Assessment of Strength Deficits in Eight Paretic Upper Extremity Muscle Groups of Stroke Patients with Hemiplegia

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This retrospective investigation was undertaken to describe and compare the initial and discharge strength deficits of eight upper extremity muscle groups of 42 patients who were hemiparetic secondary to cerebrovascular accidents (CVAs). Static strengths of the eight muscle groups were measured using a hand-held dynamometer, and strength deficits were calculated against the side ipsilateral to the side affected by the CVA. A two-way analysis of variance for repeated measures revealed significant differences ($p < .001$) in the strength deficits of the eight muscle groups and between initial and discharge strength deficits. The strength deficits of the shoulder medial rotator and abductor muscle groups were significantly less than those of any other muscle group. No difference was found in the proportion of muscle groups improving in strength in patients tested within six weeks after the onset of hemiplegia versus patients tested six weeks later. Our results do not confirm the common expectation of relatively lesser involvement of the elbow flexor muscles after a CVA. The results do suggest that patients improve in muscle strength concurrent with a rehabilitation program.

Key Words: Cerebrovascular disorders, Muscle hypotonia, Physical therapy.

Although muscle strength testing of patients with strokes has been derided by some authors, it has been used by others to monitor the motor status and recovery of patients after a stroke. Using either noninstrumental ordinal grading schemes or isokinetic dynamometry, clinical researchers have measured muscle strength and investigated muscle strength relationships in patients with hemiplegia secondary to cerebrovascular accidents (CVAs). As a result of the work of these researchers, several important conclusions can be posited regarding motor capacity in patients with strokes. Not all patients with strokes have muscle weakness that is detectable by manual means. Those patients who demonstrate weakness relative to healthy persons may do so in the muscles both ipsilateral and contralateral to the side of the CVAs. The capacity of patients with hemiplegia to activate or develop force in some muscles may be a function of joint positions. Motor capacity may be more impaired at fast than at slow velocities in the paretic muscles of patients with strokes. Muscle strength or strength improvement is related to functional activities such as gait and to functional indexes such as the Barthel Index.

Two conclusions are of particular relevance to this investigation. The first is that some muscle groups may be more or less involved than others. Brunnstrom has commented on the strength of various synergy components in patients with hemiplegia, but in doing so, she probably uses the word in a somewhat different context than we do. Moskowitz et al have suggested that the proximal segments of the upper and lower extremities demonstrate earlier and more substantial muscle strength gains than distal segments. In another article, Moskowitz attributes the assumption of a posture of flexion at the elbow to the earlier recovery of function of the biceps brachii and brachioradialis muscles, as compared with the triceps brachii muscle. The second particularly relevant conclusion is that muscle strength improvements are most marked in the first few weeks after stroke, with little improvement in most patients after six months. These writings notwithstanding, the strength of multiple upper extremity muscle groups, to the best of our knowledge, has not been measured objectively in stroke patients with hemiplegia. The relative strength, therefore, of various upper extremity muscle groups and their tendency to recover strength has not been established yet.

Given the relationship between muscle strength and the performance of some functional activities and the potential importance of muscle strength to joint alignment and range of motion, information regarding strength deficits may prove useful to clinicians involved in the rehabilitation of stroke patients with hemiplegia. The purpose of this investigation was to describe and compare the strength deficits of eight upper extremity muscle groups of stroke patients with hemiplegia on initial and discharge assessments. Our expectations were that the strength deficits of various upper extremity muscle groups would differ and that strength deficits would decrease between initial and discharge assessments.

METHOD

Data Retrieval

In this retrospective study, we reviewed the medical records of 186 stroke patients with hemiplegia who were discharged...
over an 11-month period. Of these records, 85 were of patients who had suffered their first stroke and whose dynamometer test results were obtained by four therapists, including the authors, who had demonstrated previously their capacity to perform hand-held dynamometry reliably (*r*2 of test-retest ≥ .88). These records were reviewed further to determine which of 10 tested upper extremity muscle groups were tested at least 40 times. The muscle groups so tested were the wrist extensors; elbow flexors and extensors; shoulder medial (internal) and lateral (external) rotators; and the shoulder flexors, extensors, and abductors. The wrist flexor and shoulder adductor muscle groups were tested less than 40 times.

**Patients**

All eight muscle groups of 42 patients, 24 women and 18 men, were tested. The records of these patients were used in this study. These patients were between 22 and 84 years of age, with a mean age of 64.1 ± 13.8 years. They were assessed initially 9 to 233 days, or a mean of 36.9 ± 43.8 days, after the onset of hemiplegia, with 10 of the patients first being assessed more than six weeks after the onset of hemiplegia. The 42 patients spent 10 to 52 days, or a mean of 32.3 ± 10.2 days, in rehabilitation between their initial and discharge assessments. Sixteen patients were weak predominantly on their left side, and 26 were weak predominantly on their right side.

