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Effect of shoulder girdle strengthening on trunk alignment in patients with stroke

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Abstract. [Purpose] This study investigated the effect of shoulder girdle strengthening, particularly the scapular muscles, on poststroke trunk alignment. [Subjects and Methods] The study involved 30 patients with residual hemiparesis following cerebrovascular stroke. Patient assessment included measuring shoulder muscle peak torque, scapular muscles peak force, spinal lateral deviation angle, and motor functional performance. Patients were randomly allocated either to the control group or the study group and received an 18-session strengthening program including active resisted exercises for shoulder abductors and external rotators in addition to trunk control exercises. The study group received additional strengthening exercises for the scapular muscles. [Results] The two groups showed significant improvement in strength of all shoulder and scapular muscles, with higher improvement in the study group. Similarly, the lateral spinal deviation angles significantly improved in both groups, with significantly higher improvement in the study group. Transfer activity, sitting balance, upper limb functions, and hand movements significantly improved in the two groups, with higher improvement in the latter two functions in the study group. [Conclusion] Strengthening of shoulder girdle muscles, particularly scapular muscles, can significantly contribute to improving the postural alignment of the trunk in patients with poststroke hemiparesis.
Key words: Stroke, Scapular muscles strengthening, Lateral trunk alignment

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INTRODUCTION

Cerebrovascular stroke (CVS) is a neurologic event related to diseases of the cerebral circulation. CVS has been shown to be a major cause of death and disability in all communities. According to the American Stroke Association, about 87% of strokes are ischemic, and the remaining 13% are hemorrhagic[1, 2)]. Stroke survivors can suffer some neurological impairments, such as hemiparesis, communication disorders, cognitive deficits, or disorders in visuospatial perception[3, 4)].

Hemiparesis of the upper limb is conceivably the most serious impairment and most in need of rehabilitation. Population-based studies indicated that 73–88% of first-time strokes result in an acute hemiparesis of the upper and/or lower limbs[5, 6)]. The impact of upper limb impairments on disability and health is very obvious[7, 8)]. However, limited attention has been given to upper-extremity rehabilitation after stroke, and generally functional recovery of the upper limb and hand is limited compared with that of lower extremities[9, 10)]. A scapular stabilization exercise program performed over a 4-week period resulted in improvement of upper limb function in an group of 11 chronic hemiparetic patients[11)]. Even in patients with acute stroke, passive range of motion exercises can improve the function of upper extremities[12)].

Hemiparetic patients have an altered postural alignment in standing compared with subjects without neurological deficits[13)]. Postural alignment is defined as the relationship of body parts to the line of the center of gravity (COG). Maintaining postural stability is a complex process that is an essential prerequisite for the advanced stages of motor control including; controlled mobility and skilled activity[14)]. Structures in the brainstem, the red nucleus, pontine and medullary reticular formations, vestibular nuclei, and superior colliculus, are responsible for the control of posture and spatial orientation[15)].

Applications of constraint-induced movement therapy (CIMT) for upper-extremity recovery are promising in chronic and acute stroke[16, 17)], and is less promising in subacute stroke[18)]. Other studies showed that repetitive training of isolated movements against resistance for 15 minutes twice a day for 4 weeks improved the motor function of paretic hands in subacute stroke[19)]. A systematic review with meta-analysis of randomized trials of strengthening interventions in stroke patients concluded that strengthening interventions increase strength, improve activity, and do not increase spasticity[20)].

The purpose of this study was to investigate the effect of strengthening exercises for shoulder girdle muscles, particularly the scapular muscles, on lateral trunk deviation in both static positions and functional activities in hemiparetic

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patients after stroke.

SUBJECTS AND METHODS

This study was conducted in the outpatient clinic of the Faculty of Physical Therapy, Cairo University, between December 2010 and January 2012. The study included 30 patients with cerebrovascular stroke, either ischemic or hemorrhagic, based on a clinical assessment, CT scan, and/or MRI. The study was approved by the Ethical Review Board of the Faculty. All patients provided a written informed consent prior to participation in the study.

