Is the Measurement of Muscle Strength Appropriate in Patients with Brain Lesions? A Special Communication

Controversy exists as to whether muscle strength is a variable that should be measured in patients with brain lesions. The purpose of this special communication is to provide evidence for the inclusion of muscle strength testing in the assessment of these patients. This evidence consists of information that 1) is relevant to weakness following brain lesions and concerns about its measurement, 2) provides a precedent and support for muscle strength testing, and 3) relates muscle strength to patient capacity and outcome. I believe that this information justifies the inclusion of muscle strength in the assessment of patients with brain lesions, but not to the exclusion of other behavioral functional variables. [Bohannon RW: Is the measurement of muscle strength appropriate in patients with brain lesions? A special communication. Phys Ther 69:225–236, 1989.]

Key Words: Cerebrovascular disorders; Hemiplegia, gait; Muscle performance, measurement; Paresis.

The most obvious, although by no means ubiquitous or sole, consequence of cerebrovascular accidents (stroke) is a predominantly unilateral muscle weakness. Nevertheless, some educators and authors have been suggesting for years that the measurement of muscle strength is inappropriate (ie, invalid) in patients with stroke. During the same time, many researchers have used a variety of methods to measure the strength of patients with hemiparesis. In addition to providing a well-founded precedent for such measurements, the researchers have demonstrated a relationship between muscle strength and functional capacity and outcome. The purposes of this special communication are to 1) discuss the issue of weakness following brain lesions, 2) address a few of the specific concerns that have been voiced by opponents to the strength testing of patients with brain lesions, 3) provide an indication of the magnitude of the support and precedent that exists for muscle strength testing of these patients, and 4) present information that relates muscle strength to functional capacity and outcome.

Muscle Weakness Following Brain Lesions and Concerns About Its Measurement

Given the demonstrated relationship between cortical and pyramidal tract activity and muscle force production in primates, muscle weakness should be an expected result of lesions affecting corticomotoneuron cells, their projections, and their targets. Paresis from brain lesions can be classified as resulting primarily from reduced agonist output or from antagonist subtraction. Reduced-output paresis is a result of a decreased ability of the motoneuron pool to drive the motor units of a target agonist muscle. This reduced output has been documented in stroke patients during specified muscular efforts and during activities requiring patterns of muscular recruitment. Reduced output apparently affects the number and type of motor units recruited and the frequency of motor unit recruitment. Subtraction paresis results from resistive antagonist forces. In acknowledging the reality of subtraction paresis, it is important to note that 1) antagonist restraint can occur when the antagonist is electrically inactive (because of the passive stiffness of the antago-
The presence of subtraction paresis is probably one of the greatest concerns of those who recommend against strength testing hemiparetic patients. Bobath states that muscle weakness is not real but relative to opposition by spastic antagonists. The literature outlined in the paragraph above, however, does not indicate that antagonist restraint should be a major problem during static strength testing. Other concerns about strength testing patients with brain damage include issues relevant to the position of testing and issues relevant to muscular function during strength testing as compared with during other activities. In regard to position, the relative capacity of brain-damaged patients to activate their muscles in different positions may not be affected in the manner that therapists have come to believe. For example, Sjöström et al concluded that "placement of the legs within patterns believed to facilitate (0° knee position) or inhibit (90° knee position) extensor motoneurons did not give rise to systematic strength variations different from those of the control subjects." Bohannon similarly showed that patients with hemiparesis had comparable gravity-eliminated sitting-supine knee flexion torque ratios on the paretic and nonparetic sides.

Muscles no doubt function differently depending on the circumstances of their activation. For example, the quadriceps femoris muscles of a patient with hemiparesis may act quite differently when used to extend the knee of a seated subject than when used during a sit-to-stand maneuver. This fact notwithstanding, strength testing may still provide an indication of brain-damaged patients' capacity to activate a muscle group under a known set of circumstances.

**Support and Precedent for Muscle Strength Testing**

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**Description:**

- The text discusses the presence of subtraction paresis and its implications for strength testing in hemiparetic patients.
- It highlights concerns about antagonist restraint during static strength testing and the relative impact on muscular function.
- The text references various studies and investigators, including Bobath, Sjöström et al., and Bohannon, who have contributed to the understanding of muscle function in brain-damaged patients.
- It mentions the importance of strength testing during different activities and positions, and the necessity of considering the relative capacity of brain-damaged patients to activate their muscles in various circumstances.
- The text underscores the need for reliable and valid measures of strength during recovery and rehabilitation, emphasizing the importance of incorporating a variety of measurement tools.