**Procedure**

Each patient was tested both initially and at discharge by the same one of four clinicians. A Chatillon* force gauge was used to measure, bilaterally, the static strength of the upper extremity muscle groups of each patient. The clinicians tested the eight muscle groups using a method described previously by Bohannon.22,29 This method entailed testing each muscle group in the gravity-eliminated position in the middle half of its range while patients lay supine on a mat table. Test contractions were about four seconds in duration against the dynamometer, which the examiner held stationary. During the testing, each clinician stabilized the tested patient to prohibit extraneous movements such as those associated with a synergistic pattern. Patients were observed to ensure that no augmentation of measured force occurred as a result of notable use of tonic neck reflexes. Because we wanted to compare strength between muscle groups, we expressed strength measurements as deficits. Strength deficits were calculated for each of the eight muscle groups as follows: [(Strength of nonparetic muscle group on initial assessment − strength of paretic muscle group) + Strength of nonparetic muscle group on initial assessment] × 100. In this formula, the strength of the paretic muscle group could be that obtained on either initial or discharge assessment.

**Data Analysis**

Descriptive statistics of strength deficits were calculated for the eight muscle groups. A two-way analysis of variance (ANOVA) for repeated measures was used to compare strength deficits between muscle groups and to compare initial and discharge strength deficits. We performed pair-wise comparies between muscle group strength deficits using the Tukey method.24 We used the chi-square test to compare changes in strength deficits associated with assessments of those first measured less than six weeks after the onset of hemiplegia and those first measured more than six weeks after the onset of hemiplegia. The level of significance selected for this study was *p* < .05.

**RESULTS**

Table 1 reports the means and standard deviations of the strength deficits in the eight muscle groups on initial and discharge assessments. The mean magnitude of the strength deficits was substantial, ranging from 58.3% to 72.9% on initial assessment and from 37.9% to 54.1% on discharge assessment. The ANOVA (Tab. 2) demonstrated that the strength deficits differed significantly between muscle groups. The Tukey tests, however, revealed that only four pairs of muscle groups had strength deficits that differed significantly (shoulder medial rotators—shoulder lateral rotators, shoulder medial rotators—wrist extensors, shoulder medial rotators—elbow flexors, and shoulder abductors—shoulder lateral rotators).

The Table 2 ANOVA results establish that the strength deficits of the initial assessment were significantly less than those of the discharge assessment (*p* < .001). The grand mean strength deficit for all eight paretic muscle groups decreased almost one third, or 30.5%, between assessments. Of the 336 muscle groups, or eight for each patient, compared between initial and discharge assessments, 268 (79.8%) demonstrated decreased strength deficits (ie, increased strength). The pro-

**TABLE 1**

<table>
<thead>
<tr>
<th>Muscle Groups</th>
<th>Initial</th>
<th>Discharge</th>
<th>Grand Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>s</td>
<td>X</td>
<td>s</td>
</tr>
<tr>
<td>Shoulder lateral rotators</td>
<td>69.6</td>
<td>30.4</td>
<td>54.1</td>
</tr>
<tr>
<td>Wrist extensors</td>
<td>72.9</td>
<td>29.2</td>
<td>49.8</td>
</tr>
<tr>
<td>Elbow flexors</td>
<td>70.5</td>
<td>28.1</td>
<td>50.3</td>
</tr>
<tr>
<td>Shoulder flexors</td>
<td>68.5</td>
<td>33.1</td>
<td>46.0</td>
</tr>
<tr>
<td>Shoulder extensors</td>
<td>62.0</td>
<td>29.5</td>
<td>42.9</td>
</tr>
<tr>
<td>Elbow extensors</td>
<td>59.9</td>
<td>33.4</td>
<td>42.3</td>
</tr>
<tr>
<td>Shoulder abductors</td>
<td>60.2</td>
<td>32.6</td>
<td>39.3</td>
</tr>
</tbody>
</table>

*Arranged according to the grand mean strength deficit, from greatest to least.