Clinical evaluation of the patients included neurological, musculoskeletal, and perceptual assessments using the line cancellation test. Shoulder stability was examined by palpating the space between the acromion process and humeral head. In addition, shoulder pain was assessed using the Numeric Rating Scale.

The study included pain-free hemiparetic patients with scapular asymmetry, dropped shoulder, and spinal lateral deviation towards the affected side in a sitting position. The inclusion criteria were age 45–60 years, disease duration 6–12 months, good sitting balance, and good voluntary motor control of at least stage 4 according to Brunnstrom's scale. The exclusion criteria included balance disturbance due to other causes, stroke with unilateral neglect, sensory manifestations, uncorrected visual impairment, spinal deformities, and orthopedic disorders of the lower limbs or back. Participants were randomly divided into two equal groups, a study group and control group.

All participants were subjected to the following twice; before and after treatment:

1. Shoulder girdle muscle strength: An isokinetic dynamometer (Biodex System 3, Biodex Medical Systems, Shirley, NY, USA) was used to assess the peak torque of shoulder abductors and external rotators. During the test, the patient sat in the Biodex system's chair. For each muscle group, three trials were recorded with five seconds of rest in between them. No verbal encouragement or other reinforcement was given to any patient during the actual test.

2. Scapular muscle peak force measurements: A handheld dynamometer (HHD) (Lafeyette Manual Muscle Test System, Model number 01163, Lafayette Instrument Company, Lafayette IN, USA) was used to measure the isometric peak force (kg) of the supraspinatus, upper trapezius, and serratus anterior muscles. Three trials were performed for each muscle with a rest period of 15–20 seconds so that declines in strength across trials, due to fatigue, could be avoided. The supraspinatus and upper trapezius muscle peak forces were recorded from a sitting position on a stool with the hips and knees at 90° flexion and the feet supported. The serratus anterior muscle peak force was tested from a supine lying position.

3. Two-dimensional (2D) postural assessment with the CorelDraw software: The patient was asked to expose his/her chest, upper limbs, and posterior superior iliac spines. The scapular bony landmarks, that is, the superior angle, inferior angle, and lateral scapular angle, were all palpated and marked. The lateral scapular angle was marked at a 5 cm distance from the acromion. The spinous processes of C7, the corresponding thoracic vertebrae to the scapular bony landmarks, and the posterior superior iliac spines (PSISs) were marked. The C7 spinous process, inferior scapular angles, and the two PSISs points were the main bony landmarks corresponding to the scapular and spinal angles.

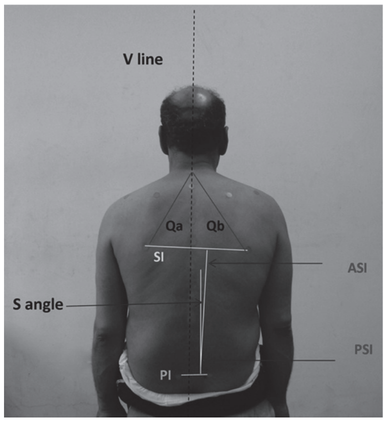

Fig. 1. Measurement of the scapular and spinal angles
The Qa angle represents the scapular upward rotation angle on the affected side, while the Qb angle represents that on the non-affected side. The SI is a line passing through the two inferior scapular angles, while the PI is a line passing through the two PSISs. The ASI is a line drawn perpendicular to the SI line, while the API is a line drawn perpendicular to the PI line. The angle of intersection of the two perpendicular lines, the ASI and API, represents the spinal lateral deviation angle (S angle).

4. Capturing the patient spine: Digital photographs of the patient spine and both scapulae were taken in the frontal plane in a sitting position with one digital video camera (DSC-W110, Sony Corporation, Tokyo Japan).

