EFFECT OF SHOULDER GIRDLE STRENGTHENING ON TRUNK ALIGNMENT IN PATIENTS WITH STROKE

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ABSTRACT

Background: postural malalignment is a common problem in patients with stroke. Although it is known that trunk control is an integral part of shoulder stability, shoulder girdle contribution in spinal malalignment is poorly studied post-stroke. Purpose: to investigate the effect of shoulder girdle strengthening on the trunk alignment in both static position and functional activities post- stroke. Subjects: 23 hemiparetic patients, with a mean age of (52.22±5.19) were divided into two groups; the control (G1; 10) group and the study (G2; 13) group. Both groups received preparatory stretching for shoulder muscles, active resisted exercises for shoulder abductors and external rotator groups, and trunk control exercises. The G2 group received additional strengthening exercises for the scapular muscles; supraspinatus, upper trapezius, and serratus anterior muscles. Methods: the muscle peak torque and peak force were measured using the isokinetic dynamometer and Lafayette manual muscle tester, respectively. The spinal lateral deviation angle was measured using the 2D photogrammetry in conjunction with the Corel Draw software. The motor functional performance was also measured using the Motor Assessment Scale (MAS) before and after the successive six weeks of treatment program. Results: All tested muscles showed significant improvement in both groups, however, G2 showed higher improvement
comparing to G1. In addition, the lateral spinal deviation angle showed a significant improvement in G1 (25.13%) and G2 (50.76 %) groups with higher improvement in G2 (t= 2.29, p=0.03). The MAS scoring showed a highly significant improvement regarding the transfer activity and sitting balance for G1 and G2 (generally, p= 0.005, p<0.0001, respectively). However, only group G2 showed a significant improvement in the upper limb functions and the hand movements, respectively (p<0.0001, 0.0002).

**Conclusion:** the shoulder girdle muscles strength, particularly the scapular muscles, is of great contribution in improving the postural alignment of the trunk in patients with stroke.

**Key words:** Shoulder girdle, Muscles strength, Trunk alignment, Stroke.
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<tr>
<td>AC</td>
<td>The Acromio-clavicular joint</td>
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<tr>
<td>ADL</td>
<td>Activity of Daily Living</td>
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<td>APAs</td>
<td>Anticipatory Postural Adjustments</td>
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<tr>
<td>API Line</td>
<td>A perpendicular line drawn to the line passing between the two posterior superior iliac spines (PI line).</td>
</tr>
<tr>
<td>ASI Line</td>
<td>A perpendicular line drawn to the line passing between the two scapular inferior angles (SI line).</td>
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<tr>
<td>CKC</td>
<td>Closed Kinetic Chain</td>
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<tr>
<td>cm</td>
<td>Centimeter</td>
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<tr>
<td>COG</td>
<td>Center of gravity</td>
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<tr>
<td>COM</td>
<td>Center of Mass</td>
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<tr>
<td>CRPS</td>
<td>Complex Regional Pain Syndrome</td>
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<tr>
<td>CT</td>
<td>Computed Tomography</td>
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<tr>
<td>CVA</td>
<td>Cerebro-Vascular Accident</td>
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<tr>
<td>2-D</td>
<td>Two dimensional</td>
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<tr>
<td>3-D</td>
<td>Three dimensional</td>
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<tr>
<td>EMG</td>
<td>Electromyography</td>
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<td>FAI</td>
<td>Frenchay Activities Index</td>
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<td>FMA</td>
<td>Fugl-Meyer Assessment</td>
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<tr>
<td>GH</td>
<td>The Gleno-Humereral</td>
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<td>GPR</td>
<td>Global Postural Re-education</td>
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<tr>
<td>HHD</td>
<td>Hand Held Dynamometer</td>
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<tr>
<td>LL</td>
<td>Lower Limb</td>
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<tr>
<td>MAS</td>
<td>Motor assessment scale</td>
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<tr>
<td>MMT</td>
<td>Manual muscle testing</td>
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<tr>
<td>MRI</td>
<td>Magnetic Resonance Imaging</td>
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<tr>
<td>MVIC</td>
<td>Maximum Voluntary Isometric Contraction</td>
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<tr>
<td><strong>NRS</strong></td>
<td>Numeric Rating Scale</td>
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<tr>
<td><strong>OKC</strong></td>
<td>Open Kinematic Chain</td>
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<tr>
<td><strong>PASS-TC</strong></td>
<td>Postural Assessment Scale for Stroke Patients that measured the Trunk Control</td>
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<tr>
<td><strong>PI Line</strong></td>
<td>The line passing between the posterior superior iliac spines.</td>
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<td><strong>PNF</strong></td>
<td>Proprioceptive Neuromuscular Facilitation</td>
</tr>
<tr>
<td><strong>PPT</strong></td>
<td>Posterior pelvic titling</td>
</tr>
<tr>
<td><strong>PSISs</strong></td>
<td>Posterior Superior Iliac Spines</td>
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<td><strong>Qa angle</strong></td>
<td>The resting scapula upward rotation angle on the affected side.</td>
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<tr>
<td><strong>Qb angle</strong></td>
<td>The resting scapula upward rotation angle on the non-affected side.</td>
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<tr>
<td><strong>ROM</strong></td>
<td>Range Of Motion</td>
</tr>
<tr>
<td><strong>RCT</strong></td>
<td>Randomized Controlled Trials</td>
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<tr>
<td><strong>S - Angle</strong></td>
<td>Spinal lateral deviation angle</td>
</tr>
<tr>
<td><strong>SAPo</strong></td>
<td>Software for Assessment of Posture</td>
</tr>
<tr>
<td><strong>SC</strong></td>
<td>The Sternocalcric joint</td>
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<tr>
<td><strong>SI line</strong></td>
<td>The line passing through the two inferior scapular angles</td>
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<tr>
<td><strong>SP</strong></td>
<td>spinous processes</td>
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<tr>
<td><strong>ST</strong></td>
<td>Scapulothoracic joint</td>
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<tr>
<td><strong>TCT</strong></td>
<td>Trunk Control Test</td>
</tr>
<tr>
<td><strong>TIS</strong></td>
<td>Trunk Impairment Scale</td>
</tr>
<tr>
<td><strong>UE</strong></td>
<td>Upper extremity</td>
</tr>
<tr>
<td><strong>UL</strong></td>
<td>Upper Limb</td>
</tr>
<tr>
<td><strong>ULN</strong></td>
<td>Unilateral neglect</td>
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<tr>
<td><strong>V-line</strong></td>
<td>Vertical Line</td>
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<tr>
<td><strong>WHO</strong></td>
<td>World Health Organization</td>
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Chapter I

Introduction
Chapter I
Introduction

Postural alignment is defined as the relationship of body parts to the line of the center of gravity (COG). It represents the position of body parts with respect to each other. Correct posture is the position in which a minimal stress is applied on each joint (Magee, 2002). The posture is a gauge of mechanical efficiency of the neuro-musculoskeletal system in the erect position. Neural, skeletal and mechanical abnormalities can disturb the normal posture (Solberg, 2008).

Maintaining a postural stability is a complex process that is an essential prerequisite for the advanced stages of motor control including; controlled mobility and skilled activity (Martin and Kessler, 2007). 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 (Shumway-Cook and Woollacott, 2007).

According to the World Health Organization (WHO), stroke is a rapid onset of an event of vascular origin, reflecting focal disturbance of cerebral function excluding isolated impairment of higher function and persisting longer than 24 hours (Olsen, 1990).

Patient with stroke who has a sustained cerebro-vascular accident (CVA) may have a number of different impairments. Motor, sensory, perceptual, communicational, mental, emotional, and respiratory impairments are the main clinical findings seen post-stroke. The extent to which these impairments interfere with the patient's functional capabilities depends on the nature of the stroke and the amount of
nervous system tissue damaged. The spectrum of motor problems is the most prevalent manifestation seen in patients post-stroke (Martin and Kessler, 2007).

Spasticity, muscle weakness, disintegration of sensory information, and loss of righting and equilibrium reactions contribute to the postural malalignment in patients with stroke. It is commonly known that pelvis malalignment has a greater contribution of trunk malalignment following stroke. The unequal weight distribution with increased weight bearing on the unaffected limb has been reported to disturb postural alignment. However, the upper extremity malalignment is commonly correlated with trunk and pelvis malalignment in patients with stroke (Acar and Karatas, 2010).

Shoulder malalignment is commonly started early post-stroke and it may lead to a delay and a limitation in restoration of function. The consequences of malalignment can be early prevented by correct handling, positioning and mobility (Gillen and Burkhardt, 1998).

There is a growing evidence to support the link between movement of the trunk and the limbs. The importance of this link for normal functioning is observed in trunk, scapular and humeral patterns in hemiplegic patients. Weakness in the musculature of both trunk and shoulder girdle affects the postural control of the trunk and the stability in antigravity positions. For that reason, postural assessment is an important element of stroke evaluation (Ryerson and Levit, 2003).

Statement of the problem:

This study was designed to answer the following question:
Do shoulder girdle strengthening exercises capable to improve the postural alignment of the trunk in patients with stroke?

**Purpose of the study:**

The key purpose of the study is to investigate whether the shoulder girdle muscle strength, particularly the scapular muscles, influences the lateral trunk deviation during both static positions and functional activities in patients with stroke. The study is also aiming at finding whether there is a correlation between the improvement in shoulder muscles strength and the trunk alignment.

**Significance of the Study**

Appropriate postural alignment promotes normal effortless and efficient movement of all body parts. After stroke, the postural alignment is disturbed all over the body. The clinical implication of the decrease in the antigravity activity of the trunk includes a loss of scapular alignment and instability of the glenohumeral (GH) joint. Conversely, a heavy hypotonic shoulder complex will inhibit efficient trunk extension and, therefore, disturb trunk alignment, anticipatory postural adjustment mechanisms (APAs), and balance (Raine et al., 2009). Moreover, the alignment of the whole upper limb from distal to proximal and vise versa can indirectly influence the muscle tone in other areas (Bobath 1991, Massion, 1994).

Malaligned shoulder girdle, observed in stroke patients, can influence the trunk alignment and consequently causes lateral trunk deviation towards the affected side. The problem with lateral trunk deviation is that the curves can advance over time as the gravity pulls the shoulder and the spine down. The asymmetric load leads to more
complicated postural and cardiopulmonary problems (Byrne and Ridgeway, 1998).

As the postural control is directly related to disability, evaluation of the postural alignment of the trunk could be a helpful tool in establishing a rational rehabilitation plan post-stroke. In addition, understanding the interaction between shoulder and trunk complex movements would have implications for clinical practice in the rehabilitation of stroke patients at different stages.

Limitations of the study

Limitations of the study were mainly due to:

1. Compliance of participants to physiotherapy sessions.
2. Lack of three-dimensional analysis system to assess the trunk alignment in all motion plans.
3. There was no follow up for the patients after the end of the treatment program in order to find out if improvement was carried on, and to evaluate the long-term effects of the treatment program on both muscle strength and postural alignment.
4. Individual differences between patients that may affect the measurement outcomes.
5. Psychological status and co-operation of the patients.

Delimitation of the study

This study was delimited to:

1. Thirty patients diagnosed as having stroke; caused by cerebrovascular accident (CVA) due to carotid circulation disruption, were divided into control (G1) and study (G2) groups.
2. Stroke patients with the age range from 45 to 60 years; as the stroke is commonly seen at that age. In addition, the influence of aging process on the posture is expected to be involved in the older patients. All the patients were selected from the out-patient-clinic of the Faculty of Physical Therapy at Cairo University.

3. Stroke patients demonstrated residual hemiparesis from a single onset with the illness duration range between six and twelve months; to eliminate the interference of spontaneous recovery at the early onset. Moreover, the postural changes are expected to appear at this duration as a sequel of weakness rather than contractures.

4. Patients with scapular asymmetry and trunk lateral deviation observed from sitting position with supported feet.

5. Mild spastic shoulder muscles: grade 1 to +1 spasticity according to Modified Ashworth scale.

6. Patients with at least stage 4 motor recovery according to Brunnstrome stages.

7. Patients with good sitting balance.

8. Pain free hemiplegic shoulder or patients of unrestricting mild degree of pain (score 1, 2, or 3 according to the Numeric Rating Scale) which occurs as a sequel of stroke.

**Basic Assumption**

It was assumed that:

1. All participants had exerted their maximum effort throughout the whole study and faithfully followed the instructions that had been given to them.

2. Clinical methods of evaluation were reliable and valid.

3. All equipments used in the study were reliable and valid.
4. The calibration of the equipments used in the study; was precise and ensured to minimize any source of error.

5. All other factors, in particular environmental factors such as cold and noise, have been controlled for all participants throughout the study.

**Null Hypothesis**

It was hypothesized that:

1. There will be no significant differences in the trunk alignment between the pre-test and post-test phases in G2.

2. There will be no significant differences in the trunk alignment between the pre-test and post-test phases in G1.

3. There will be no significant differences in shoulder girdle muscles strength between G1 and G2 in post-test phase.

4. There will be no significant differences in trunk alignment between G1 and G2 in post-test phase.

5. There will be no significant effect of shoulder girdle muscles strength on trunk alignment in the post-test phase for both groups.

**Definition of Terms**

**Dynamometer**

A dynamometer is a device for measuring force, moment of force (torque), or power ([en.wikipedia.org/wiki/dynamometer](en.wikipedia.org/wiki/dynamometer)).