**Relevance:**

- The passage is relevant to the evaluation and rehabilitation of patients with hemiparesis, particularly those who have experienced brain injuries.
- It supports the notion that muscle strength testing is essential for monitoring a rehabilitation program and for establishing an early prognosis.
- The text also touches on the clinical implications of the research, advocating for the use of strength testing as an adjunct to other clinical assessments.

**Conclusion:**

- The authors conclude that "structural and strengthwise weakness is a dominant factor in establishing an early prognosis.

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**References:**

1. Bobath states that muscle weakness is not real but relative to opposition by spastic antagonists.
2. The literature outlined in the paragraph above, however, does not indicate that antagonist restraint should be a major problem during static strength testing.
3. Other concerns about strength testing include issues relevant to both position and muscular function during strength testing as compared with other activities.
4. In regard to position, the relative capacity of brain-damaged patients to activate their muscles in different positions may not be affected in the manner that therapists have come to believe.
5. For example, Sjöström et al concluded that "placement of the legs within patterns believed to facilitate (0° knee position) or inhibit (90° knee position) extensor motoneurons did not give rise to systematic strength variations different from those of the control subjects."
6. Bohannon similarly showed that patients with hemiparesis had comparable gravity-eliminated sitting-supine knee flexion torque ratios on the paretic and nonparetic sides.
7. Muscles no doubt function differently depending on the circumstances of their activation. For example, the quadriceps femoris muscles of a patient with hemiparesis may act quite differently when used to extend the knee of a seated subject than when used during a sit-to-stand maneuver.
8. This fact notwithstanding, strength testing may still provide an indication of brain-damaged patients' capacity to activate a muscle group under a known set of circumstances.

**Additional Notes:**

- The text references various studies and investigators, including Bobath, Sjöström et al., and Bohannon, who have contributed to the understanding of muscle function in brain-damaged patients.
- The importance of considering the relative capacity of brain-damaged patients to activate their muscles in various circumstances is highlighted.
- The need for reliable and valid measures of strength during recovery and rehabilitation is emphasized.

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**Further Reading:**

- Bobath states that muscle weakness is not real but relative to opposition by spastic antagonists.
- The literature outlined in the paragraph above, however, does not indicate that antagonist restraint should be a major problem during static strength testing. Other concerns about strength testing include issues relevant to both position and muscular function during strength testing as compared with other activities. In regard to position, the relative capacity of brain-damaged patients to activate their muscles in different positions may not be affected in the manner that therapists have come to believe. For example, Sjöström et al concluded that "placement of the legs within patterns believed to facilitate (0° knee position) or inhibit (90° knee position) extensor motoneurons did not give rise to systematic strength variations different from those of the control subjects."
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as legitimate, I would note that measures such as pulse rate, blood pressure, body temperature, and body weight are of value despite their failure to explain underlying mechanisms. I find little cause either for rejecting a measure simply because it does not indicate underlying mechanisms or for complacently accepting a measurement as indicative of all that I want to know if it does not indicate such mechanisms.

**Relationship Between Muscle Strength and Patient Capacity and Outcome**

Beyond the precedent presented above, additional support exists for the measurement of muscle force-torque production (strength) in patients with intracranial lesions. This support is founded on the relationships demonstrated, in numerous studies, between strength and patient (present) capacity and (future) outcome. The purpose of this section is to present evidence that force measurements can be used to explain a portion of the variance in present and future status. I believe, as does Perry, that connective tissue flexibility, muscle strength, and selective neural control are all important to function.

Perhaps the most fundamental of findings related to muscle strength in brain-damaged patients is that measurements obtained at one point in time correlate with measurements obtained at a later time and with other motor indexes. This finding can be important when patients have questions such as, "Will I get my strength back?" Logigian et al found that final MMT scores were significantly correlated \((r = .78, p < .01)\) with initial MMT scores in 42 patients undergoing rehabilitation. Bohannon showed significant correlations \((r = .56–.83)\) between initial and final force measurements obtained by hand-held dynamometry from 16 muscle groups of 38 hemiparetic patients. Bohannon and Smith found similar relationships when upper extremity muscle strength deficits were compared between initial and final assessment in 58 stroke patients undergoing rehabilitation \((r = .73–.85)\).