5. Image analysis and angles calculation: The scapular and spinal angles were calculated using computerized photogrammetry with the CorelDraw Graphics Suite (X5) software (Fig. 1). The scapular resting upward rotation angle is the angle between two lines, that is, the line connecting the C7 spinous process and inferior angles and the vertical (V) line passing through C7. The Qa angle represents the scapular upward rotation angle on the affected side, while the Qb angle represents that on the the non-affected side. The lateral spinal deviation angle lies between two lines, that is, a line passing through the two inferior scapular angles (SI) and a line passing through the two PSISs (PI). After defining the SI and PI lines, a perpendicular line (ASI) was drawn to the SI, and another perpendicular line (API) was drawn to the PI. The angle of intersection of the two perpendicular lines, ASI and API, represents the spinal angle (S angle). The direction of the angle represents the direction of spinal lateral deviation.

A selective six-week strengthening exercise program was applied for the shoulder girdle muscles (shoulder abductors and external rotators) to the two groups. The patients received 3 sessions weekly (a total of 18 therapeutic sessions). They received preparatory stretching exercises for the pectoralis major, latissimus dorsi, rhomboids major and minor, and teres major muscles prior to starting the strengthening

Table 1. General characteristics of patients in both the control and study groups

	Control group n = 10	Study group n = 13
Age (yrs)	52.2±5.2	53.6±3.2
Weight (kg)	79.9±5.9	80.7±5.7
Height (cm)	165.7±6.7	166.6±4.9
Duration of illness (months)	8.8±2.3	8.1±2.0
Hemiparetic side (Rt/Lt)	3/7	2/11
Gender (M/F)	9/1	12/1

Table 2. Shoulder abductor and external rotator peak torques in the two studied groups before and after treatment

	Control group n = 10	Study group n = 13
Shoulder abduction peak torque (N·m)		
Before treatment	23.4±9.9	23.9±8.7
After treatment	25.1±9.3†	33.7±7.9†
% Change, median (range)	10.3% (2.0–17.1%)	32.5% (15.7–50.5%)*
Shoulder external rot. peak torque (N·m)		
Before treatment	9.7±4.8	9.4±4.8
After treatment	11.7±5.1†	16.9±6.3†
% Change, median (range)	18.3% (4.5–29.7%)	48.7% (24.9–61.2%)*

N·m: newton meters
*Significant difference between groups; †Significant difference within group

Table 3. Supraspinatus, upper trapezius, and serratus anterior muscle peak forces in the two studied groups before and after treatment

	Control group n = 10	Study group n = 13
Supraspinatus peak force (N)		
Before treatment	1.3±0.5	1.4±0.5
After treatment	1.5±0.4†	2.2±0.5†*
% Change, median (range)	10.8% (4.3–45.5%)	33.3% (18.5–61.1%)*
Upper trapezius peak force (N)		
Before treatment	2.3±0.4	2.3±0.5
After treatment	2.6±0.4†	3.4±0.6†*
% Change, median (range)	9.6% (3.6–21.7%)	28.9% (12.5–64.3%)*
Serratus anterior peak force (N)		
Before treatment	2.4±0.7	2.3±0.7
After treatment	2.5±0.6†	3.1±0.6†*
% Change, median (range)	7.0% (2.9–28.6%)	25.7% (10.5–45.0%)*

N: newtons
*Significant difference between groups; †Significant difference within group

exercises. In addition, trunk control exercises, that is, active flexion, side bending, and rotation in a sitting position, were applied. The study group received additional strengthening exercises focusing on the scapular muscles, that is, the supraspinatus, serratus anterior, and upper trapezius muscles.

The data for shoulder muscle strength, scapular muscle strength, scapular and spinal angles, and the score of Motor Assessment Scale (MAS) for stroke patients were collected before and after treatment. All statistical analyses were performed using the IBM SPSS Statistics version 20. Numerical data were expressed as means and standard deviations or medians and ranges as appropriate. Qualitative data were expressed as frequencies and percentages. The χ^2 test (Fisher's exact test) was used to examine the relation between qualitative variables. For quantitative data, comparison between two groups was done using the independent Mann-Whitney test. Comparison of repeated measures was done using the Wilcoxon signed-rank test. The Spearman rho method was used to test correlation between numerical variables. A p-value < 0.05 was considered significant.

RESULTS

The study primarily involved 30 patients. Seven patients did not complete the study due to personal circumstances (4 patients), health problems (2 patients), or loss during follow-up (1 patient). Results are presented for 23 patients (10 in the control group and 13 in the study group). Demographic and clinical characteristics of the two groups are presented in Table 1. The two groups were comparable in all characteristics.