**Isokinetic Muscle Contraction**

An isokinetic muscle contraction is one in which the muscle contracts at constant rate of speed. This type of muscle contraction usually requires special training equipment (isokinetic dynamometer) that
increases the load as the muscle contraction is speeding up (www.isokinetic.com/isokinetic).

Lafayette Manual Muscle Tester (MMT)

The Lafayette MMT is a hand-held strength measurement system that provides an objective data about the muscle force (Amundsen, 1990).

**Peak Force**

Peak force is the maximum muscle contraction that occurred in a preset constant time (Kendall and McCreary, 2005).

**Peak Torque**

Peak torque is the maximum torque value which occurs in the range of movement. It may only be approximated during isometric testing but is usually able to be measured during constant angular velocity movement (Delitto et al., 1991).
Chapter II

Review of Literature
CHAPTER II

LITERATURE REVIEW

This chapter reviews the postural alignment of shoulder girdle complex and trunk under the following titles:

I. Kinesiology and Functional anatomy of the Shoulder Girdle Complex.

II. Kinesiology and Functional Anatomy of the Trunk.

III. Postural Control Mechanisms.

IV. Interdependency of Trunks and Upper Limbs Alignment and Function.

V. General Clinical Manifestations following stroke.

VI. Postural Malalignment in Patients with Stroke:

1. Pelvis malalignment
2. Scapular malalignment.
3. Glenohumeral (GH) joint malalignment
4. Spinal malalignment

VII. Assessment and Treatment methods of Shoulder Girdle Muscles Weakness following Stroke:

1. Hand Held Dynamometer "Lafayette Manual Muscle Tester (MMT)"
2. Isokinetic Dynamometer

VIII. Motor Performance Skills Assessment Post-stroke

IX. Postural Assessment:

1. Assessment of the scapular upward rotation angle.
2. Assessment of the lateral deviation of the spine (scoliosis).

X. The 2D analysis of Posture using Digital Phogrammetry and Corel Draw Software Program:

1) Kinesiology and Functional anatomy of the Shoulder Girdle Complex

The shoulder complex is the functional unit that results in the movement of the arm with respect to the trunk. The primary function of the shoulder complex is to position the upper extremity in space to allow the hand to perform its tasks (Oatis, 2004).

Shoulder complex is a set of four articulations involving the sternum, clavicle, scapula and the humerus bones. These series of articulations provide extensive range of motion (ROM) to the upper extremity thereby increasing the ability to manipulate objects (Dvir, 2000) (Fig. 2.1).

![Fig. (2.1): The joints of the shoulder complex (adapted from Neumann, 2009).](image)

With the arm in the anatomical position, the long axis of the clavicle is oriented slightly above the horizontal plane and about 20° posterior to the frontal plane. This orientation allows the lateral end of the clavicle to articulate with the scapula at the oval-shaped acromial facet forming the acromioclavicular (AC) joint. While the rounded and prominent sternal
end of the clavicle articulates with the sternum forming the sternoclavicular (SC) joint (Neumman, 2009).

The scapula is a triangular shaped bone with three angles: inferior, superior and lateral angles. The scapula articulates with the head of the humerus at the slightly concave glenoid fossa forming the GH joint. The glenoid fossa is tilted upwardly about five degrees relative to the scapular medial border (Fig. 2.2) (Oatis, 2008).

Fig. (2.2): Anterior view of the right scapula; an approximately five degrees upward tilt of the glenoid fossa relative to medial border of the scapula (adapted from Oatis, 2008).

At rest, scapula is upward rotated and elevated. It is normally positioned against the posterior-lateral surface of the thorax with the glenoid fossa facing about thirty-five degrees anterior to the frontal plane. This orientation of the scapula is called scapular plane (Fig. 2.3) (Neumann, 2009).
Fig. (2.3): Superior view of both shoulders in the anatomical position. Angle (A): the orientation of the clavicle deviated about 20 degrees posterior to the frontal plane. Angle (B): the orientation of the scapula 35 degrees anterior to the frontal plane. Angle (C): retroversion of the humeral head about 30 degrees posterior to the medial-lateral axis at the elbow (adapted from Neumann, 2009).

In the static position, the scapula is typically positioned between the second and the seventh rib, with the medial border located about 2.5 inches lateral to the spine. This "resting" posture of the scapula varies considerably from one person to another (Johnson et al., 2001).

The anatomical position of the scapula is commonly found to be as following: the superior angle of the scapula is corresponding with the level of the spinous processes of vertebrae T2 or T3, the root of the spine of the scapula corresponding with the spinous processes of T3 or T4, and the inferior angle level with T7, T8 or T9, but may be as low as T10 (Sobush et al 1996).

The head of the humerus faces medially and superiorly, forming an approximate 135° angle of inclination with the long axis of the humeral shaft. Relative to the medial-lateral axis through the elbow, the humeral head is rotated posteriorly about 30° within the horizontal plane. This rotation, known as retroversion, orients the humeral head in the scapular plane for articulation with the gleniod fossa (see Fig 2.3) (Neumann, 2009).
Articulations at the Shoulder Complex:

The *scapulothoracic (ST) joint* is not a true joint. It represents a point of contact between the anterior surface of the scapula and the posterior-lateral wall of the thorax joint. Although this joint is an atypical joint and lacks all of the traditional characteristics of a joint, its primary role is to amplify the motion of the humeral glenoid joint, thus increasing the range and diversity of movements between the arm and the thorax (Johnson et al., 2001).

The *Glenohumeral (GH) joint* is a synovial multiaxial spheroidal joint between the hemispherical head of the humerus and the shallow glenoid fossa of the scapula that is deepened by a fibrocartilaginous rim, the glenoid labrum. A synovial membrane lines the inner wall of the joint capsule and extends to line the intracapsular portion of the long head of biceps and surrounds its tendon as descends into the bicipital groove (Fig. 2.4) (Standring, 2008).

![Fig. (2.4): Lateral view of the GH joint with the humerus removed (adapted from Standring, 2008)]
The ST joint Stability:

The scapula is stabilized to the thorax by ligamentous attachments at the acromioclavicular joint and stabilization mechanisms provided by the muscles. These mechanisms hold the scapula and allow the scapular gliding on the thoracic wall during movements of the shoulder joint. The scapular muscles work through synergistic cocontraction to guide and coordinate the movement between the shoulder joints complex, thereby maintaining scapulohumeral rhythm (Burkhart et al., 2003).

Trapezius, serratus anterior, subscapularis, levator scapulae and rhomboids muscles provide dynamic stability to the scapula during its gliding motion on the thoracic wall. When the muscles are weak or fatigued, scapulohumeral rhythm is compromised and shoulder dysfunction results (Masek, 2008).

The Glenohumeral (GH) joint stability

GH joint stability is required for proper alignment during resting position and dynamic activities. An important component of the GH stability is the properly aligned scapula in the normal upward rotation that keeps the normal tension provided by the capsular and muscular structures (Neumman, 2009).

The glenoid labrum, the glenohumeral ligaments and negative pressure within the joint all provide a static stability at the GH joint (Standring, 2008). The coracoacromial arch, formed by the coracoacromial ligaments and the acromion, prevents the upward dislocation of the humerus. In healthy adult, only about one centimeter (1cm) distance exists between the undersurface of the arch and the humeral head (Lemos, 1998).
In addition to the non-contractile elements (ligaments and capsule), the postural muscles of the upper extremity mainly the supraspinatus, and the posterior deltoid, provide a secondary source of static stability. They generate active forces that are directed nearly parallel to the superior capsular force vector (Biglianni et al., 1996).

The tendons of subscapularis, supraspinatus, infraspinatus and teres minor fuse with the lateral part of the joint capsule to form the ‘rotator cuff’. The rotator cuff muscles provide a dynamic stability to the glenohumeral joint. Weakness of the rotator cuff may result in increased superior glide of the humeral head during shoulder elevation. Moreover, it may cause increased anterior and posterior gliding of the GH joint during abduction in the scapular plan which result in impingement of the bursa, tendons, nerves, and blood vessels (Oatis, 2004, Neuman, 2009).

Latissimus dorsi and pectoralis major muscles, which are large powerful axiohumeral muscles, add a significant strength to all motions of the shoulder girdle except the lateral rotation (Oatis, 2008).

**Kinematics at the Shoulder Complex:**

It is essential to recognize the distinction between shoulder elevation and scapular elevation. Shoulder elevation involves motion at all joints of the shoulder complex (SC, AC, GH and ST joints) while scapular elevation involves movement only at the ST joint which indirectly produces elevation at the SC and downward rotation of the AC but does not involve motion at the GH joint (Oatis, 2004).

**Kinematics at the ST joints**

The ST joint is one of the least congruent joints in the body. No actual bony articulation exists between the scapula and the thorax, which
allows tremendous mobility in many directions, including protraction, retraction, elevation, depression, tilting and upward rotation (outward-inward) (**Hamilton and Luttgens, 2002**) (Fig. 2.5).

**Fig. (2.5):** Motion of the right scapula against the posterior-lateral surface of the thorax. A: elevation and depression. B: Retraction and protraction, C: Downward and upward rotation (**adapted from Neumann, 2009**).

**The role of scapula:**

The scapula performs major roles in the production of smooth, coordinated movement at the shoulder girdle. A stable scapula can efficiently transfer the force generated in the proximal segments; pelvis and trunk, to the arms and hands so that the entire arm can move as a unit around a stable base (**Voigt et al., 2000**).

The coordinated movement of scapula with the moving humerus, keeps the humeral head constrained within the glenoid and so maintains the proper glenoid alignment throughout the full range of shoulder motion. The properly aligned glenoid fossa during shoulder movements facilitates the muscular constraint by maintaining the proper length-tension relationships for efficient contraction of the rotator cuff muscles which in turns provides the dynamic stability to the shoulder joint (**Van der Helm and Pronk, 1995**).
The scapular musculature provides also controlled mobility at the same time of dynamic stability through the eccentric contraction of the scapula muscles during sudden or thrust movements of the upper extremity. Eccentric contraction provides force deceleration that keeps the body safety during motion (Voight et al., 2000).

There is a link between the abnormal scapular position and regional muscle imbalance rather than weakness (Alizadeh et al., 2009).

**Kinematics at the GH joint:**

The GH joint is a universal joint because it moves in all of the three motion planes. Shoulder flexion-extension, abduction-adduction, and external-internal rotations are the main movements occur at the GH joint (Neumman, 2009).

**The scapulo-humeral rhythm and scapular upward rotation importance**

In the healthy shoulder, a natural kinematic rhythm exists between GH elevation and scapulothoracic upward rotation which known as scapulohumeral rhythm (Fig. 2.6) (Neumman, 2009). The scapulohumeral rhythm contributes significantly to the stability of the shoulder joint as well as the maintenance of the deltoid muscle position for effective action (Hamilton and Luttgens, 2002).

There has been much discussion about the ratio of glenohumeral joint to scapulothoracic joint motion during elevation. Most literature reported that the overall ratio of GH to ST upward rotation being 2:1 for the full arc of 180° elevation; with 120° elevation at the GH joint and 60° upward rotation at the scapula (Morrey and An, 1990). On the other hand, McQuade and Smidt (1998) investigated the effects of load on
the scapulohumeral rhythm. As the load increases, the scapulohumeral rhythm changes to a ratio of 4.5:1.

Kendall et al (1993) noted the importance of maintaining the upward rotation of the scapula to enhance the passive stability of the GH joint. A typical dysfunction pattern of the scapula is a protracted and downwardly-rotated position. Kibler (1991) noted the association of protracted and downwardly-rotated scapular posture with an impingement risk. On the other hand, Mottram (1997) reported that poor cervicothoracic and lumbar postures will enhance the inappropriate scapular position. Positions of the scapula may alter tension imparted on the upper limb neural tissue. In addition, lack of muscular control may perpetuate postures which add to irritation of neural tissue.

For efficient upward rotation of the scapula, the serratus anterior, upper and lower trapezius must be strong and at their optimum length-tension relationship. Also, the pectoralis minor must be sufficiently flexible, otherwise a passive insufficiency may occur and restrict the full upward rotation of the scapula (Roseborrough and Lebec, 2007).
Shoulder *external rotation* is an important element during the shoulder elevation as it protects the structures at the subacromial arch from being injured by the acromion. From the anatomic position, about $60^\circ$ to $70^\circ$ of external rotation are usually possible, but much variation can be expected among people. Regardless the position at which the GH rotations occur, there is usually a movement at the ST joint. Maximum external rotation usually includes scapular retraction at the ST joint (*Harryman et al., 1990*).

*Functional anatomy and force coupling mechanisms around the shoulder girdle*

Coordination of the muscle action at the shoulder during elevation is regulated by the neural subsystem described by Panjabi (1992). This neural subsystem provides a critical link between the active and passive
stabilizing mechanisms of the GH joint (Hodges and Richardson, 1996, Hess, 2000). The neural subsystem will be discussed later in this chapter.

The musculature attached to the scapula plays a role in controlling scapular motion, through the synergistic cocontractions and force coupling and therefore provides stability for both of the ST and GH joints. It is generally known that "the rotator cuff –deltoid" force coupling is crucial for the effective arm elevation. On the other hand, the coordinated "trapezius-serratus anterior" coupling together with rhomboid, allows the scapular upward rotation that is necessary for a full arm elevation (Acosta and Dewald, 2005).