**TABLE 2**

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>SS</th>
<th>MS</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Muscle groups (A)</td>
<td>7</td>
<td>18242.2</td>
<td>2606.0</td>
<td>7.61</td>
<td>.001</td>
</tr>
<tr>
<td>Error</td>
<td>41</td>
<td>50919.4</td>
<td>1241.9</td>
<td>.73</td>
<td>NS</td>
</tr>
<tr>
<td>Assessment (B)</td>
<td>1</td>
<td>66687.0</td>
<td>66687.0</td>
<td>53.70</td>
<td>.001</td>
</tr>
<tr>
<td>Error</td>
<td>287</td>
<td>51071.5</td>
<td>177.9</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
portion of muscle groups that demonstrated decreased strength deficits was 78.9% in patients first assessed less than six weeks after onset of hemiplegia and 82.5% in patients first assessed more than six weeks after onset of hemiplegia. These proportions do not differ significantly ($\chi^2 = 0.49, df = 1, p = NS$).

DISCUSSION

In accordance with our general expectations, the strength deficits of various upper extremity muscle groups did differ significantly. Our specific expectations were based on our own clinical perceptions and our interpretations of others’ work. First, we expected the elbow flexor muscles to be less involved than the elbow extensor muscles. Second, we expected the proximal shoulder muscles to demonstrate smaller deficits than the more distal muscles of the elbow and wrist. Contrary to our specific expectations, the elbow flexor muscles demonstrated a strength deficit that was statistically no less than that of the elbow extensor muscles. Although the strength deficits of the shoulder medial rotator and abductor muscles were less than those of some more distal muscles, no clear difference between proximal and distal muscles, excluding the hand that was not tested, was found in this study.

How might the findings of strength deficit differences and lack of differences among the muscle groups of the 42 patients be explained? Although we are uncertain, we do believe that some of the muscle groups that often are assumed to be stronger after stroke seem stronger simply because they are stronger in healthy subjects, not because they are any less affected by the brain lesion. In a study of healthy, young women, for example, one of us (R.W.B.) found that the elbow flexor muscles were among the strongest and the elbow extensor and shoulder lateral rotator muscles among the weakest of 10 upper extremity muscle groups tested. Differences in fiber type distribution and motor unit size among the various muscle groups might affect their status after CVAs. Another possible factor contributing to the lack of significant differences in strength deficits between specific muscle groups may be the large individual differences among stroke patients with hemiplegia that make clear trends among groups of patients difficult to establish. The large standard deviations in our study support this possibility.

If imbalances in muscle strength contribute to joint malalignment and eventual limitations in ROM, significant differences in strength deficits between muscle groups, such as the shoulder medial and lateral rotator muscles, merit further investigation. Such differences possibly might be found to be associated with problems such as adhesive capsulitis, which evidently is prevalent among stroke patients with hemiplegia. The finding that the strength deficits determined on initial and discharge assessments differed upheld our expectations. Although the changes that occurred in the upper extremity strength deficits between initial and discharge assessments cannot be linked directly with, or attributed to, the patients’ rehabilitation program, the changes do verify that the patients progressed while undergoing rehabilitation. This progress does not appear to be limited to the first few weeks after the CVAs. Although only 1 patient was tested more than six months after onset of hemiplegia, the same proportion of muscle groups improved in the 10 patients who had suffered a CVA more than six weeks previously and in the 32 patients who had suffered a CVA less than six weeks previously. Some measures that we have used for program evaluation, but that are less sensitive than hand-held dynamometry, have not demonstrated the changes in the motor recovery during rehabilitation manifested by the patients in this study. One such system of measures, the Program Evaluation Conference System, uses an ordinal grading system to grade the number of extremities involved. Other ordinal schemes may be similarly insensitive to changes in specific aspects of patient status. Clinicians, therefore, may wish to rely on measurement tools such as dynamometers when the documentation of motor status or progress is critical.

This study has investigated differences in strength deficits between muscle groups and between assessment times. The results, therefore, should not be construed to represent differences that might exist in other components of motor function such as amplitude of active movement or motor control. The reader should realize the limitations associated with calculating strength deficits relative to the nonparetic side’s strength on initial assessment. The muscles of the nonparetic side of patients with hemiplegia may be weaker than the same muscles of healthy persons. Furthermore, the nonparetic side, like the paretic side, may become stronger during rehabilitation. The relationship between strength deficits and other variables may be as important in clinical decision making as the results reported herein. We, therefore, recommend further studies to investigate these relationships.

CONCLUSIONS

Statistical analyses of strength deficits have verified that muscle strength improves in stroke patients with hemiplegia undergoing rehabilitation and have raised several interesting questions. Are muscle groups of the upper extremity affected disproportionately in the manner we have come to believe? Are failures to note improvement in stroke patients with hemiplegia a result of insensitive measurement techniques? Are patients less likely to improve simply because of an increased latency between the onset of the CVA and the time of their rehabilitation? These and other questions merit further investigation.
REFERENCES