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Research Article

Trunk Muscle Strength in Relation to Balance and Functional Disability in Unihemispheric Stroke Patients

ABSTRACT

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Objective: To evaluate trunk muscle strength in unihemispheric stroke patients and to assess how it relates to body balance and functional disability in this patient group.

Design: This prospective case-comparison study investigated isometric and isokinetic reciprocal trunk flexion and extension strength at angular velocities in 38 unihemispheric stroke patients and 40 healthy volunteers. The Berg balance scale was used to assess balance and stability, and the FIM™ instrument was used to evaluate functional disability in the patient group. Patients were evaluated as soon as they were able to stand long enough for testing.

Results: Peak torque values for trunk flexion and extension were lower in the stroke patients than in the controls. The differences were significant for trunk flexion and for trunk extension. In both groups, peak torque values for trunk flexors were greater than peak torque values for trunk extensors. There was a significant positive correlation between trunk muscle strength and Berg balance scale score at discharge. Trunk muscle strength was not correlated with FIM total score or FIM motor score, but the locomotion-transfers FIM subscore at discharge was positively correlated with trunk muscle torque values, except for isometric extension.

Conclusion: The findings indicate trunk flexion and extension muscle weakness in unihemispheric stroke patients, which can interfere with balance, stability, and functional disability.

Key Words: Stroke, Trunk Muscle Strength, Isokinetic Testing, Balance, Functional Disability

Trunk control and stability, coordination of movement patterns, and balance all involve complex pyramidal and extrapyramidal systems that are frequently disrupted by stroke.[1] Patients with stroke usually present with difficulty in maintaining balance, disorders of posture, head and trunk malalignment, and asymmetry of weight distribution at all stages after stroke.

Adequate balance is fundamental for performing most physical functions. Trunk control is required to maintain a body position, to remain stable when changing positions, to perform activities of daily living, and for mobility.[2] It was shown in previous studies that static balance is significantly correlated with length of hospital stay, locomotor function, and functional abilities after stroke.[3–9]

Biomechanically, specific trunk movements are necessary to maintain postural control, and the function of trunk muscles is an essential factor for balance, transfers, gait, and the range of activities in daily living. When weight is shifted in any plane, the trunk responds with a movement to counteract the change in the center of gravity.

Malfunction of limb muscles in stroke patients is well documented, but little is known about the effect of stroke relative to trunk muscle activity. Unlike limb muscles, the innervation of trunk muscles is supplied from both cerebral hemispheres.[10–13] Therefore, unilateral stroke could potentially deteriorate the function of trunk muscles on both the contralateral and ipsilateral sides of the body. Indeed, several recent studies have demonstrated weakness of trunk flexion and extension and bilateral rotatory muscles in unihemispheric stroke patients.[14–18] However the ways in which trunk muscle performance relate to balance and functional status have not been evaluated to date. The aim of this study was to compare the trunk muscle performance in unihemispheric stroke patients and healthy control subjects and to determine whether trunk muscle strength is linked to balance and functional disability in this patient group.

MATERIALS AND METHODS

The study included 38 patients who had experienced their first stroke and who were admitted for a comprehensive rehabilitation program at our unit. The definition of stroke was the one issued by the World Health Organization: a vascular lesion of the brain that results in rapidly developing clinical signs or focal or global loss of brain function that persists for at least 24 hrs. In all cases, the diagnosis was confirmed by neurologic examination and computed tomography or magnetic resonance imaging. The inclusion criteria for the study were as follows: unilateral supratentorial hemispheric lesion, ability to flex and extend the trunk without difficulty, and ability to understand and follow verbal instructions. Medically unstable patients; patients with a history of any neurologic disease; patients with psychiatric disorders, alcoholism, or vestibular and orthopedic disorders that could affect balance; and patients with a recent history of low back pain or disorders of the musculoskeletal system were excluded.