The prime muscles that abduct the GH joint are the supraspinatus and the middle deltoid muscles. These muscles are activated at the onset of elevation, reaching a maximum level of firing near 90° of abduction. The supraspinatus stabilizes the humeral head as the deltoid abducts the shoulder and therefore prevents the impingement of the head of humerus on the acromion process (Hamilton and Luttgens, 2002, Floyd and Thompson, 2004, Standring 2008) (Fig. 2.7).

Fig. (2.7): Anterior view of the right shoulder; the force coupling between the deltoid and rotator cuff during active shoulder abduction (adapted from Neumann, 2002).
Ihashi et al. (1998) found that the supraspinatus has an external rotation and internal rotation actions depending on the shoulder position. In the lower ranges of abduction with the arm in internal rotation, stimulation of the supraspinatus muscle produces further internal rotation of the humerus. In contrast, when the humerus is in neutral or externally rotated position, the humeral external rotation is produced. Moreover, as the abduction increases, the supraspinatus muscle stimulation results in external rotation of the humerus.

The serratus anterior and all parts of the trapezius muscle cooperate during the scapular upward rotation. These muscles drive the scapula through upward rotation and provide stable attachment sites for distal mobilizers (deltoid and supraspinatus). The serrates anterior muscle is the most effective upward rotator due to its larger moment arm for this action. The upper and lower fibers of the trapezius and the lower fibers of the serratus anterior form a force couple that upwardly rotates the scapula. This force couple works in elevation to produce and maintain the upward rotation of the scapula and thus minimizing the impingement and facilitating the optimal GH congruency (Mottram, 1997; Voight et al., 2000, Floyd and Thompson, 2004, Oatis, 2008) (Fig 2.8).
Fig. (2.8): force coupling formed by trapezius and serratus anterior muscles. The adduction and abduction pull of the trapezius and serratus anterior counteract each other while the two muscles produce upward rotation of the scapula (adapted from Oatis, 2008).

The combined action of the upper and lower trapezius muscles allows the scapula to rotate upwardly without being displaced superiorly or inferiorly on the thorax. Balanced flexibility and strength between the upper and lower fibers of trapezius muscle helps in stabilizing the scapula optimally during shoulder elevation. Moreover, it helps in positioning the head and shoulder girdle against gravity (Masek, 2008).

In addition to the scapular upward rotation function, the serratus anterior muscle also plays a role in trunk rotation when the scapula is fixed. On the other hand, the trapezius muscle performs extension, lateral flexion and contralateral rotation of the head and neck, in addition to its
role along with the levator scapulae and rhomboids muscles in elevating the scapula (Cael, 2010).

II. Trunk kinesiology and functional anatomy

The trunk is the largest segment of the body representing more than 60% of the human body mass. It plays an integral role in both upper and lower extremity functions as it can significantly alter the function of the extremities. The trunk must be accurately controlled by the neuromuscular system during different activities to control the body balance (Najarian et al., 2005).

Skeletal system of the trunk consists of the vertebral column, pelvis and rib cage. There are 33 vertebrae in the vertebral column, arranged into four curves supporting the spine by offering a spring like response to loading (Neumann 2009).

The vertebral column acts as a modified elastic rod, providing rigid support and flexibility and providing the connection between the upper and lower extremities. In addition to the protection of the neural tissues within the spinal canal and intervertebral foramina, the basic biomechanical functions of the spinal system are weight bearing, balance and allowing movements between body parts (Najarian et al., 2005).

Cervical and lumber curves are referred as lordotic curves while thoracic and sacral are referred as kyphotic curves. Seven vertebrae form the cervical curve which develops as an infant begins to lift his or her head. 12 vertebrae form the thoracic curve that is already present since birth. Five vertebrae form the lumber curve which develops in response to weight bearing and is influenced by pelvic and lower extremity positioning. The last curve is the sacrococcygeal curve, formed by five
fused sacral vertebrae and the four or five fused vertebrae of the coccyx (Hamill and Knutzen, 2009) (Fig 2.9).

![Diagram of Spinal Column](image)

Fig (2.9): Posterior and lateral views of the vertebral column showing the four basic anteroposterior curves; cervical and lumbar lordosis, thoracic and sacral kyphosis (adapted from Hamilton and Luttgens, 2002).

The resultant movement of each vertebra is determined by the direction of the articular facets. The **motion segment** of the spine is composed of two adjacent vertebral bodies, the facet joints created by their articular processes, the intervertebral disc between them, and the associated soft tissue structures. The intervertebral disc and the facet joints allow spinal flexion, extension, side bending and rotation at the level of the motion segment (Wang et al., 2000).

**Factors Influencing Stability and Mobility of the Spine**

Spinal stability is of fundamental significance to the human body. The mechanical stability of the spine can be provided through the alternating anteroposterior curves of the spinal column that influence the
nature and the degree of movements in the different regions. The anteroposterior curves serve as a safeguard against the development of abnormal lateral spinal curve (scoliosis) (Magee, 2008).

The spinal stabilizing system consists of three subsystems which are passive, active and neural systems. The passive musculoskeletal subsystem includes vertebrae, facet articulations, intervertebral discs, spinal ligaments, joint capsules as well as the passive mechanical properties of the muscles. The active musculoskeletal subsystem consists of the muscles and tendons surrounding the spinal column. The neural subsystem consist of the feed-forward and feedback neuromotor control provided through the various receptors located in ligaments, tendons, muscles and the neural control centers. These passive, active and neural control systems, although conceptually separated, but are functionally interdependent. The main function of the stabilizing system is to provide a sufficient functional stability to the spine by matching the instantaneously varying stability demands during different spinal postures, static and dynamic loads (Panjabi 1992, 2003).

**Movements of the trunk**

The movements of the spinal column resemble the movements of a ball and socket joint. Flexion, extension, hyperextension, lateral flexion and rotation are the main movements at the trunk. The degree of freedom of each movement provided at each spinal segment is different. Spinal flexion occurs more freely in the cervical, upper thoracic and lumbar region. Extension and hyperextension occurs most freely in the cervical and at the lumbosacral junction. Lateral flexion motion is freer in the cervical region and quite free in the lumbar region and the thoracolumbar junction. The thoracic spine has limited spinal extension and side bending
because of the spinous process orientation and the presence of the ribs (Standring, 2008) (Fig. 2.10).

It was reported that the lateral flexion of the trunk is always accompanied by a certain amount of rotation. Spinal rotation is also accompanied by a slight amount of unavoidable lateral flexion to the same side (Hamilton and Luttgens, 2002).

![Fig.(2.10): Spinal movements in the different planes, forward bending (flexion) occurs at the sagittal plane, hyperextension occurs at the sagittal plane, side (lateral) bending occurs at the frontal plane and rotation occurs at the transverse plane (adapted from Hamilton and Luttgens, 2002).](image)

**Functional Anatomy of the Trunk Muscles**

Muscles of the trunk are arranged in three layers, the superficial, intermediate and deep layer. The deep muscular layer of the back is separated from the superficial layer by the thoracolumbar fascia. Shoulder girdle muscles; deltoid, pectoralis major, trapezius lattisimus dorsi, sternocledomastoid together with the abdominal fascia and the abdominal externus muscles form the superficial part of the trunk muscles (Standring, 2008) (Fig. 2.11).

The serratus anterior with the other abdominal muscles and erector spinae form the intermediate layer of the trunk muscles. The deep muscles of the trunk are formed of several muscles that move the ribs during breathing and protect the underlying organs (Oatis, 2008).
Fig. (2.11): Muscles acting on the trunk including shoulder muscles, muscles of the intermediate layer, abdominal muscles and interinsic muscles (adapted from Oatis, 2004).

The shoulder muscles assist in supporting the thoracic region mainly during cervical extension and side bending (Oatis, 2008).

III. Postural Control Mechanisms

The term posture is often used to describe both biomechanical alignment of the body and the orientation of the body to the environment. Alignment of the body refers to the relationship of body segments to each other, as well as to the position of the body with reference to the gravity and the base of support. Alignment of body segments over the base of support determines the effort required to support the body against gravity. In addition, this alignment determines the movement strategies that will be effective in controlling posture (Shumway-Cook and Horak, 1992).
Postural control involves controlling the body position in space for the purposes of stability (balance) and orientation. As all tasks require postural control, every task has its own orientation and stability components which vary with the task and the environment. Postural stability is the ability to control the center of mass (COM) in relationship to the base of support (Horak and Macpherson, 1996).

Postural orientation is defined as the ability to maintain an appropriate relationship between the body segments themselves and between the body and the environment during task performance. The relative weights placed on each of these inputs are dependent on the goals of the movement task and the environmental context (Shumway-Cook and Woollacott, 1995, Horak and Macpherson, 1996).

During the upright posture, the activity increases in the antigravity postural muscles to counteract the force of gravity; this is referred to as postural tone. Somatosensory inputs from the neck activated by changes in head orientation can also influence the distribution of postural tone in the trunk and limbs. These have been referred to as the "tonic neck reflexes". Inputs from the visual and vestibular systems also influence postural tone. The postural tone in the trunk is the key element for the control of normal postural stability in the erect position (Schenkman and Butler, 1992, Massion and Woollacott, 2004).

The appropriate activation of abdominal muscles, mainly, and erector spinae is correlated with providing core stability that is important for the efficient postural control. The preponderance type I fatigue-resistant muscle fibers in the erector spinae muscles, mainly at the thoracic region, plays a role in the postural support and in stabilizing the costovertebral joints. The muscular contraction along with the righting
reactions maintains the trunk in an upright alignment (Beattie et al., 2000, Oatis, 2008).

In the upper limb, the trapezius, supraspinatus and part of the deltoid are tonically active in the antigravity postures as the horizontal pull of supraspinatus is required to hold the head of the humerus in the glenoid cavity (Mok et al., 2004).

**Defining Systems for Postural Control**

Postural control for stability and orientation requires complex interaction of musculoskeletal and neural systems. Musculoskeletal components include joint range of motion, spinal flexibility, muscle properties and biomechanical relationships among linked body segments. The essential neural components to postural control include: (a) motor processes, (organized neuromuscular synergies), (b) sensory/perceptual processes (integrated visual, vestibular and somatosensory systems) and (c) higher level processes essential for mapping the sensation to action and ensuring the anticipatory and adaptive aspects of postural control (Hirschfeld, 1992, Schenkman and Butler, 1992, Shumway-Cook and Woollacott, 2007).

Adaptive postural control involves modifying sensory and motor systems in response to changing environmental demands. While the anticipatory postural adjustments consist of activity at the postural muscles that begins immediately prior to the onset of voluntary movement and serves to minimize displacement of the center of gravity associated with that movement. The pattern of anticipatory postural activity is specific to the voluntary task to be performed, but it is temporally and spatially adaptable according to many variable; speed of
motion, displacement, load, symmetry, and postural support (Moore et al., 1992, Shumway-Cook and Woollacott, 2007).

The motor system levels for postural control:

The motor system levels for postural control can be subdivided into three levels: highest, middle and lowest. The highest level represents the association areas of neocortex and basal ganglia of the forebrain. This level is concerned with the motor strategy which means the goal of the movement and the best movement pattern that achieves that goal. The middle level represents the motor cortex and cerebellum and is concerned with the coordination required to smoothly and accurately achieve the strategic goal; involving the time and space sequences of muscle contractions. The lowest level represents the brain stem and spinal cord and is concerned with the motor execution that involves activation of the motor neuron and interneuron pools that generate the goal-directed movement and make any necessary adjustments of posture (Bear et al., 2001).

The correct function of each level of the motor system relies on the sensory information. At the highest level, sensory information generates a mental image of the body and its relationship to the environment. At the middle level, the output is based on the memory of sensory information from past movements. At the lowest level, sensory feedback is used to maintain posture, muscle length and tension before, during and after each voluntary movement (Olson, 2006).

In neurologically impaired patients, the motor components of the postural control including both the musculoskeletal and neuromuscular systems are disturbed. Disturbances in the feed-forward (anticipatory) and feed-back control mechanisms are considered the major factors that
disturb the ability of neurological patients to control the posture. The musculoskeletal problems represent a major constraint to the normal postural control. It can contribute to an inability to sustain an ideal alignment of the body segments in the upright position, and therefore require an excessive force to counter the effects of gravity and sustain a vertical posture (Schenkman, 1990, Shumway-Cook and Woollacott, 2007).

IV. Interdependency of Trunks and Upper Limbs Alignment and Function

Anatomically, the only bony attachment which connects the entire upper limb to the axial skeleton is the SC joint. Therefore the clavicle serves as an anatomic link between the shoulder complex and trunk. Any malalignments in the proximal segments will have deleterious effects on the upper extremity. The shoulder girdle muscles running between the scapula, humerus and trunk can emphasize the interdependence of trunk alignment and the upper extremity control (Gillen and Burkhardt, 2004).

Motion at the shoulder complex involves a balance of movement and muscles control from the spine, pelvis and lower limbs. This balance between body segments is known as kinetic chain reactions (Hodges and Richardson, 1996, Hess, 2000).

The efficient upper limb function requires stability at different body levels to allow free movements of the limb away from the body. Dynamic stability is required proximally on both sides of the body at the thoracoscapular region, and more distally at the pelvis and lower limbs. The proximal trunk stability provides the foundation for the shoulder muscles to move the upper limb (Raine et al., 2009).
It appears that deeper trunk muscles are activated to stabilize the spine irrespective of the direction that the upper limb moves in. While the more superficial trunk muscles are working mainly as a direction specific to the limb movement (Kibler, 1998, Magarey and Jones, 2003).