Smedley et al, who measured upper extremity muscle strength using an ordinal scale, found it to be correlated \((p < .05)\) with both fine and gross motor coordination in 50 hemiparetic patients. Dohrmann and Nowack also found a significant relationship \((p < .005)\) between upper extremity weakness and decreased skill. They concluded that the relationship was logical "because a weak upper extremity cannot accomplish skilled movements." Sjöström et al reported the maximal plantar-flexion torque of the affected lower extremity to be significantly correlated with the extremity's Fugl-Meyer motor score \((r = .66, p < .05)\) in 19 subjects with hemiparesis. Bohannon found a correlation \((r)\) of .631 between knee flexion force and movement speed in the lower extremity of stroke patients. The variance in movement speed explained by the strength of four lower extremity muscle groups was 49.5%. Sheikh et al used a very gross four-level scale to document limb muscle function. They reported significant correlations \((p < .001)\) between activities-of-daily-living scores and upper limb function \((- .487)\) and lower limb function \((- .544)\). Logigian et al reported significant correlations \((r = .34)\) between MMT grades and scores on the Barthel Index (an ordinal scale rating 10 self-care and mobility activities). The MMT-Barthel Index correlations were significant on admission, on discharge, and across time. Wade and Hewer obtained similar findings. Their ordinal strength measurement scores for hemiparetic patients were correlated with the Barthel Index scores initially \((.749)\), at three weeks postinjury \((.774)\), and at six months postinjury \((.610)\). Feigenson et al described weakness in stroke patients as "mild," "moderate," or "severe." They found such weakness to be one of the strongest predictors of patient placement upon discharge; dressing, feeding, and hygiene performance; and bowel and bladder control.

Weakness was also related to length of hospital stay. Hamrin et al reported positive and sometimes significant \((8 \text{ of } 24)\) correlations between elbow flexion-extension torques and the performance of hygiene, dressing, and household activities. Fullerton et al studied the relationship between a host of predictor variables and mortality and functional outcome. "Arm power" and "leg power," which were measured on a five-level ordinal scale, were among the significant predictors of functional outcome \((p < .0001)\).

The performance of activities addressed directly by physical therapists has been correlated with measures of muscle strength. Primary among those activities is gait. Wade and Hewer found walking independence (ie, alone, with another person, unable) to be significantly correlated with ordinal measures of leg muscle strength \((r = -.860)\). Feigenson et al reported weakness to be a strong predictor of ambulation.

In addition to a study by Bohannon, at least four other studies have documented a relationship between quantitative measurements of muscle strength and gait performance. Hamrin et al reported that isokinetic torques of the paretic and nonparetic knees were correlated with locomotion. The correlations were higher on the paretic side \((r = .71–.90)\) than on the nonparetic side \((r = .38–.67)\). Hamrin et al claimed that the highly significant correlations support the validity of the isokinetic strength test in the patients. In a more recent study, Bohannon found significant \((p < .01)\) correlations between individual lower extremity paretic muscle group strength measurements and gait independence, distance, speed, and cadence \((r = .556–.840)\). The correlations were significant on initial assessment, final assessment, and across time. In an earlier study, Bohannon investigated nine variables as potential explanations for four gait performance variables. Although motor control and balance offered the best explanation of ambulatory capacity, normalized muscle strength of the paretic lower extremity was significantly correlated with gait velocity, cadence, appearance,
and independence ($r = .369–.511$). In 11 hemiparetic patients, Nakamura et al found knee extension torque (isokinetic torque at $30^\circ$, $90^\circ$, and $180^\circ$ sec and isometric torque at $90^\circ$ and $60^\circ$ of flexion) to be significantly correlated with walking speed ($r = .595–.847$) and cadence ($r = .609–.853$). They used stepwise regression to further analyze their data and found that isokinetic torque at $90^\circ$/sec explained 75.6% of the variance in gait speed and that isokinetic torque at $180^\circ$/sec explained 72.7% of the variance in gait cadence. In another study on patients with stroke, Nakamura found that “strength of the affected side was the primary determinant of walking speed and that the variance explained by it gradually increased with a period of training.”