A total of 25 of the patients were men and 13 were women, mean age was 59.1 ± 10.2 yrs (range, 32–85 yrs), and mean body weight was 73.9 ± 14.9 kg. Disease duration was defined as the time from stroke onset to rehabilitation admission and ranged from 9 to 150 days (mean, 39.1 ± 37.3 days). A total of 29 patients had cerebral infarct, and nine had intracerebral hemorrhage located in the middle cerebral artery territory. There were 29 patients had right hemispheric stroke, and nine with left hemispheric stroke. Cortical lesions were noted in 16 patients, subcortical lesions in 14 patients, and cortical and subcortical lesions in the other eight patients.

The control group consisted of 40 healthy volunteers (24 males and 16 females). The control group had a mean age of 62.6 ± 9.2 yrs (range, 46–78 yrs) and a mean body weight of 72.9 ± 10.8 kg.

Testing of Trunk Muscle Strength. The Cybex 770 NORM Isokinetic Dynamometer (Lumex, Ronkonkoma, NY) was used to evaluate reciprocal concentric and isometric trunk flexion and extension muscle strength in the patient and control groups. Previous studies have demonstrated the reliability and accuracy of this dynamometer.[19–22] The TEF Modular Component attached to the NORM unit was used. The subject was positioned and secured in the TEF Modular Component in a vertical standing position according to the manufacturer's instructions. The axis of rotation was set at the point at which the midaxillary line intersects the lumbosacral junction, which was approximately 3.5 cm below the top of the iliac crest. The lower body was stabilized in a slightly bent-knee position (15 degrees of knee flexion) using tibial, popliteal, and thigh pads. The trunk was stabilized using pelvic, scapular, and chest pads. The vertical standing position was determined as the anatomic zero position. The range of motion was preset to 110 degrees, and range of motion stops were placed such that the range extended from 95 degrees of flexion to 15 degrees of extension.

Each patient and control subject underwent a single set of dynamometric evaluation. In the patient group, this was done as soon as the individual was able to stand long enough to complete the test protocol. The same physicians tested all subjects at the same time of the day. Reciprocal concentric trunk flexion and extension was assessed at angular velocities of 60, 90, and 120 degrees/sec. During each trial, five submaximal warm-up repetitions preceded each test velocity. A rest period of 15 secs was allowed between the warm-up repetitions and the actual test session. In each test procedure, the subject performed five maximal concentric contractions. Testing started with the trunk in the full extension position. Isometric flexion and extension measurements were done at 60 degrees of trunk flexion position during 10 secs of contraction. There was a 30-sec rest period between the recordings at each angular velocity. During the tests, subjects were allowed to view the Cybex NORM computer monitor and were verbally encouraged during the test session to exert maximal physical effort. Peak torque values (in foot-pounds) were included in the analysis.

Assessment of Balance and Functional Disability. Balance was evaluated with the Berg balance scale (BBS), a clinical test that assesses 14 common tasks.[23] The performance of each task is graded on a 5-point ordinal scale of 0–4, with 0 indicating inability to complete the task and higher scores reflecting better balance. Scoring is based on the patient's ability to meet specific time and distance requirements.

The BBS measures not only sitting balance, but also higher-level balance activities, such as standing on one leg and stepping. The test is easily administered and has been shown to have strong internal consistency and high interrater and intrarater reliability in patients with acute stroke.[24,25]

Functional disability was assessed using raw scores of the FIM™ instrument.[26] This instrument measures activities of daily living, including self-care, sphincter control, transfers, locomotion, communication, and social cognition, and is therefore more comprehensive than the BBS scoring. Consequently, in addition to assessing FIM total and FIM motor scores, we focused on specific subscores from selected domains of the FIM instrument. The FIM categories of locomotion and transfers are the ones that most closely reflect what the BBS measured. Therefore, we combined the scores in these two categories (five items total) to form the FIM–locomotion and transfers score. All FIM and BBS assessments were conducted within 72 hrs of admission and at the time of discharge.