Thoracic spine mobility provides a base for the shoulder activity and it is essential for the movement of upper body and orientation of the upper extremities for hand use (Willems et al. 1996, Lee et al., 2005).

Humeral, scapular and thoracic segments demonstrate consistent, synchronous interactions. The facilitation of normal muscles synergy and recruitment of trunk muscles occur automatically to provide the anticipatory postural adjustments (APAs) needed before the postural perturbations caused by arm movement (Raine et al., 2009).

Unilateral and bilateral arm movements produce significantly different ranges and patterns of spinal motion and also different ranges of scapular rotations in subjects with different age categories, height or weight (Crosbie et al, 2008).

The stability of scapulothoracic joint has been considered to have a role in the core stability of the trunk due to primarily the role of scapular muscle and fascia attached onto the scapula in stabilizing the trunk (Mottram, 1997).

On the other hand, weakness of the deltoid, trapezius and serratus anterior muscles results in scapular instability which impairs the core stability mainly during arm elevation. Biomechanically, the scapular instability creates a postural impairment by disturbing the chain reactions of the body. These reactions result in excessive movement in the pelvis and lower back. The excessive movement at the lower back does not
allow the abdominal muscles to stabilize the pelvis and serve as a base from where the arm movements originate. This results in visible inefficient pelvic movement with cumulative loads along the spine. It could be concluded that, weakness of the shoulder girdle muscles is not only influencing the gross and fine functions of the upper extremity but it can also affect the spine directly and constitutes an indirect risk factor for the development of back problems (Solberg, 2008).

V. General Clinical Manifestation following Stroke

Stroke is the most common and long-term disabling neurological condition. Following stroke, the brain and body progress through the following series of stages; flaccidity, spasticity and synergy stages. A gradual progression from one stage to another usually occurs; not exclusive but can occur simultaneously in the hemiparetic side (Cailliet, 1991, Fuller et al., 2003).

Motor impairment is one of the most prevalent manifestations seen in patients following stroke. Muscle weakness, spasticity, abnormal muscular coactivations, synergistic pattern and motor planning deficits associated with symptoms of stiffness, contracture and motion impairments are the most common problems seen post-stroke (Canning et al., 2000, Martin and Kessler, 2007).

Loss of trunk control and impaired balance are commonly observed in stroke patients with either mild or severe involvements. Improper trunk control may lead to assuming asymmetrical posture and therefore causes a dysfunction in the upper and lower limbs control (Carr and Shepherd, 2003).
Post-stroke muscle weakness arises primarily from a lesion at the pyramidal tract itself and secondary from the consequence of the lack of activity and mobility. Immediately following a stroke, the reduced muscular force production is due to a loss of descending input to the spinal motor neuron pool reducing the activation of motor units. Six months after stroke, a reduced force production also occurs; but due to a decrease of the cross sectional area of the muscle and a reduction of the motor units due to disuse (Hara et al., 2000).

The severity of muscle weakness varies among stroke patients, probably reflecting such factors as lesion size and location. There is a relative sparing of muscles of the trunk following stroke due to their bilateral innervations. Weakness of the trunk muscles does not, therefore, appear to be the major problem following stroke but the ability to keep balance and maintain a stable posture is the major sequel of stroke (Carr and Shepherd, 2003).

It is commonly known that scapular elevators and upward rotators, shoulder flexors, abductors and external rotators are the weakest shoulder girdle muscles following stroke (Cailliet, 1991).

Excessive tone and posturing of the UL could be explained by the underlying low-tone trunk which is not able to provide a reference point of stability for the UL movement. Development of the upper extremity flexor synergy pattern includes shoulder/scapular depression (downward rotation and retraction), humeral adduction and internal rotation is also reported in patients with stroke (Bobath 1991, Massion, 1994, Byrne and Ridgeway, 1998).

Soft tissue tightness can also develop as a sequel of muscle weakness, spasticity or abnormal patterns of muscle activation. Patients,
whose primary problems are weakness and lack of movement control, develop tightness in their muscles and soft tissues due to disuse and immobility. In the upright position, the dangling position of the arm places a stretch on the deltoid and rotator cuff muscles, and results in predictable patterns of tightness in the pectorals, latissimus dorsi and lower fibers of trapezius. Tightness of these muscles restricts the mobility at the GH joint and scapula during the shoulder movements (Ryerson and Levit, 2003).

VI. Postural Malalignment Following Stroke

Postural malalignment after stroke is a common sequel and results from one or combination of the neural and patho-mechanical factors that arise from disturbed musculoskeletal system. Loss of righting and equilibrium reactions, weakness of the trunk muscles (especially the lower back and abdominal muscles), and perceptual (neglect) dysfunction all influence the postural control following stroke. In addition, the unbalanced muscle activity, which results from spasticity, muscle tightness, and weakness (particularly around the pelvis), has an impact on the postural alignment. Moreover, altered midline awareness and motor control deficits, visual and cognitive impairments can disturb the postural alignment in patients with stroke (Gillen and Burkhardt, 2004).

Unilateral neglect (ULN) is a common cause of postural malalignment following stroke. The reported incidence of ULN varies widely from 10% to 82% following right-hemisphere stroke and from 15% to 65% following left-hemisphere stroke. There are many classifications for ULN; sensory, motor, representational, personal, and spatial neglect (Stone et al., 1993). Sensory neglect is defined as being unaware of sensory stimuli on the affected side of the body and it can be
further classified into visual, auditory and tactile (somatosensory) neglect (Beschin and Roberton, 1997). On the other hand, motor neglect is defined as the failure to generate a movement response to a stimulus even though the person is aware of the stimulus (Heilman et al., 2000).

Traditionally, the assessment of ULN in the clinical setting has involved the use of “pen-and-paper” tests such as line bisection, cancellation tasks, copying, and drawing. These tests are popular in clinical settings because they are simple and quick (Carr and Shepherd, 2003). Many versions of the cancellation task exist including: cancellation of shapes, stars, numbers, letters, lines, bells and circles (Plummer et al., 2003).

The degree of postural malalignment, following stroke, is positively correlated with the extent of lesion, duration of illness, the amount of range of motion (ROM) loss, and muscle weakness (Gillen and Burkhardt, 2004).

1. Pelvis malalignment post stroke:

Loss of the pelvis control following stroke is widely discussed as a real cause of postural malalignment. Following stroke, patients tend to assume sitting position with posterior pelvis tilting (PPT) that is revealed by the weak abdominal muscles. The PPT, indeed, increases the imbalance between the abdominal and back muscles and results in both lumber lordosis reduction and increased spinal flexion. In addition, the abdominals weakness (especially the obliques) together with the lack of balance between these muscles on both sides of the body results in trunk and ribcage rotation. At the same time, asymmetrical weight bearing on the lower limbs (LLs) aggravates the pelvic inclination and spinal lateral flexion (Davies, 2004).
2. Scapular malalignment post stroke

Normally, the distance between the scapular inferior angle and the vertebral column should be greater than the distance between the medial border of the scapular spine and the vertebral column (Fig. 2.12). In hemiplegic patients, the scapula loses its orientation on the thoracic wall and assumes a position of relative downward rotation (Gillen and Burkhardt, 2004).

![Fig. (2.12) : Normal resting posture of scapula in upward rotation. The (A) line represents the distance between medial border and vertebral column while (B) represents the distance between scapular inferior angle and vertebral column. Normally, distance B should be greater than (A). If (A) distance equals or greater than B, the scapula is assumed to be relatively downwards (adapted from Gillen and Burkhardt, 2004).](image)

Generally, scapular downward rotation post-stroke is correlated with many factors. During the flaccid stage, the inactive upward rotators; mainly the trapezius, serratus anterior and rhomboids muscles together with the loss of the muscular support to the humerus provided by the
supraspinatus and deltoid muscles, leads to depression, protraction and downward rotation of the scapula. This mechanical disturbance causes significant angular changes of the glenoid fossa, and subsequently contributes to shoulder subluxation. In addition, it increases the capsular stretch of a flaccid shoulder that predisposes to the irreversible damage and the consequent shoulder pain (Faghri et al, 1994).

As the spasticity develops, the retracted posture of the scapula with the internally rotated humerus restricts the scapular elevation, upward rotation and humeral external rotation. In addition, weakness of the serratus anterior and trapezius muscles, spastic rhomboids, levator scapula and latissimus dorsi, and the downward pull of both tight pectoral muscles and teres major all disturb the normal scapulothoracic rhythm during arm elevation. Impingement of the rotator cuff muscles and shoulder pain are commonly developed as a result of the mechanical disturbance caused by this muscular imbalance (Cailliet, 1991).

In addition, pelvic inclination with the lateral flexion of the trunk toward the hemiparetic side can result in a relatively downward scapular rotation and can further alter the scapulothoracic relationship (Cailliet, 1991) (Fig. 2.13).

When the scapula loses the upward rotation position, the passive tension provided by the superior capsular structures is significantly reduced and the gravity can pull the humerus down in which the GH joint becomes mechanically unstable and eventually subluxed (Neumman, 2009). Alteration of scapular kinematics and resting positions affect both the shoulder performance and kinematics and increase the demand on the rotator cuff musculature. In addition, the metabolic cost of reaching
forward is increased which in turn decreases the maximal rotator cuff strength (Happee and Van-der-Helm, 1995, Lukasiewicz et al., 1999).

![Diagram](image)

**Fig. (2.13):** Scapular –Spinal alignment. A, Scapular alignment with a straight spine (x-y glenoid angle). B, paresis with downward rotation of sapular(A-B) glenoid angle. C, Relative downward rotation of scapula with functional scoliosis (C-D glenoid angle) (adapted from Caillient, 1991).

3. Spinal lateral deviation post stroke

Loss of righting and equilibrium reactions, weakness of trunk muscles, pelvic malalignment, scapular depression and downward rotation, excess activity in unilateral trunk flexors and latissimus dorsi, perceptual dysfunction, and visual impairments can all lead to the common spinal lateral flexion toward the hemipratic side (Caillient, 1991, Teasell, 1998).

4. Glenohumeral (GH) joint malalignment

Loss of the normal pelvic, trunk and scapular alignments post-stroke have an impact on the stability and alignment of the GH joint. As the scapula is pulled downward, the humerus is forced to move down and laterally by the slope of the glenoid fossa. Moreover, the unopposed gravitational pull on the weak muscles can force the humerus to be pulled
downward. Besides, the lateral trunk flexion towards the affected side, put the humerus in a slightly abducted position which predisposes to subluxation by eliminating the postural supporting mechanism created by both of supraspinatus and superior portion of the capsule (Caillient, 1991) (Fig 2.14).

Fig. (2.14): Biomechanics of subluxation secondary to malalignment. AB indicates an aligned spine. Instead the spine assumes a position of lateral flexion (CB). The scapula downwardly rotates (GH), resulting in a downward angulation of the solenoid fossa (XY). Because of the scapula position, the supraspinatus (S) loses its mechanical line of pull, making it ineffective and prone to overstretching. The final result is a subluxation of the glenohumeral joint (adapted from Caillient, 1991).

The GH joint malalignment is not only influencing the proximal stability of the UL and trunk, but it directly impacts the alignment and control of the distal extremity. The internal rotation alignment of the humerus after stroke blocks the forearm rotation and hand stability during functional grasping (Gillen and Burkhardt, 1998).

It was also discussed that the GH malalignment contributes to the development of shoulder pain following stroke. Seventy to Eighty percentage of stroke patients experience a shoulder discomfort. Because the healthy shoulder is a prerequisite for effective hand function, and
different activities of daily living (ADL), the reported shoulder pain after stroke can directly influence the patient functional recovery and subsequently leading to a real disability (Poduri, 1993).

Many scales can be used to assess the pain such as Visual Analogue Scale and Numeric rating scale (NRS). NRS is valid to assess the intensity of pain in adults and children (> 9 years old). It is graded from one to ten and has four grades for pain intensity; none, mild, moderate and severe (McCaffery and Beebe, 1993).

VII. Assessment and Treatment of Shoulder Girdle Muscles Weakness following Stroke

Muscle power is the rate of doing work and, therefore, the product of force and velocity. Muscle strength refers to the ability of a muscle to develop active tension and produce force. Muscle strength can be assessed either manually or using instrumented methods (Sisto and Hudson, 2007).

Manual muscle testing (MMT) is an integral part of a musculoskeletal evaluation and it is the most common method for assessing the muscle strength. MMT scores the muscle strength according to whether the muscle can move the lever arm against gravity (3/5–5/5), without gravity (2/5) or demonstrate a palpable contraction (1/5). MMT is considered a valid method for assessing the muscle strength. However, it has been reported to be relatively insensitive to the minor changes in the muscle strength because it depends on the examiner’s judgment of the amount of resistance applied during the test. When greater accuracy of results is needed, instruments can be used to provide a precise reading of the muscle strength (Ellenbecker, 1996).
Dynamometers, or force measuring devices, can be categorized as hand-grip dynamometers, hand-held dynamometers (HHD) and isokinetic dynamometers. Each provides a quantitative indication of the muscle force or torque that the individuals are able to bring to bear on the environment under specific conditions (Bohannon, 2005).

In stroke patients, the MMT, functional muscle assessment; get to stand, HHD and isokinetic dynamometers are all considered as valid and reliable methods for assessing the muscle strength (Bohannon, 2005).