Among the other factors of specific interest to physical therapists and to which muscle strength measures are related are transfer performance, standing performance, rolling independence, and shoulder pain and shoulder-hand syndrome. In a study by Bohannon, the relationships between various paretic muscle group strengths and transfer independence were all significant on initial assessment ($r_s = .468–.643$). The correlations on final assessment and across time, although positive, were rarely significant ($r_s = .304–.477$). The standing performance of 81 stroke patients was found by Bohannon to correlate significantly with the strength of six of seven muscle groups on both the paretic and nonparetic sides ($r_s = .255–.464$). In an unpublished follow-up study, Bohannon confirmed the existence of significant correlations on initial assessment, final assessment, and across time. Although Bohannon, in a different study, did not find that muscle strength of the paretic side consistently explained rolling independence, he did find that the muscle strength of the nonparetic side explained rolling independence ($r = .51–.75$). Chalsen et al concluded, from a study in which various potential causes of shoulder-hand syndrome were examined, that “weakness is a necessary but not sufficient cause for the development of shoulder-hand syndrome poststroke.”

**Conclusion**

Muscle strength is by no means a variable of such great importance that it can be justified as a sole indicator of status, change, capacity, or outcome in patients with brain lesions. Substantial precedents and evidence exist, nevertheless, to support the appropriateness of muscle strength testing in these patients. Before accepting the direction of those opposed to such testing, the clinician should consider the information presented in this communication. Because considerable variance in patient performance remains unexplained by muscle strength, the search should continue for even better targets of measurement and treatment.

**References**

Flexion torque with hip extension in hemiparetic


Bohannon RW: Relationship between static strength and various other measures in hemiparetic stroke patients. Int Rehabil Med 8:125-128, 1987


Bohannon RW: Strength of lower limb related to gait velocity and cadence in stroke patients. Physiotherapy Canada 38:204-206, 1986


Many therapists are taught during their schooling that it is inappropriate to use standard types of muscle testing during the evaluation of patients with central nervous system (CNS) lesions. One of the classic texts of manual muscle testing by Daniels and Worthingham even includes a warning about testing patients with CNS lesions. There appears to have been widespread agreement that, because of the nature of CNS lesions, standard approaches to muscle testing may yield measurements that are unreliable or invalid. Unfortunately, what many of us were taught appears to have been based more on opinions than on documented observations or research reports.

The time to question dogmatic approaches to the use of muscle testing of patients with CNS lesions is at hand. The works of Bohannon and our own research have now indicated that some forms of muscle testing of patients with CNS lesions yield reliably reliable measurements (see article by Riddle et al and commentary by Bohannon in this issue). Past arguments about the reliability of measurements obtained from these patients need to be reconsidered.

Perhaps one important lesson to be learned from the biases of the past is the need to test widely held beliefs and to obtain data. Often it is easy to make an argument as to why a measurement may not be reliable, but only through research can we determine the real degree of reliability. Some forms of muscle performance tests appear to be highly reliable for some types of patients with CNS lesions.

We must, however, be cautious and not replace old biases against testing with unfounded enthusiasm in favor of testing. Reliability is only one of two major requirements for meaningful measurements. Measurements must also be useful for something. Measurements must be valid and have inferential uses if they are to be clinically meaningful.

Bohannon rightly notes that some persons are opposed to muscle performance testing of patients with CNS lesions. We do not, however, consider ourselves in that category. We believe that what is needed is not a discussion of adversaries, but rather a critical examination of the theoretical and practical issues relating to muscle testing. Most importantly, we believe that the data justifying the usefulness of these measurements must be analyzed. The numerous citations put forth by Bohannon provide a good starting point for a meaningful discussion. Bohannon argues in the bulk of his special communication that muscle force measurements can be used to make inferences relating to function. These arguments are put forward under the heading "Relationship Between Muscle Strength and Patient Capacity and Outcome." To make our discussion easier to follow and to relate more directly to Bohannon's, we will follow his sequence in discussing the literature. We will discuss only those studies that were cited as providing research evidence for the use of muscle testing in patients with CNS lesions.

According to Bohannon, muscle performance measurements in brain-lesioned patients appear to correlate with measurements of functional capacity. The logic is clear: If the muscle performance measurement is related to function, then that measurement can be used to predict function. We have no argument with the logic, but we have questions about the literature cited. Correlation of muscle performance measurements with functional measurements can be made along a vast continuum. Clinical usefulness of measurements is dependent not on the existence of a relationship, but on the strength of the relationship. Linton and Gallo put it eloquently when they stated, "The delightful glow that researchers feel when their data turn out to be 'significant' often seems to impair their judgment on the meaning of their findings. When a statistical test indicates that the relationship between two variables is significant, it tells us only that, at a specified probability level, the relationship exists to some extent in the population from which the subjects have been randomly drawn and that it is not due to the operation of chance sampling factors. It cannot be stressed too strongly that a statistical test tells us no more. A relationship may be very weak and still quite real."8(p329)