Statistical Analysis. Descriptive statistics were used to calculate demographic and clinical characteristics of the patient and control groups. Pearson's product-moment correlation coefficients were calculated to assess the strength of the linear relationships between continuous data. An independent-samples t test was conducted to compare age, body weight, and isokinetic and isometric trunk muscle strengths in the two groups. Proportions were compared with the χ^2 test, and Fisher's exact test was used for small cell sizes. A paired-samples t test was used to compare trunk flexion and extension torque values in both groups. All statistical analyses were conducted using SPSS for Windows, version 9.0 (SPSS, Chicago, IL). P values of <0.05 were considered to indicate statistical significance.

RESULTS

The demographic and clinical characteristics of the patient and control groups are shown in Table 1.

TABLE 1
Clinical and demographic features of the patient and control groups

	Patient Group (n = 38)	Control Group (n = 40)		
Age, yrs	59.1 ± 10.2	62.1 ± 9.3	$t = -1.34$	$P = 0.18$
Body weight, kg	73.9 ± 14.9	72.9 ± 10.8	$t = -0.36$	$P = 0.72$
Sex, male/female	25/13	24/16	$\chi^2 = 0.28$	$P = 0.6$
Side of hemiparesis, left/right	29/9	—		
Hemorrhage/infarction	9/29	—		
Disease duration, days	39.1 ± 37.3	—		
LOS, days	49.9 ± 23.9	—		
FIM™ admission, total	78.4 ± 21.4	—		
FIM discharge, total	102.4 ± 15.7	—		
FIM motor, admission	45.8 ± 19.2	—		
FIM motor, discharge	68.3 ± 15.6	—		
FIM-LT, admission	13.2 ± 7.5	—		
FIM-LT, discharge	25.9 ± 5.6	—		
BBS, admission	17.1 ± 13	—		
BBS, discharge	37.1 ± 11.4	—		

LOS, length of hospital stay; FIM-LT, locomotion/transfers FIM subscore; BBS, Berg balance scale.
Data are provided as mean ± standard deviation unless otherwise noted.

TABLE 2

Isometric and concentric isokinetic peak torque values (in foot-pounds)

	Patient Group (n = 38)	Control Group (n = 40)	Independent-Sample t Test, P Value
Isometric flexion	58.97 ± 28	63.4 ± 33.8	0.53
Isometric extension	48.4 ± 26	54.8 ± 38.1	0.39
Paired-sample t test, P value	0.009	0.003	
60 degrees/sec of flexion	30.1 ± 29.7	41.8 ± 26.9	0.04
60 degrees/sec of extension	21.5 ± 18.9	29.9 ± 14.4	0.03
Paired-sample t test, P value	0.006	0.001	
90 degrees/sec of flexion	19.6 ± 24.6	32.6 ± 22.9	0.02
90 degrees/sec of extension	14.1 ± 15.2	22.6 ± 14.4	0.01
Paired-sample t test, P value	0.079	0.000	
120 degrees/sec of flexion	12.1 ± 14.2	24.2 ± 19.9	0.00
120 degrees/sec of extension	9.3 ± 10.6	13.1 ± 10.1	0.11
Paired-sample t test, P value	0.205	0.000	

Data are provided as mean ± standard deviation unless otherwise noted.

There were no significant differences between the two groups with respect to mean age, body weight, and sex distribution.

Table 2 lists the isometric and concentric isokinetic peak torque values for the two groups. The peak trunk flexor torque values at angular velocities of 60, 90, and 120 degrees/sec and peak trunk extensor torque values at angular velocities of 60 and 90 degrees/sec in the patient group were significantly smaller than the corresponding values in the control group ($P < 0.05$). The peak torque values for isometric trunk flexion and extension and for trunk extension at 120 degrees/sec angular velocity in the patient group were also lower than the corresponding values in the control group, but these differences were not statistically significant. In both groups, the concentric isokinetic trunk muscle torque values decreased with increasing angular velocity (Figs. 1 and 2).