1. The Hand Held Dynamometer "Lafayette Manual Muscle Tester (MMT)"

Generally, the instrumented muscle strength testing has been demonstrated to be more reliable than the manual standard method. The Hand Held Dynamometers (HHDs) are an efficient and convenient tool for measuring isometric strength. HHDs have been shown to be reliable and valid instruments for assessing the muscle strength (Stratford and Balsor 1994, Sisto, 2007).

The dynamic Lafayette Manual Muscle Tester (MMT) is one of the methods used for the instrumented muscle strength testing. The interrater reliability for handheld dynamometers is good when the assessment is applied with a standard procedure. The peak force results measured by the handheld dynamometer are considered valid measures of muscle strength (Amundsen, 1990). Measuring the shoulder and scapular stabilizing muscles strength using a hand-held dynamometer have been proven to be reliable and valid (McClure et al. 2007).
2. The Isokinetic Dynamometer

The isokinetic testing is a preferable form of assessing the human function. It is considered as the best of all the alternative procedures (isotonic or functional capacity evaluation). It meets generally the accepted professional standards of measuring human performance because it was reported to have a high validity and reliability. Among the various types of strength testing equipment, most researchers have advocated using isokinetic dynamometers in clinical and laboratory settings. Isokinetic testing is considered as the most common testing method of muscle strength (Rochongar, 2004).

Isokinetic means 'same velocity' and refers to the tests that are performed at a predetermined constant velocity. If the user pushes harder, the generated torque of the muscle is increased (Dvir, 1995). The dynamometers provide a functional assessment of the muscle power in which the muscle force can be dynamically measured under a controlled movement velocity (Sisto and Hudson, 2007).

In particular, the isokinetic muscle strength testing provides three different strength variables: peak torque, total work and average power. In most research, peak torque measure has been used to evaluate the muscle strength of the affected extremities in stroke patients and it has shown high test-retest reliability (Hsu et al. 2002).

The Biodex system III multi-joint testing and rehabilitation system (Biodex medical system, Shirley, NY, USA) is one of the isokinetic systems that have been widely used in research, clinical setting, and rehabilitation (Rochcongar, 2004).
The basic elements of a traditional isokinetic system are as follows: (1) a force acceptance unit interfacing the subject and the system, consisting of metallic attachment on the lever arm with or without foam pad, this unit is connected to the lever arm with load cell, (2) the load cell converting a force signal into an electrical signal, (3) the lever arm moving radial about a fixed axis, (4) a head assembly housing the servomotor responsible for moving the lever arm and has a fully adjustable orientation, (5) a seat or plinth for positioning the subject and it may be independently adjusted either vertically or horizontally, (6) a digital touch control unit/panel consisting of a personal computer and an operator equipment, and (7) specific attachments for different segments of the human body to provide various applications (Dvir, 1995).

The reliability of isokinetic measurements of the shoulder joint can be influenced by several factors. First, the axis of the dynamometer has to be lined out to the axis of the joint. Second, the influence of the body and joint position should provide the optimal length-tension position. Third, the choice of the preset angular velocity in isokinetic measurements of the shoulder joint also influence the peak torque. Low and high angular velocities are often used; the assumption is that a low angular velocity relates to maximal voluntary contraction and a high angular velocity relates to muscle coordination which is important in functional activities (Meeteren et al., 2002).

3. Strengthening interventions used in patients with stroke

Strength training is commonly considered to be a progressive resistance exercise. However, any intervention that involves attempted repetitive effortful muscle contractions can result in increased motor unit
activity, thereby potentially increasing the muscle strength after stroke (Ada et al., 2006).

The effect of strength training may depend on the time after stroke, since the mechanism underlying loss of strength changes over time. It also may depend on the level of initial strength (Hara et al., 2000, Ryan et al., 2002).

Strengthening interventions could therefore include electrical stimulation, biofeedback, muscle re-education, and mental practice in addition to the progressive resistance exercise (Ada et al., 2006).

VIII. Motor performance Skills Assessment Post-stroke

After a stroke, the ability of a patient to maintain the trunk control in sitting and standing positions is a fundamental skill for achieving autonomy in ADL. The trunk control performance of patients after a stroke has been found to be closely associated with the long-term functional improvement (Wang et al., 2005).

Many functional performance scales can be used to assess the motor skills in patients with stroke such as the Trunk Control Test (TCT), the Fugl-Meyer scale, the Motor Assessment Scale (MAS), the Trunk Impairment Scale (TIS), the Postural Assessment Scale for Stroke Patients that measured the trunk control (PASS-TC), the Barthel Index of Activities of Daily Living, and the Frenchay Activities Index (FAI) (Verheyden et al., 2006).

The MAS is based on a task-oriented approach evaluation that assesses performance of functional tasks rather than isolated patterns of movement (Martin and Kessler, 2007). The MAS is a valid and reliable scale used for the motor functional evaluation following stroke. The scale
is highly reliable with an average inter-rater correlation of 0.95 and an average test-retest correlation of 0.98. It was reported that the concurrent validity and interrater reliability of using MAS for stroke patients are high and significant (Poole and Whitney, 1988, Carr and Shepherd, 1998, Masur, 2004).

IX. Postural Assessment

Postural asymmetries are associated with the risk of progression in idiopathic scoliosis and therefore affect the functional activities and limit the participation in active life. Correction of posture is an important goal of physiotherapy interventions to prevent the curve progression and the development of structural scoliosis (Fortin et al., 2012).

1. Assessment of scapular alignment

Scapular evaluation is challenging because there is no lever arm to help quantify the scapular movements plus the overlying scapular muscles mass that obscure the surface landmarks moving under the skin (Warner et al., 1992).

The evaluation of scapular function is critical to overall success in managing injuries in the shoulder girdle and upper extremities. The first step in the evaluation process is to observe the scapula, both statically and dynamically. Observation and measurement of the static position of the scapula are important for investigating both shoulder and spinal pathology, mainly the neck, which are the second and the third most common sites of musculoskeletal pain (Voight et al., 2000, da Costa et al., 2010).

Dynamic scapular movement can be evaluated during slowly raising and lower the arm in both flexion and abduction. Smooth controlled
movement during both the ascending and descending phases of the motion plus the amount of lateral sliding of scapula from the spine are important to detect scapular dyskinesis (Voight et al., 2000, Ludewig and Cook, 2000, Kibler and McMullen, 2003).

Many methods have been used to assess the scapular position statically or dynamically, both in the clinical and research work. The laboratory methods include electromechanical digitizers, electromagnetic tracking systems, 3D motion analysis systems, Moire topography, radiology, the scapula locator method and Palpation Meter. The clinical measurement of scapula position can be applied through using some tools as the modified digital inclinometers, Kibler's method, tape measures, calipers and the Perry Tool (McKenna et al., 2004, da Costa et al., 2010, Shaheen et al., 2011).

**Measuring scapular position and orientation**

The orientation of the scapula includes three angular measurements; upward rotation, anterior tilt and internal rotation, and two linear measurements; scapular elevation and scapular abduction. Scapular upward rotation occurs perpendicularly to the anterior—posterior axis and corresponds to the translation and lateralization of the inferior angle of the scapula in relation to the spinal column in the frontal plane. Scapular internal rotation occurs perpendicularly to the longitudinal axis and corresponds to the movement of the medial edge of the scapula away from the thoracic cage in the transverse plane. Scapular anterior tilt occurs perpendicularly to the lateral-medial axis and corresponds to the anterior movement of the coracoid process in the sagittal plane (Neiva et al., 2009) (Fig. 2.15).
Fig. (2.15): The scapular upward rotation, posterior tilting and internal rotation angles. On the left, the scapular upward rotation angle measured using surface landmarks during active elevation; the angle between the scapular spine and the vertical line between T2 to L5 (adapted from Yano et al., 2010).

Scapular orientation and kinematics show a lot of variations in the literature. This can be revealed by many factors as: differences in the used assessment instrumentation, the planes of movements, the definitions of orientations axis, the determination of angular values relative to the starting position, the measuring range, trunk position, and population categories as well as the use of static versus dynamic motion (Yano et al., 2010).

Scapular upward rotation is commonly measured in the literature during arm elevation using the 3D motion system or using the inclinometers (Borsa et al., 2003, Watson et al., 2005). Regarding the accuracy of measurement methods, Sobush et al. (1996) reported that there was no statistical significant difference found between the measurement of scapular position using the surface landmarks and radiographs.
The upward rotation angle is also called scapulothoracic angle. The value of the upward rotation angle within normal populations varies in the literature. In the resting position, scapular upward rotation was found to start from 3° to 28.2° (±8.4°) depending on the direction of the intersecting lines forming the angle and the method of measurement (Sobush et al. 1996, Lukasiewicz et al., 1999, Endo et al., 2004, Watson et al., 2005, Alizadeh et al., 2009, Yano et al., 2010, Struyf et al., 2011). It was also reported that the mean scapular upward-rotation values ranging from 30° to 35° in healthy shoulders (Johnson et al., 1993).

Sobush et al. (1996) calculated the upward rotation formed by the bisecting two lines; the line between the superior and inferior angles of scapula, and the perpendicular line to both distance between the superior angle and the mid thoracic line and the distance between the inferior angle and mid thoracic line (Fig. 2.16a).

Lukasiewicz (1999), Watson et al. (2005), Alizadeh et al. (2009) and Neiva et al. (2009), measured the upward rotation angle from the intersection of a straight line passing through the C7 and T7 markers and a straight line passing through the medial edge of the scapula over the root of the spine and the inferior angle of the scapula (Fig. 2.16b). In addition, Endo et al. (2004) defines the upward rotation angle as the angle between the scapular spine line and the horizontal line (Fig. 2.16c).

On the other hand, Yano et al. (2010) calculated the angle of upward rotation through the bisection of the scapular spine line and the line passing from T2 to L5 (see Fig. 2.15).
Fig (2.16 a): The resting scapular angular position ($\beta$) in the frontal plane using surface landmarks. The angle formed between the bisecting lines; one between the superior and inferior angles of scapula, and the other perpendicular to both of the distance between the superior angle and the mid thoracic line (SA) and the inferior angle and mid thoracic line (IA) (adapted from Sobush et al., 1996).

Fig. (2.16b): Measurement of resting scapular position (a) represents the resting upward rotation angle between two lines; one passing through C7-T7 and the other passing through the root of scapular spine and the inferior angle (adapted from Neiva et al., 2009).
Fig (2.16 c): Radiological measurement of the scapular upward rotation angle during active abduction; the angle between the scapular spine line and the horizontal measured on x-ray (adapted from Endo et al., 2004).

The symmetry of scapular position and motion remains unproved despite the common practices comparing the clinical and kinematic analyses of both normal and pathological shoulder complex (Matsuki et al., 2011).

Sobush et al. (1996) reported that there is no significant difference in the anatomical location of the scapulae of the dominant and non-dominant sides regarding the linear distance from the vertebral column and the angular rotational positions. The authors also found that the dominant scapula is slightly lower than the non-dominant by an average of 0.49±0.74cm. This difference has a level of statistical significance of \( p=0.02 \). Yoshizaki et al (2009) also reported a non-significant dominance effect on both scapular upward rotation and scapulohumeral rhythm using the 3-D motion analysis.

To the contrary, Warner et al (1992) found a scapular asymmetry in 14% of normal subjects on static testing and 18% in dynamic testing using the Moire topographic analysis. Oyama et al (2008) showed
similar results using electromagnetic tracking devices except for the resting scapular upward/downward rotation.

It was reported that, the resting scapular upward rotation increased with aging which is revealed by the forward shoulder position with protraction that occur as a consequence of aging (Struyf et al., 2011). On the other hand, the dynamic scapular upward rotation that accompanies the active shoulder abduction was found to be decreased with aging (Endo et al., 2004).

2. Assessment of Lateral Deviation of the Spine (Scoliosis)

The common causes of postural asymmetry include the leg length difference, pelvic obliquity and scoliosis. Scoliosis is considered to be the most often structural postural deformity of a spinal origin (Timgren and Soinila, 2006).

Scoliosis is defined as a three-dimensional deformity of the spine. The most pronounced component of scoliosis is in the frontal plane, comprising the lateral bending of the spine with rotation of vertebra in the transverse plane. In most cases of idiopathic scoliosis, a decreased thoracic kyphosis is usually detected (Reamy and Slakey, 2001).

Biomechanics of Scoliosis:

Scoliosis can be classified into main three categories; nonstructural scoliosis, transient scoliosis and structural scoliosis. Nonstructural scoliosis includes both postural scoliosis and compensatory scoliosis. Transient scoliosis is that related to sciatic scoliosis, hysterical scoliosis or inflammatory scoliosis. On the other hand, structural scoliosis includes scoliosis that occurs due to idiopathic, congenital, neurofibromatosis,
mesenchymal disorders, neuromuscular factors or traumatic factors (Kulkarini and Ambareesha, 2007).

Primary scoliosis occurs in the thoracic and lumbar vertebrae. The onset of scoliosis occurs when laterally rotatory alterations develop in a straight spine. The term "lateral-rotatory" is used to denote that two motions are inseparable that is the laterally flexed spine rotates about its longitudinal axis. The anatomical alterations associated with scoliosis occur in the structures that are normally responsible about vertebral alignment. Muscles, ligaments and inter-vertebral joint capsules are shortened on the concave side of the curve. Together, these structural changes result in rotation of the vertebral bodies and limit the movement of lateral flexion toward the convex side (Farady, 1983).