Table 2 shows the peak torque values of shoulder abductors and external rotators in the two groups before and after the strengthening exercise program. Before treatment, there was no significant difference between the two groups in shoulder abduction and shoulder external rotation peak torque. After treatment, both muscles showed significantly higher peak torque in the study group compared with the control group. The two muscles showed significant improvement in strength after the exercise programs in the two groups. However, the percentage of improvement was significantly higher in the study group.

Table 3 shows the peak force values for the supraspinatus, upper trapezius, and serratus anterior muscles in the two groups before and after the strengthening exercise program. Before treatment, there was no significant difference between the two groups in supraspinatus, upper trapezius, and serratus anterior peak force. After treatment, the three muscles showed significantly higher peak forces in the study group compared with the control group. The three muscles showed significant improvement in strength after the exercise programs in the two groups. However, the percentage of improvement was significantly higher in the study group.

Table 4 shows the scapular upward rotation angle and spinal lateral deviation angle in the two groups before and after the strengthening exercise program. Before treatment, there was no significant difference between the two groups in the scapular upward rotation and spinal lateral deviation angles. After treatment, the scapular upward rotation angle

Table 4. Scapular upward rotation angle and spinal lateral deviation angle in the two studied groups before and after treatment

	Control group n = 10	Study group n = 13
Scapular upward rotation angle (degrees)		
Before treatment	31.3±4.2	30.4±3.0
After treatment	33.3±3.8†	36.6±2.4†*
% Change, median (range)	6.1% (0.6–10.2%)	15.9% (4.6–27.4%)*
Spinal lateral deviation angle (degrees)		
Before treatment	7.3±2.2	7.7±2.1
After treatment	5.5±2.3†	3.8±1.8†
% Change, median (range)	27.3% (12.6–41.2%)	51.8% (24.7–78.7%)*

*Significant difference between groups; †Significant difference within group

Table 5. Correlation between the peak forces of the three scapular muscles and the scapular upward rotation angle and lateral spinal deviation angle

	Scapular upward rotation angle	Spinal lateral deviation angle
Pretreatment peak force		
Supraspinatus	0.457*	−0.638*
Upper trapezius	0.224	−0.361
Serratus anterior	0.462*	−0.671*
Posttreatment peak force		
Supraspinatus	0.797*	−0.592*
Upper trapezius	0.713*	−0.855*
Serratus anterior	0.634*	−0.862*

Values are presented as correlation coefficients (r). *Significant correlation

was significantly larger in the study group compared with the control group. After treatment, the spinal lateral deviation angle was significantly smaller in the study group compared with the control group. The two angles showed significant changes after the exercise programs in the two groups. However, the percentage of change was significantly higher in the study group.

The peak force of the three scapular muscles showed a strong positive correlation with the scapular upward rotation angle and strong negative correlation with the spinal lateral deviation angle, especially after treatment (Table 5). The two angles showed significant negative correlation before treatment ($r = -0.422$, $p = 0.045$) and after treatment ($r = -0.619$, $p = 0.002$).

DISCUSSION

This study demonstrated beneficial effects of a six-week strengthening exercise program for the shoulder girdle muscles and scapular muscles in hemiparetic patients on the strength of these muscles and the spinal lateral deviation angle. Strengthening of the scapular muscles resulted in a significantly higher effect in these two aspects. There was a strong positive correlation between the peak force of the three scapular muscles with the scapular upward rotation angle and strong negative correlation with the spinal lateral deviation angle.

Scapular muscle strengthening was associated with a significant increase in the scapular upward rotation angle and significant decrease in the spinal lateral deviation angle. The two angles were positively affected by strengthening of the shoulder girdle muscles, but the effect was more pronounced after scapular muscle strengthening. In fact, the peak torque values of the shoulder abductors and external rotators were higher after scapular muscle strengthening. This effect can be explained by the normal synergist coactivation reported between shoulder girdle muscles working at the glenohumeral and scapulothoracic levels in addition to the neurophysiologic effect of resisted exercises[21)]. Improvement of the strength of the scapular muscles in the control group despite the lack of training can also be explained by the synergist coactivation between different shoulder muscles.