In the control group, isometric and concentric isokinetic torque values for trunk flexors were significantly higher than trunk extensors at all three angular velocities (Table 2). The flexor torque values were also higher than the extensor torque values in the patient group, but the difference at angular velocities of 90 and 120 degrees/sec were not statistically significant.

The relationships between trunk flexor and extensor torque values and FIM and BBS scores in the patient group are presented in Table 3. With the exception of the flexion torque value at an angular velocity of 120 degrees/sec and the torque value at isometric extension, the trunk muscle flexion and extension torques at all angular velocities tested showed moderate to strong positive correlations with BBS score at discharge. Admission BBS scores were positively correlated only with extension torque values at angular velocities of 60 and 90 degrees/sec.

Regarding relationships with FIM total scores at admission and discharge, the only significant findings were the weak positive correlations between flexion and extension trunk muscle torques at an angular velocity of 60 degrees/sec and FIM total score at admission. The flexor and extensor torque values at an angular velocity of 60 degrees/sec were also correlated withthe FIM motor scores at admission and discharge. Concerning relation-

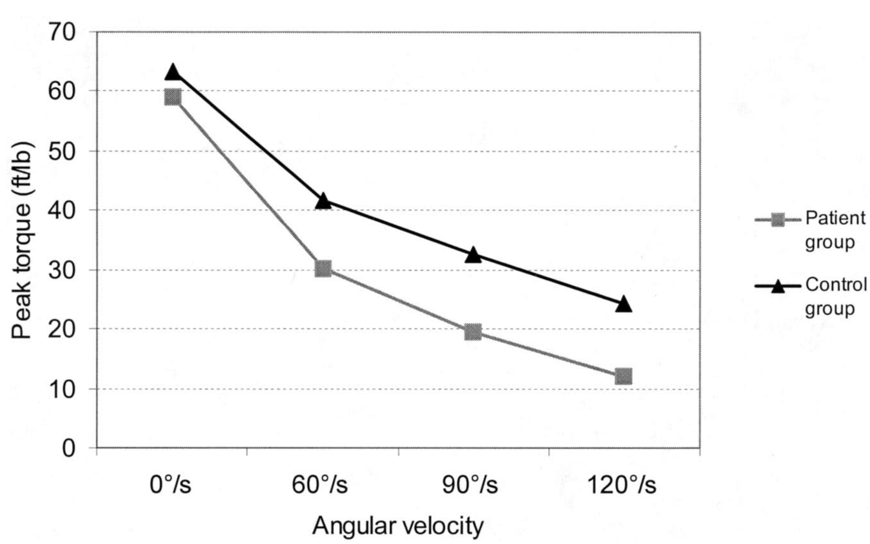

Figure 1: Changes in trunk flexor peak torque values with increasing angular velocity in both groups.

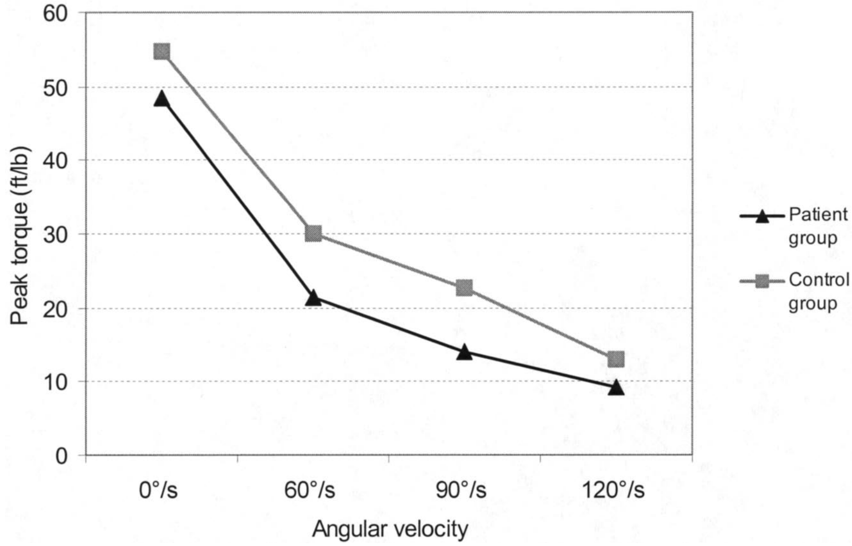

Figure 2: Change in trunk extensor peak torque values with increasing angular velocity in patient and control groups.