As the scoliosis progresses, the vertebrae and spinous processes in the area of the major curve rotate towards the concavity of the curve. As the vertebral bodies rotate, the spinous processes (SP) deviate more and more to the concave side and the ribs follow the rotation of the vertebrae, causing the characteristic rib hump seen in thoracic region. If scoliosis is neglected, the curves may progress dramatically, creating a significant fixed physical deformity with cardiopulmonary problems (Richardson, 2003).

In neurologically impaired patients, the muscular imbalance mainly of the paraspinal muscles produce an unequal load across the spine and pelvis, which would initiate the remodeling of the vertebrae and intervertebral discs and ultimately produce lateral curvature of the spine (Urban et al., 2004).
General Assessment Methods of Scoliosis:

There are several non invasive methods that can be used to assess the postural alignment of the spine. Observing the patients posture with the presence of body asymmetry is the first sign of detecting scoliosis. Asymmetrical shoulders and pelvic levels are commonly detected in scoliosis. The head may not be centered directly above the pelvis when viewing the patient from behind (Lonstein-Orsini, and Whitman, 1999).

The forward bending test "The Adm's bend test" is performed in order to gauge the rotational asymmetry present by demonstrating the degree to which one side of the body is more prominent than the other. The two sides of the thoracic and lumber spines are compared from a forward bending position to note the presence of right or left thoracic prominence (Magee, 1997).

Plumb line is used to assess the back decomposition by measuring the distance from the plumb line at C7 to the gluteal cleft and note the direction of the deviation. Postural evaluation scoring sheet and scoliometer can be also used as non invasive methods for assessing scoliosis (Magee, 1997).

The Cobb's angle remains the standard method to monitor the changes in scoliosis over time, and is calculated from radiographs. It provides information on the vertebral alignment, and it is formed by the intersection of the lines drawn on the borders of the superior and inferior end-vertebra (more inclined vertebrae) and the perpendiculars drawn to these lines. The Cobb's method has been applied to measure the curve progression, to select the type of intervention, and to evaluate its efficacy. Adult scoliosis is defined as a spinal deformity in a skeletally mature
patient with a Cobb’s angle of more than 10° in the frontal plane (Kuklo et al., 2006, Buchowski, 2009, Saad et al., 2009) (Fig. 2.17). Scoliotic curves are named for the location of the apex vertebrae, and may be described as thoracic, thoracolumbar, lumbar or double major (Fig. 2.18) (Rarnneniark and Gustafsan, 2000).

![Fig (2.17): The Cobb’s angle in scoliosis diagnosis (adapted from Rarnneniark and Gustafsan, 2000).]

![Fig. (2.18): The scoliotic curves according to their location; thoracic, thoracolumbar, lumbar or double major (adapted from Rarnneniark and Gustafsan, 2000).]

Moiré topography, ultrasound-based spinal column examination systems and computerized photogrammetry are considered as objective
methods that can be used also to assess the spinal alignment (Reamy and Slakey, 2001).

X. The two Dimensional (2D) analysis of Posture using the Digital Photogrammetry and Corel Draw Software Program

The x-ray is considered the most accurate method to assess the static positioning using the bony landmarks. However, the clinical assessment of postural alignment using the non invasive techniques, such as the 2D postural video analysis, have the advantages of being less expensive and more appropriate for screening evaluations. Furthermore, these techniques do not expose individuals to ionizing radiation that may be harmful especially with pregnant women, disabled or young populations (Lafond et al., 2007).

Patients who had idiopathic scoliosis often undergo radiographic evaluations every three, six, or 12 months according to the guidelines of Society on Scoliosis Orthopaedic and Rehabilitation Treatment (Weiss et al., 2006). However, health professionals have been worried about the adverse effects of high doses of radiation. Thus, over the last few decades, research has been conducted with the aim to lower as much as possible the patients' exposure to x-rays (Levy et al., 1996).

Traditional non invasive methods of trunk deformity evaluation such as the scoliometer and observational postural evaluations are recognized as appropriate methods to detect postural alterations related to scoliosis and, consequently, are widely used in the follow up of scoliosis (Amendt et al., 1990, Denton et al., 1991, Korovessis and Stamatakis, 1996, Penha et al., 2005).

Other objective evaluation methods such as scanners, stereophotogrammetry, as well as the use of special software could replace or,
at least some day, may decrease the periodic radiographic evaluations. However, in spite of the moderate agreement with radiographic aspects and acceptable reliability, all authors agreed that they could not replace radiographic measurements (Thometz et al., 2000, Hackemberg et al., 2003, Ovadia et al., 2007, Saad et al., 2009).

The 2D postural analysis is not able to measure the rotations and translations in six degrees of freedom. It provides a postural analysis mainly in the frontal and sagittal plane with four degrees of freedom while missing the transverse plane (Saad et al., 2012).

With the development of technology, the postural analysis on photographs "digital photogrammetry" is now considered an alternative to quantitative assessment of asymmetries in the postural assessment as it can be used for linear and angular measurements (ASPRS, 2000, Dunk et al., 2004, Penha et al., 2005).

Digital photography allows the recording of subtle changes and the inter-relations between different parts of the human body that are difficult to measure or record by observation or by other non invasive methods such as plumb line testing. Photogrammetry provides the possibility of saving the files digitally with an economy of space and easy access to these records. Another advantage of digital photography is the possibility of conjugation with computerized measuring processes, resulting in computerized photogrammetry (Cowan et al., 1996, Iunes et al., 2005).

Computerized photogrammetry is the combination of digital photography and software that is specifically developed for postural assessment such as Software for Assessment of Posture (SAPo). Other software that is not specifically developed for postural assessment, such as Corel Draw software, can be also used for the 2D postural analysis as
it allows the angular and linear measurements of horizontal and vertical distances (Watson and MacDoncha, 2000, Ferreira et al., 2010).

Hayes et al. (2001) and Sato et al. (2003) have shown a high reliability of photometric techniques for the assessment of the shoulder, head and trunk posture and range-of-motion.

1. Corel Draw Graphics Suite (X5) Software Program and Postural Assessment

The digital phogrammetry with CorelDraw system is reported as a highly reliable method in evaluating the spinal lateral inclination (scoliosis). It possibly can be used as supplementary information in the decision making for therapeutic interventions, which could decrease the number of radiographs necessary for the follow-up of scoliosis. Photogrammetry showed a high repeatability index to evaluate scoliosis for the thoracic and thoracolumbar curves. The limitations of photogrammetry for the evaluation of scoliosis are the measurements of curves with great rotational components and the curves in the lumbar region (Saad et al., 2009).

Saad et al. (2012) also reported a high reliability for assessing the spinal scoliosis and scapular alignment using the photogrammetry and the Corel Draw software.

Iunes et al. (2005) reported that computerized photogrammetry using the Corel Draw software presented high inter- and intra-rater reliability for the angular measurements of asymmetry and postural deviation assessments in the frontal plane (intraclass correlation coefficient = 0.70).
Another study by Fortin et al. (2012) supported the high reliability (0.94) of using the 2D photogrammetry for the thoracic scoliosis and scapular positions measurements. The authors' results revealed a standard error ranges from 0.5° to 1.1° for the spinal alignment and from 0.5° to 0.8° for the scapular elevation angle. In addition, Fortin et al. (2012) found that the measurement errors for scoliosis angles were similar to measurement errors usually reported for Cobb's angle measurement on radiographs.

2. Measurement methods of the lateral spinal angles using the photogrammetry and Corel Draw software:

There are many methods used to assess the spinal lateral deviation angles using the digital photogrammetry combined with the CorelDraw software program. Saad et al. (2009) reported two methods to measure the scoliosis curve angles in the frontal plane. The first method corresponds with the measurement of the scoliotic angle between the apical vertebrae (the furthest marked vertebra from the midline) and the superior and inferior limit vertebrae (vertebrae near the midline) (Fig 2.19a). While in the other method, the scoliotic angle is measured in a similar way to measurements of the radiographic Cobb's angle (Fig 2.19b).
Fig (2.19 a): Measurement of the lateral spinal curvature using method 1 of photogrammetry with Corel Draw Program (adapted from Saad et al., 2009).

Fig (2.19 b): Measurement of the lateral spinal curvature using method 2 of photogrammetry with Corel Draw Program (adapted from Saad et al., 2009).

Fortin et al. (2012) reported another method for measuring the frontal thoracic scoliosis angle that is formed by the line passing from the upper end-vertebra of the curve to the apex of the thoracic scoliosis, and the vertical line passing through the apex.
Summary of literature:

The properly aligned shoulder girdle and trunk are required to keep the efficiency of the postural muscles to maintain the body position in space, and to keep balance during activities of daily living (Raine et al., 2009).

Patients with stroke usually present with disorders of posture at different body levels; head, shoulder, pelvis and trunk with a consequent asymmetry of weight distribution at all stages after stroke. Trunk alignment and postural control, coordination of movement patterns, and balance all require the interaction between the complex pyramidal and extrapyramidal systems that are frequently disrupted by stroke (Karatas et al., 2004).

Hence, the aim of the present study was to investigate the role of shoulder girdle muscles strengthening in improving the postural alignment in patients with stroke in both static posture and functional activities in addition to correlate between the shoulder girdle muscles strength and spinal alignment.
Chapter III

Materials and Methods
Chapter III

SUBJECTS AND METHODS

The present study was held in the out-patient clinic in the Faculty of Physical Therapy at Cairo University, between December 2010 and January 2012; to investigate the effect of shoulder girdle muscles strengthening on the lateral deviation of the spine in patients with stroke during both static position and functional activities. In addition, finding whether there is a correlation between the shoulder muscles strength and trunk alignment was examined.

This chapter includes subjects' selection, instruments and testing procedures, treatment procedure, data collection and statistical analysis.

Subjects Selection:

Thirty patients were included in the study. The patients were diagnosed as stroke caused by cerebro-vascular accident (CVA), either ischemic or hemorrhagic, based on both clinical assessment and radiological investigations of the brain including Computed Tomography (C.T scan) and/or Magnetic Resonance Imaging (MRI).

Once patients agreed to participate in this work, an informed consent was provided and signed prior to participation in the study (Appendix I). Clinical evaluation (Appendix II) including; neurological, musculoskeletal and perceptual (unilateral neglect) assessment, using the line cancellation test, (Appendix III) were performed to all patients. Shoulder stability was also clinically examined through palpating the space between the acromion process and humeral head. In addition, shoulder pain was assessed using the Numeric Rating Scale (see item III.1, Appendix II).
Hemiparetic patients who showed scapular asymmetry, dropped shoulder and spinal lateral deviation towards the affected side, at sitting position, were included in the study. Patients included in the study were selected according to the following criteria:

**Inclusion criteria:**

1. First onset unilateral hemorrhagic or ischemic stroke due to carotid circulation disruption.
2. Six to twelve months of illness duration.
3. Age ranges from 45 to 60 years.
4. Mild spasticity of the shoulder muscles; adductors and internal rotators (1 to +1) according to Modified Ashworth's Scale (Appendix IV).
5. Good voluntary motor control of at least stage (4) according to Brunstrom's stages of motor recovery (Sawner and La-Vigne, 1992) (Appendix V).
7. Patients with scapular asymmetry and trunk lateral deviation observed from sitting position with supported feet.
8. Pain free hemiplegic shoulder or patients of unrestricting mild degree of pain (score 1, 2, or 3 according to the Numeric Rating Scale) which occurs as a sequel of stroke.

**Exclusion Criteria**

1. Balance disturbance due to neurological disorders other than stroke (e.g, Parkinson’s disease, inner ear, vestibular or cerebellar dysfunctions).
2. Stroke patients with unilateral neglect.
3. Patients with sensory manifestations as polyneuropathic or diabetic patients.
4. Uncorrected visual impairment.
5. Congenital anomaly of the spine or scapulae.
6. Fixed spinal deformity like scoliosis, kyphosis or kyphoscoliosis.
7. Musculoskeletal impairments of the shoulder girdle; rotator cuff syndrome, frozen shoulder that disturb the shoulder posture and mobility.
8. Moderate degree of shoulder pain (grade 4 to 10 according to Numeric Rating Scale).
10. History of trauma or surgery to the rib cage, spine, or shoulder girdle.
11. Orthopaedic disorders of the lower limbs as true leg length discrepancy.
12. Musculoskeletal disorders such as low backache, arthritis or degenerative diseases affecting the posture and motor performance as ankylosing spondylitis.
13. Respiratory disorders or conditions that may influence the posture of the skeletal system of the back (eg., asthma).

**Study design**

Pre-test, Post-Test, Control Group Design was used. Subjects were divided randomly into two equal groups G1 and G2.

- Group G1 represents the control group.
- Group G2 represents the study group.

**Methodology**

**Assessment instrumentations:**

1. Two Dimensional (2D) video camera
A digital video camera (Model DSC-W100) was used to capture the patient spine before and after the treatment program (Fig. 3.1).

Fig. (3.1): Digital video 2 D Camera (Model DSC-W100).

2. CorelDraw Graphics Suite (X5) Software

CorelDraw Graphics Suite (X5) is non-specified postural software that can be used to replace the sophisticated methods of postural assessment. In the present study, it was used to measure the resting scapular upward rotation and trunk lateral deviation angles before and after accomplishing the treatment program.

3. Disposable Adhesive Dots

The rounded disposable adhesive dots were used to mark the bony surface landmarks of the spine, pelvis and scapula (Fig. 3.2).