The resting scapular upward rotation angle was specifically measured in the present study, as it reflects the strength of the three studied scapular muscles, the trapezius, serratus anterior, and supraspinatus. These muscles work together to maintain the scapula’s elevation and upward rotation orientation. We also measured the scapular and spinal angles in the sitting position to eliminate the effect of unequal weight shifting on the lower limbs so that we could concentrate on the effect of the shoulder girdle muscles[22)].

Based on previous studies[19, 23–25)], we planned the training dose to be 1 h/d, 3 d/wk for 6 weeks (18 h). Previous authors recommended 4–6 weeks as an optimum duration of strengthening exercises to be effective in stroke patients. We extended to the maximum of six weeks, as the extent of strength gain was positively correlated with the intensity and the number of exercising units[24)].

Based on the study of Mottram[26)], the current study considered manual resisted exercises rather than any other types of strengthening interventions. These exercises primarily reeducate the stability and control around the scapula to improve postural alignment. Folland and Williams[27)] and Falvo et al.[28)] found that resisted exercises may enhance the recruitment, firing rate, and synchrony at the level of the motor neuron by enhancing neural adaptation.

The shoulder muscles selected to be strengthened in the current study were abductors and external rotators, as shoulder external rotation is more important than internal rotation in providing stability to the shoulder joint[26)].

External rotators gained the highest improvement in the two groups. This can be explained by synergist coactivation of these muscles during scapular muscle strengthening. Escamellia et al.[29)] reported that shoulder abductors and external rotators showed increased firing activity during serratus anterior muscle strengthening with a forward pushing exercise.

The significant improvement in the resting scapular upward rotation angle in the two groups in this study can be attributed to the relation between scapulothoracic stability and trapezius-serratus anterior force coupling[30]. Shoulder stability exercise can improve range of motion, muscle strength, and grasping power of the upper limb[31]. Improvement of scapular muscle strength can also influence postural stability of the shoulder girdle and the proximal trunk[32].

In a group of normal young males, Alizadeh et al.[33] tested the effect of a progressive exercise program including resistive strengthening, stretching, and postural exercises on the position of the scapula. They reported improvement of the scapular position by 70% with their exercise program. This improvement was correlated with improved strength of the scapular elevators, mainly the trapezius muscle. The primary result of the present study was the significant improvement of the spinal alignment in the two groups with better improvement after scapular muscle strengthening. The spinal lateral deviation angle showed strong negative correlation with the peak force of the three scapular muscles. To our knowledge, this study seems to be the first to consider the influence of shoulder muscle strengthening on spinal alignment in patients with stroke. Gomes et al.[34] published a case study that supports the effect of shoulder girdle posture on spinal alignment in patients with stroke. They reported mild improvement of scapular position and spinal lateral deviation after global postural reeducation (GPR) exercises for scapular and pelvis girdle muscles, and they attributed the improvement in spinal alignment to the effect of the GPR technique in providing better scapular and pelvic alignment. Mottram[26] and Williams et al.[35] found that scapulothoracic joint stability provided mainly by trapezius-serratus anterior coupling had an important contribution to the core stability of the trunk. In addition, the rotator cuff group could have an influence on scapular alignment and therefore core stability, although it does not have direct attachments to the spinal column or rib cage[29]. In conclusion, this can be considered a pilot study on the effect of shoulder and scapular muscle strength on postural alignment in stroke patients. The study provided preliminary evidence that manual resisted exercises for shoulder muscles (external rotators and abductors) and scapular muscles (serratus anterior, trapezius, and supraspinatus) significantly reduced lateral spinal deviation angle in the sitting position. In addition, these exercises rectified the position of the scapula on the affected side.

The limitations of this study can be summarized as the relatively small sample size, which limits generalization of the study's results. In addition, inclusion of only patients above 45 years old did not allow evaluation of the physiotherapy program for younger patients who are involved in higher grades of activity and need gait correction.

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