ships with FIM–locomotion and transfers, all the flexor and extensor torques at all angular velocities were moderately correlated with discharge FIM–locomotion and transfers score, except for isometric and 120-degrees/sec isokinetic trunk extension.

DISCUSSION

Balance is a complex process that requires interactions between the vestibular, visual, proprioceptive, musculoskeletal, and cognitive systems. It is described as the ability to maintain equilibrium in a gravitational field by keeping or returning the center of body mass over its base of support. Balance is also defined as the ability to react to destabilizing forces quickly and efficiently so as to regain stability via postural adjustments before, during, and after voluntary movement and in response to external perturbation. Changes in the center of mass or support base due to self-initiated or environmental disturbances require the coordinated activity of ankle, knee, hip, and trunk muscles to restore force equilibrium and to preserve balance.

The ability to maintain balance while sitting and standing is necessary for functional activities such as transferring, reaching, and walking. In fact, previous studies have demonstrated that balance ability is closely related to functional status; therefore, postural stability is considered as a prognostic clinical tool for functional recovery in stroke patients.[3–9,27] Stroke commonly disrupts the automatic postural responses that contribute to sitting balance and standing balance. Both trunk and limb muscles are involved in the coordination and regulation of automatic postural responses. Malfunction of limb muscles in stroke patients has been extensively documented, but the literature contains little information on trunk muscle activity.

It has been demonstrated that the innervation of trunk muscles is basically supplied from both cerebral hemispheres.[10–13] As a result of this bilateral innervation, patients with unihemispheric stroke show less impairment of trunk muscle function than limb muscle function on the ipsilateral side. Evaluation of muscle performance in stroke patients is complicated by a wide variety of factors, such as spasticity and incoordination; however, at our unit, we have rarely observed obvious trunk muscular weakness in a hemiplegic pa-

TABLE 3
Pearson's product-moment correlation coefficients for relationships between trunk flexor and extensor torque values and FIM^{TM} and Berg balance scale scores (BBS) in the patient group

	FIM Total		FIM Motor		FIM-LT		BBS	
	Admission	Discharge	Admission	Discharge	Admission	Discharge	Admission	Discharge
60 degrees/sec of flexion	0.37[a]	0.34	0.41[a]	0.36[a]	0.39[a]	0.41[a]	0.30[a]	0.42[a]
90 degrees/sec of flexion	0.24	0.32	0.23	0.30	0.24	0.35[a]	0.23	0.32[a]
120 degrees/sec of flexion	0.18	0.31	0.18	0.30	0.19	0.36[a]	0.20	0.39[a]
60 degrees/sec of extension	0.40[a]	0.28	0.51[a]	0.38[a]	0.50[a]	0.42[a]	0.52[a]	0.64[a]
90 degrees/sec of extension	0.26	0.21	0.34[a]	0.29	0.36[a]	0.33[a]	0.5[a]	0.62[a]
120 degrees/sec of extension	0.10	0.14	0.20	0.25	0.25	0.26	0.31	0.51[a]
Isometric flexion	0.21	0.26	0.28	0.31	0.23	0.41[a]	0.21	0.37[a]
Isometric extension	0.15	0.19	0.14	0.18	0.01	0.19	0.10	0.14

FIM-LT, FIM locomotion and transfers.
[a]$P < 0.05$.