Fig. (3.2): Disposable adhesive dots
3. The Biodex Isokinetic Dynamometer

Isokinetic is commercially known as Cybex II, Kin/Com, Biodex system. It involves the dynamometer which provides equal and opposite resistance to the force provided by the muscles, once the predetermined velocity has been reached (Dvir, 1995). The Biodex system III, isokinetic dynamometer, was used in the present study to assess the shoulder muscles peak torque.

The isokinetic dynamometry for the shoulder joint has been increasingly used in the clinical practice since 1980. The isokinetic testing has been demonstrated to be safe, reliable, and valid method for assessing the muscle strength (Frontera et al., 1993, Wilk et al., 1994, Brown, 2000).

The Isokinetic Dynamometer Components

The Biodex system (Biodex medical system, Shirley, NY, USA) is equipped with a dynamometer height adjustment, side-to-side adjustment, positioning chair with 360° of rotation range, motorized seat height adjustment, front-to-back chair adjustment, and adjustable straps for stabilization and motion isolation (Fig. 3.3: a, b, c, d1, d2). It is also provided with a computer system providing a variety of programs. All information and testing protocol are introduced through a keyboard into its processing unit. When the isokinetic testing procedures are performed, the final results are provided in the form of testing data chart, graph recording, and printed results (Drouin et al., 2004).
Fig. (3.3a): Biodex Isokinetic system (Adapted from Faculty of Physical Therapy, Cairo University). The components are: A- Computer System, B- Digital Touch Control Panel, C- Examiner Testing Chair, D- Dynamometer, and E-Positioning Chair.

Fig. (3.3b): Isokinetic dynamometer components (Adapted from Faculty of Physical Therapy – Cairo University).

Fig. (3.3c): Components of the isokinetic testing chair (Adapted from Faculty of Physical Therapy – Cairo University).
Fig. (3.3d1): The shoulder attachment for flexion and abduction motions (Adapted from Faculty of Physical Therapy – Cairo University).

Fig. (3.3d2): Shoulder attachment for external rotation motion (Adapted from Faculty of Physical Therapy – Cairo University).

4. The Dynamic Lafayette Manual Muscle Tester (MMT)

The Lafayette Manual Muscle Tester (MMT) was used in the present study to assess the peak force of the scapular muscles; supraspinatus, serratus anterior and upper trapezius muscles.

The Lafayette MMT (manufactured by the Lafayette Instrument Company) is a hand-held strength measurement system that provides accurate, objective, and reliable results. The device has three curved interchangeable padded attachments used according to the size of the tested region. These curved attachments provide stability on contoured surface of the tested body part (Sisto and Hudson, 2007).

The Lafayette MMT System measures the peak force (pounds or kilograms), peak force time, and total test time and it stores up to 52 tests. The test time is selectable from 1–10 s with an audible tone that indicates the end of the pre-set time. The unit also provides a built-in calibration routine that verifies a valid calibration (Sisto and Hudson, 2007) (Fig. 3.4 a,b).
5. The Motor Assessment Scale (MAS)

The MAS was used in the present study to assess the motor performance level of the trunk and upper extremities (Appendix VI).

The MAS is a brief and easily administered assessment of eight areas/items of motor functions and one item is related to the muscle tone. The scale was developed by Carr et al. (1985) to assess the activities of daily living and functional mobility for the adult stroke patients from 18 years old and over 64. Items are assessed using a 6-point scale (1 to 6). A score of 6 indicates the optimal motor behavior (Carr and Shepherd, 1998, Poole and Whitney, 1988, Masur, 2004).

Assessment procedure:

During collecting data throughout the study, the sequence of assessing the patient shoulder girdle muscles strength, scapular and spinal angles, and the motor performance level was randomized across participants, to eliminate the
expected effect of the muscle firing following the exercises on both postural alignment and functional outcomes.

1. Measurement of the shoulder girdle muscles strength

a- The shoulder muscles peak torque measurements

The isokinetic dynamometer (Model: The Biodex System III, Biodex Medical System, Shirley, NY, USA) was used to assess the peak torque of shoulder abductors and external rotators during the pre-test and post-test phases of the study.

The concentric isokinetic mode was used at a pre-set angular velocity of 90°/s because it is considered to be more suitable for stroke patients (Hsu et al., 2002). Before applying the test, a demonstration of the testing procedure was performed to the patient. The patient height and weight were recorded before the test, using a universal weight and height scale, as these measurements are basic information required by the isokinetic system.

During the test, the patient was seated on the Biodex system chair. Three straps; one around the patient waist and two crossing the chest, were applied to ensure the proper stabilization of the patients and to perform a selected shoulder movement.

The lever arm of the dynamometer is adapted to the extremity length while the rotation axis of the lever is aligned with the rotational axis of the shoulder joint, as described in the Biodex Applications Manual. The dynamometer handle allows free rotation for pronation and supination which is important component during shoulder external rotation motion.

The Biodex chair position, dynamometer tilt, and orientation were determined according to the manufacturer recommendations. Calibration is
performed before starting the measurement in which the starting and end position of the shoulder ROM is manually entered.

For the shoulder abductor peak torque, a specific shoulder attachment was used and the torque was detected from 0° to 90° against gravity. A target angle of 90° was chosen as the muscular force required at that range is the highest. In addition, the 90° is expected to be feasible for most patients (Fig. 3.5a). For the shoulder external rotators, the shoulder attachment is fixed to the dynamometer with 70° abducted shoulder and 90° flexed elbow. The torque was detected from 0° to 45° against gravity. A target angle of 45° was chosen since this is expected to be feasible for most patients (Fig. 3.5b).

The patient was asked to perform one practice series of five shoulder movements through the whole calibrated range. For each muscle group, three trails were recorded with a five seconds rest in between. No verbal encouragement or other reinforcement was given to any patient during the actual test.

Fig. (3.5a): Shoulder abductor muscles isokinetic testing.  
Fig. (3.5b): Shoulder external rotator muscles isokinetic testing.
b- The scapular muscles peak force measurements

A hand-held dynamometer (HHD) (Model: Lafeyette Manual Muscle Test System Model number 01163) was used to measure the isometric peak force (Kg) of the supraspinatus, upper trapezius, and serratus anterior muscles at a preset testing time of 3 seconds. The applied procedure of the muscle testing using the Lafayette MMT is the same of that used during the standard manual muscle testing as described by Kendall and McCreary (2005) (Fig. 3.6a, b, c).

A demonstration for the test procedure was performed to patients while there were no verbal commands given to them during the actual testing. The patient arm was placed in the appropriate position for each of the tested muscle and he was instructed to hold the arm against the applied resistance. The peak force was recorded in the present study using the make test method because this method is reported with stroke patients for better reliability level. In the make test, the examiner applies resistance in a fixed position and the patient exerts a maximum effort against both the dynamometer and examiner. The examiner is only required to sustain an isometric contraction and read the highest value on a dynamometer (Burns and Spanier, 2005). Three trials are taken for each muscle with a rest period of 15-20 seconds so that declines in strength across trials, due to fatigue, can be avoided (Andrews et al., 1996).

The supraspinatus muscle peak force was recorded from sitting on a stool with the hips and knees are at 90° flexion, and the feet were supported. The patient was asked to maintain the shoulder at a fixed 15° of abduction, elbow extension, and neutral forearm. The isometric peak force was recorded against the applied resistance at the distal forearm level (Fig. 3.6a).

The upper trapezius muscle peak force was recorded from the same sitting position as described above. The patient is asked to keep his arms beside the body and maintain the shoulders in shrugging position. The isometric peak force
was recorded against the applied resistance; just medial to the acomion process (Fig. 3.6b).

The serratus anterior muscle peak force was tested from supine lying position. The patient is asked to maintain the shoulder at 90° flexion. The isometric peak force was recorded against the applied resistance on the level of proximal phalanges from a fisted hand (Fig. 3.6c).

Fig. (3.6a): Manual muscle testing of the supraspinatus muscle from sitting position using the Lafayette Manual Muscle Testing (MMT) system.
2. The 2D Postural assessment "CorelDraw Software"

The resting scapular upward rotation and spinal lateral deviation angles measurements

a) Marking the scapula

The patient was asked to expose the chest, upper limbs and the posterior superior iliac spines. The scapular bony land marks; the superior angle, the inferior angle, and the lateral scapular angle were all palpated and marked using the adhesive dots (Fig. 3.7). The lateral scapular angle was marked at a 5 cm distance from the acromion, so it could be detected by the camera. Lewis et. al. (2002) reported that that skin surface palpation is a valid method to determine the scapular position.
b) Marking the spine and pelvis

The spinous processes of C7, the corresponding thoracic vertebrae to the scapular bony landmarks, and the posterior superior iliac spines (PSISs) were also marked using the adhesive dots (Fig. 3.7). The C7 spinous process, inferior scapular angles, and the two PSISs points were the main bony landmarks that corresponding to the scapular and spinal angles. The others points were marked to make it easier to detect the spinal deviation, before and after the treatment program, when observing the patient spine.

Fig. (3.7) : Skin marking of the scapular angles, corresponding spinous process and PSISs from sitting position using an adhesive dots. (1) the C7 spinous process, (2) the superior scapular angle, (3) the lateral scapular angle, (4) the inferior scapular angle, (5) the two PSISs (Adapted from Faculty of Physical Therapy, Cairo University).

c) Capturing the patient spine

After identifying the necessary landmarks, the patients were asked to look straight ahead and to sit with a normally comfortable position; with shoulders, arms, hands and lower extremities assuming the positions they normally would
during relaxed sitting position. The patient’s feet were supported with the hips and knees aligned at 90° flexion (Sobush et al., 1996).

Digital photographs of the patient’s spine and both scapulae were taken in the frontal plane during sitting position with only one digital video camera, Model DSC-W110 (see Fig. 3.1). Three images are taken for each patient in each trial. In order to minimize the error during the 2D analysis, the camera was properly set up; parallel to the ground on a stable surface that is perpendicular to the ground at 60 cm from the floor and 2.5 meters from the chair where the patient sits on. This setting ensured viewing the whole markers of the patient spine at the frontal plan as recommended by Saad et al. (2009).

d) Image analysis and angles calculation

The scapular and spinal angles were calculated using the computerized phrogrammetry with the CorelDraw Graphics Suite (X5) software. Photos are loaded into the program that automatically calculates and displays the angles once the markers, corresponding to the calculation, are manually selected.

The scapular resting upward rotation angle, was defined in the present study as the angle corresponding to two lines; the line connecting the C7 spinous process and inferior angles, and the vertical (V) line passing through the C7. The Qa angle represents the scapular upward rotation angle on the affected side while Qb represents the non-affected side (Fig. 3.8). This method of measuring the upward rotation angle is corresponding with its definition in the frontal plane that is described by Neiva et al. (2009).

The lateral spinal deviation angle was measured in relation to the inclination between two lines; a line passing through the two inferior scapular angles (SI) and another line passing through the two PSIS (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 intersection between 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 (Fig. 3.8 and Fig. 9a, b).

Fig. (3.8): Measurement of the scapular and spinal angles. The Qa angle represents the scapular upward rotation angle on the affected side while Qb on the non-affected side. (SI) is a line passing through the two inferior scapular angles while (PI) is passing through the two PSISs. The (ASI) is a perpendicular line drawn to the SI line while (API) is perpendicular to the PI line. The intersection between the two perpendicular lines (ASI) and (API) represents the spinal lateral deviation angle (S angle).
3. The Motor Assessment Scale (MAS) measurements

The patient motor performance was tested using the MAS during the pre- and post-testing phases of the study. Patients were asked to perform the items concerning the trunk postural control (2 and 3) and upper extremity functions (6 and 7) while other items were not tested (Appendix VI). Items 2 and 3 examine the patient performance during getting from side lying to sitting and balanced sitting posture, respectively. Items 6 and 7 are related to the upper limb functions and hand movement (Fig. 3.10a – 13b). Scores are given according to the detected motor performance. For each item, score (6) represents the best functional performance while score (1) represents the lowest.
The required equipments that are used during applying the MAS include stool, plinth, table, stopwatch, polystyrene cup, rubber ball of 14 cm (5-in) diameter, two tea cups with water, and a cylindrical shaped object like a jar.

Fig. (3.10a): Transfer of a left hemiparetic patients from side lying to sitting: starting position (Item 2, MAS).

Fig. (3.10b): Transfer from side lying to sitting (Item 2: MAS).
Fig. (3.11): Balance Sitting; A left hemiparetic patient is reaching the ball forward (Item 3: MAS).

Fig. (3.12a): A left hemiparetic patient is doing active flexion and extension of elbow while holding the arm in space (Score3: UL Functions, MAS).
Fig. (3.12b): A left hemiparetic patient tries to rotate the trunk from standing position towards the affected arm while keeping the elbow straight and the shoulder supported on wall (UL Functions, Score: 6; starting position).

Fig. (3.12c): The end position of the task in which the patient tries to rotate the trunk to the affected side while keeping a straight elbow and stable shoulder (UL Functions, Score: 6: end position, MAS).
Fig. (3.13a): A left hemiparetic patient tries to do active wrist extension against gravity while holding a cylindrical object (Hand Movement, Score:1, MAS).

Fig. (3.13b): A left hemiparetic patient tries to fingers opposition. (Hand Movement, Score:6, MAS).

