hand and distal portion of the forearm beyond the edge of a chair's armrest. The patient is asked to first extend the unsupported hand at the wrist and then extend the fingers to the maximum extent possible. Approximately 20% to 25% of the stroke population with chronic motor deficit can carry out these movements with excursions of at least 20° and 10° at the two locations, respectively (thereby exceeding the second exclusion criterion listed above). All of the patients who met this criterion in the work to date exhibited marked motor improvement when given treatment for overcoming learned nonuse. The percentage of stroke patients with chronic motor deficit who do not meet this criterion but who would also benefit from this therapeutic approach is at present unknown. It would clearly not be as high as in the current work, but at least some of these patients might also be helped.

The median decrease in performance time for all timed tasks from the first baseline to the last treatment session on the Emory Motor Function Test was more than three times as great in this experiment as for the 21 primary subjects in the study by Wolf and coworkers.[25] Thus, adding training of the affected limb to the restraint procedure would appear to greatly increase the extent to which learned nonuse can be overcome. It seems unlikely that training of the affected extremity alone would produce large treatment effects (especially in the life situation); it is the combination of the two techniques that is probably the significant factor.

The results can be understood in the following manner. If the neural substrate for a movement is destroyed by CNS injury, no amount of intervention designed to overcome learned nonuse can be successful in helping recover lost function. However, many stroke patients (at a minimum those defined by the inclusion criteria of this project) have considerably more motor ability available than they make use of. As noted above, the suppression of this additional motor capacity is set up by unsuccessful attempts at movement in the acute poststroke phase; this inability to make attempted movements is associated with the cortical shock or diaschisis characteristic of that period.[7,8,9,19] Recovery from cortical shock occurs over time; increased motor activity should then become increasingly possible, but the suppression of movement remains unabated and inhibits use of the limb. However, if individuals are correctly motivated to use this unexpressed ability, they will be able to do so. The Motor Activity Log data suggest that the comparison group subjects did begin to increase use of the affected extremity; but because the conditions of daily life are the context in which the learned nonuse originally developed, the life situation continued to provide support for suppression of affected limb function. Therefore, the new motor abilities were not practiced frequently with the result that the amount of improvement was relatively small and was eventually lost entirely. The waking-hours restraint used in the experimental group, however, provided the conditions under which various new uses of the limb could be practiced repeatedly, thereby permanently overcoming the motor suppression. Consequently, performance time, quality of movement, and the range of activities engaged in all improved substantially. The results thus suggest that though learned nonuse is an incapacitating condition, it can nevertheless be reversed or overcome by appropriately directing the attention of an impaired subject. This objective can be accomplished to differing extents by a variety of means. Prolonged restraint of the intact limb is effective in facilitating the expression of the latent motor ability and repeated practice in using the newly emerging motor ability can also be an important factor.

An alternative hypothesis is that the experimental interventions resulted in some type of neural reorganization, perhaps involving sprouting, that permitted improved motor performance. This possibility is rendered unlikely, however, by the speed at which the motor improvement took place. By the end of the first day of restraint, over 50% of the complete improvement observed for the Motor Activity Log had already occurred. This has the appearance of an unmasking of an ability that is already present, rather than the initiation of a neural restitution process.

The learned nonuse theory states that one of the two main functions of interventions designed to overcome learned nonuse is to increase the motivation to use the affected limb. Because the attention-control procedure in this experiment would undoubtedly result in an increase in this type of motivation, it may be viewed as a type of reduced treatment and is therefore potentially more powerful than an attention-control procedure alone for comparison purposes. This further supports the position that the improvement in movement in the restraint group is not due to the operation of attention/placebo factors. These considerations are of interest because chronic stroke patients are now a largely untreated population.

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