tient in the chronic stage. Some patients with unihemispheric stroke may have trunk muscle weakness that is not detectable by physical examination alone. Indeed, in previous studies using isokinetic dynamometry, Tanaka et al.[14,15] showed that hemiplegic patients had poorer reciprocal trunk flexor, extensor, and rotatory muscle strength than healthy controls. The authors concluded that such weakness may be overlooked when manual muscle testing is used and can be detected only with instrument testing. In the studies by Dickstein et al.,[28,29] electromyographic analysis demonstrated that temporal synchronization between bilateral erector spine muscles during trunk extension was poorer in hemiplegic patients than in healthy controls. The results also revealed better synchronized activity during symmetric trunk flexion than symmetric trunk extension and wide variability in the activation pattern of the bilateral erector spine muscles in the hemiplegic group. Other important findings from the same studies were relatively low synchronization between the activities of extensor muscles on the unaffected side and lack of evidence for extensor muscle malfunction on the paretic compared with nonparetic side.

Our results are largely consistent with those of previous reports. Compared with control findings, we recorded lower isokinetic peak torque values for trunk flexors and extensors in our unihemispheric stroke patients. Although the isometric trunk flexion and extension torque values were also lower in the patient group, this weakness was not as pronounced as isokinetic trunk muscle torques and was not statistically significant. In both the control and patient groups, the peak torque values decreased as angular velocity increased. The difference in trunk flexion strength between the patient and control groups for trunk flexion was more marked at higher angular velocities.

There are several possible explanations for trunk muscle weakness in hemiplegic patients. As mentioned above, because the nerve supply to the trunk muscles comes from the motor cortex of both hemispheres, an upper motor lesion may cause slight bilateral trunk weakness that is not as severe as the resultant limb weakness. Insufficient recruitment of high-threshold motor units is another possible explanation for poor muscle contraction, especially at high angular velocities. Trunk muscle weakness caused by disuse may be relevant to previous investigations. In other reports in the literature, trunk strength evaluations were conducted a long time after stroke rehabilitation was completed.[14,15] In the report by Tanaka et al.,[15] the average interval between the onset of stroke and strength testing was 27.2 mos. In contrast, the corresponding interval in our investigation was 39 days, and we conducted the isokinetic evaluations during rehabilitation. Although weakness can occur quickly after immobilization and disuse-related weakness might be a factor in the patients studied, we believe that in our study group, this was not as prominent as in other studies.

To our knowledge, this is the first study that investigated the relationships between trunk muscle strength, balance, and functional disability in patients with unihemispheric stroke. The results indicate that trunk muscle torque is positively correlated with balance score at discharge. This highlights the importance of trunk muscle strength in postural stability. Considering the predictive value of balance on functional outcome in stroke patients, it is reasonable to speculate that trunk muscle strength might be related to functional disability. However, we found no clear relationships between trunk muscle strength and FIM total score or FIM motor score in our series. This may be because of the structure of FIM instrument.[26] This multi-item scale is divided into six areas of ability, namely, communication, social cognition, sphincter control, self-care, transfers, and locomotion. The latter two categories are the ones most closely related to what is measured in the BBS. When we focused on these elements, analysis did reveal a moderate positive correlation between the locomotion-transfers subscores of the FIM instrument and trunk muscle strength in stroke patients.

Even mild weakening of trunk muscles in unihemispheric stroke patients can interfere with balance, stability, and functional disability. Although manual trunk muscle testing may reveal nothing abnormal in such cases, it must be kept in mind that most of these individuals have mild trunk muscle weakness. If possible, dynamometric trunk muscle strength measurements should be done to investigate more thoroughly for trunk muscle weakness, and a trunk muscle strengthening program should be included as part of the rehabilitation program. Reestablishing trunk muscle function may improve stability, and make easier the reeducation of limb muscles and help the patient better manage daily living activities. Dynamometric systems can also be used as exercise tools for trunk muscle strengthening programs at different angular velocities in stroke patients.

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