**Treatment procedure**

A selective six weeks strengthening exercises program was applied for the shoulder girdle muscles to the patients participated in both groups. The patients received three sessions weekly with a total number of 18 therapeutic sessions.
Both groups received preparatory stretching exercises for the pectoralis major, lattisimus dori, rhomboids major and minor, and teres major muscles prior to starting the strengthening exercises. Stretching exercises were applied to improve the scapular and humeral mobility.

The selective treatment program that was applied to each group is described below:

- **Group (G1)** received active resisted strengthening exercises for the shoulder abductors and external rotators. In addition, the trunk control exercises; active flexion, side bending, and rotation during sitting position were applied.

- **Group (G2)** received selective strengthening exercises focusing on the scapular muscles; supraspinatus, serratus anterior and upper trapezius muscles, in addition to the same protocol applied with G1.

During strengthening exercises, a maximum directing resistance was applied manually throughout the whole available ROM and below the patient level of fatigue. Verbal and manual guidance were given whenever needed to enhance the quality of movement in either group.

**I. Group (G1) Treatment Program**

1) **Preparatory stretching of the shoulder girdle muscles**

Stretching exercises were applied to the pectoralis major, lattisimus dori, rhomboids major and minor, and teres major muscles as described by Ylinen, (2007) (Fig. 3.14a to Fig. 3.14d). The exercises were applied gradually, within the available ROM and pain limits.
Fig. (3.14a): Stretching of the pectoralis major muscle from supine position. The arrows show the direction of stretching.

Fig. (3.14b): Stretching of the latissimus dorsi muscle from side lying position. The arrows show the direction of stretching.

Fig. (3.14c): Stretching of the rhomboids major and minor muscles from sitting position with arms crossing the chest. The arrows show the direction of stretching.
Fig. (3.14d): Stretching of the teres major muscle from side lying position with elevated arm and flexed elbow. The arrows show the direction of stretching.

2) Shoulder muscles strengthening exercises

Shoulder abductor and external rotator muscles strengthening exercises were applied to the patients as described by Kisner and Colby (2007) (Fig. 3.15a, b). The strengthening exercises were initiated with assistance, mild resistance and progressed to moderate resistance. The intensity of the exercises was increased gradually by introducing one or combination of the following; increasing the amount of manual resistance, increasing the lever arm, or increasing the resistance holding time at the end of the ROM.

The patient was instructed to repeat each exercise for 10 times in two sets with 10 seconds for resting between the trials. At the end of the available ROM, the patient is asked to hold the limb position against the applied resistance. The holding time is gradually increased from 6 to 10 seconds as the patient performance progress through the rehabilitation. The exercises were performed with a low effort and slow repetitions to facilitate the recruitment patterns of the scapular muscles (Mottram, 1997). The exercises are prescribed below:

- **Active resisted shoulder abduction**

  The patient was sitting on a stool with his feet supported while the examiner was standing behind the patient; guiding the patient movement and giving him
the suitable resistance. The patient was asked to do active shoulder abduction within the available ROM and against the resistance while keeping his trunk aligned (Fig. 3.15a).

- **Active resisted shoulder external rotation**

  The exercise was also applied at sitting position with supported feet, adducted arm, and 90° flexed elbow. The examiner was standing beside the patient; stabilizing his arm beside the body, guiding the movement, and giving resistance. The patient was asked to do active shoulder external rotation within the available ROM and against the applied resistance while maintaining his trunk aligned in the mid position (Fig. 3.15b).

![Fig. (3.15a): Active resisted shoulder abduction from sitting position. The (a) arrow represents the movement direction while (b) represents the direction of resistance.](image1)

![Fig. (3.15b): Active resisted shoulder external rotation from sitting position. The (a) arrow represents the movement direction while (b) represents the direction of resistance.](image2)

3) **Trunk control exercises**

The trunk control exercises were initiated with assistance and guidance, to complete the full range, and progressed till the patient becomes able to do a more
controlled motion alone with less compensatory movements. The upper trunk exercises; flexion, side bending, and rotation, were applied to patients as described by Karthikbabu et al. (2011) from sitting on a suitable heighted stool with supported feet, erect back, adducted arms, and extended elbows. Each exercise was repeated 10 times in two sets with 10 seconds rest in between (Fig. 3.16a 1-2, b 1-2, c). The exercises are prescribed as follows:

- **Active trunk flexion**

  The patient started the exercise from sitting position while the examiner stands facing him and holding his upper extremities (UEs). The patient is asked to do active trunk flexion with neutral spinal alignment and symmetrical weight bearing on both lower limbs (LLs), as much as possible. The examiner guides the patient direction of motion through the handling of the UEs (Fig. 3.16a 1-2).

- **Active trunk lateral flexion**

  The patient started the exercise from sitting position while the examiner stands behind the patient and holding the lateral sides of the trunk; just below the inferior angles of both scapulae. The exercise was executed by initiating movement from the shoulder girdle; so as to bring the hand towards the floor while keeping the trunk extended. The examiner guides the patient motion through handling of his trunk to improve the patient midline awareness. Besides, the patient is instructed to return to the mid position before start moving to the other side (Fig. 3.16b 1-2).

- **Active trunk rotation**

  The patient started the exercise from sitting position while the examiner stands behind the patient and holding both ULs in hyperextension position; to facilitate trunk symmetry and extension, and to direct the patient rotation. The patient is asked to do active trunk rotation while keeping the trunk extended and
at a position of the midline. The patient was instructed to return to the midline position before rotating to the other direction. Manual guidance can facilitate the patients when needed (Fig. 3.16c).

Fig. (3.16a1): Active trunk forward flexion from sitting position.

Fig. (3.16a2): Active trunk forward flexion from sitting position.

Fig. (3.16b1): Active trunk lateral flexion to left side from sitting position.

Fig. (3.16b2): Active trunk lateral flexion to right side from sitting position.
II. Group (G2) Treatment Program

1. Preparatory stretching of the shoulder girdle muscles (see Fig. 3.14 a, b,c,d), active resisted strengthening exercises for shoulder abductors and external rotators (see Fig. 3.15 a, b) , and trunk control exercises (see Fig. 3.16a to Fig. 3.16c) were all applied to group G2 typically as described for group (G1).

2. The selective strengthening exercises for the scapular muscles; supraspinatus, upper trapezius, and serratus anterior muscles were applied only to this group as described by Kisner and Colby (2007) (Fig. 3. 17a-b-c). Each exercise is repeated 10 times in two sets with a rest of 10 seconds in between. The patient holds the limb position against resistance for 6 up to 10 seconds at the end of the available ROM. The exercises are prescribed below:

- **Upper trapezius muscle strengthening "Shoulder shrugging exercise"

  Shoulder shrugging exercises were applied from sitting on a stool with supported feet, adducted arms and extended elbows while the examiner was standing behind the patient guiding his movement and giving a suitable resistance. The patient was asked to do the movement within the available ROM
and against the resistance while keeping his head and trunk aligned during the shoulder movement (Fig. 3.17a).

- **Supraspinatus muscle strengthening**

  The patient was asked to sit with adducted arm, extended elbow, and a forearm in a position between supination and pronation. The examiner was standing behind the patient grasping the patient distal forearm and giving a suitable resistance. The patient was asked to abduct his arm, in the frontal plane, within the first 15° of shoulder abduction while keeping his head and trunk aligned stable, and elbows extended (Fig. 3.17b).

- **Serratus anterior muscle strengthening "Forward pushing exercise"**

  The patient assumed a sitting position with 90° flexed shoulders, extended elbows, and neutral forearm; between supination and pronation, with both thumbs pointing up. The patient was asked to keep his head and trunk properly extended as much as he can. The examiner was standing facing the patient and grasping his hands giving the suitable resistance. The patient is asked to push forwards by his ULs against the applied resistance while keeping the trunk stable and elbows extended (Fig. 3.17c).
Fig. (3.17a): Active resisted shoulder elevation (shrugging) from sitting position to strengthen the upper trapezius muscle. The (a) arrow represents the movement direction while (b) represents the direction of resistance.

Fig. (3.17b): Active resisted shoulder abduction to strengthen the supraspinatus muscle from sitting position. The (a) arrow represents the movement direction while (b) represents the direction of resistance.
Home routine and general instructions on proper sitting and standing postures were also given to all patients in both groups.

**Data Analysis and Statistical Design**

The data of shoulder external rotators and abductors peak torque, the supraspinatus, serratus anterior and upper trapezius muscles peak force, the scapular and spinal angles, and the MAS scoring were all collected at two phases; the pre- and post-testing phases. All statistical analyses were performed using the SPSS version (11.0). The difference between parameters was considered statistically significant if the probability "P" value is < 0.05 (Motulsky, 1999). The data were analyzed as following:
Descriptive analysis includes:

1. The mean value ($x$) as an average describing the central tendency of the observations.
2. The standard deviation ($\pm SD$) as a measure of the dispersion of the results around the mean.

Inferential statistics:

1. Paired t-test to compare the measurement outcomes in the same group.
2. Independent t-test to compare the measurement outcomes between the two groups.

The correlation analysis was tested using the Pearson correlation coefficient ($r$) to study the correlation between the peak force value of supraspinatus, serratus anterior and upper trapzeius muscles, and the spinal angle. In addition, the same test was used to study the correlation between the scapular and spinal angles.
Chapter IV

Results
CHAPTER IV
RESULTS ANALYSIS

The present study was conducted to investigate the effect of shoulder girdle muscles strengthening, particularly the scapular muscles, on the trunk alignment in the frontal plan in both static position and during functional activities in patients with stroke. The study also examined the correlation between the shoulder muscles strength and trunk alignment.

The data were collected from 30 stroke patients. Unfortunately, four patients, two from the control group and two from the study group, withdrew from the study during the first three weeks of the treatment program because of changes in their personal circumstances. Another two patients dropped out shortly from the control group because of a health problem. In addition, the communication was lost with one patient during the 4th week of the treatment. Consequently, complete data records were obtained from 23 patients who successfully completed the training protocol for six successive weeks.

The main measurement outcomes of the present study include:

1. The shoulder abductor and external rotator muscles peak torques; recorded by the Biodex system III isokinetic dynamometer.

2. The scapular muscles; supraspinatus, upper trapezius, and serratus anterior peak force; recorded by the Lafayette Manual Muscle Testing (MMT) System.

3. The resting scapular upward rotation and spinal lateral deviation angles were recorded from sitting position; using the two dimensional (2D) digital photogrammetry in conjunction with the Corel Draw software.
4. The Motor Assessment Scale (MAS) was used to evaluate the functional performance.

All data were recorded on two phases; the pre-testing and the post-testing phase of the study. The results were statistically compared within each group and between both groups using the SPSS version 11.0. In addition, a correlation analysis between the shoulder muscle strength and trunk alignment was tested. The level of significance was set at (p < 0.05) for all tests.

The results of the study will be represented as following:

I. General characteristics of subjects.

II. The Isokinetic Peak Torque Measurement.

III. The Peak Force Measurement.

IV. The 2D postural Assessment "Corel Draw Software":

1) Resting scapular upward rotation angle.

2) Lateral spinal deviation angle.

V. The Motor Assessment Scale (MAS) measurements of:

1) Upper limb Functions.

2) Hand movement.

3) Transfer from side lying to sitting.

4) Balanced sitting.

VI. The correlation analysis between the spinal lateral deviation angle and the peak force of the studied scapular muscles: the supraspinatus, upper trapezius, and serratus anterior muscles.

VII. The correlation analysis between the spinal lateral deviation angle and the resting scapular upward rotation angle.
I. General Characteristics of Subjects:

23 right handed patients with stroke were assigned randomly into two groups; the control group (G1) and the study group (G2).

Ten patients (one female and nine male) were included in group G1. Three patients were represented by right hemiparesis and seven represented by left. The age range was 47-57 years (yrs) with a mean of (52.22±5.19) yrs. The weight ranged from 70 to 87 kilograms (Kg) with a mean of (79.88±5.86) Kg. The height ranged between 160 and 178 centimeters (cm) with a mean of (165.66±6.65) cm. The duration of illness ranged from six to twelve months with a mean illness duration of (8.8 ± 2.34) months.

Thirteen patients (one female and twelve male) were included in group G2. Two patients were represented by right hemiparesis and eleven represented by left. The age ranged from 50-59 yrs with a mean of (53.61±3.15) yr. The weight ranged from 70 to 86 Kg with a mean of (80.69±5.72) Kg. The height range was 160-175 cm with a mean of (166.61±4.94) cm. The duration of illness ranged from six to twelve months with a mean duration of illness of (8.07 ± 1.97) months.

The two groups, G1 and G2, were matched in their physical characteristics with no significant differences in their ages, weights and heights where the t- value and p-values, for groups G1 and G2, are (0.78, 0.44), (0.32, 0.75), and (0.38, 0.7); respectively.

The data in Table (1) represent the matching of the general characteristics between the two groups.
Table (1): General characteristics of patients in both G1 and G2 groups.

<table>
<thead>
<tr>
<th>General Characteristics</th>
<th>G1</th>
<th>G2</th>
<th>Comparison</th>
<th>S</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (yrs)</td>
<td>52.22 ±5.19</td>
<td>53.61 ±3.15</td>
<td>0.78</td>
<td>0.44</td>
</tr>
<tr>
<td>Weight (Kg)</td>
<td>79.88 ±5.86</td>
<td>80.69 ±5.72</td>
<td>0.32</td>
<td>0.75</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>165.66 ±6.65</td>
<td>166.61 ±4.94</td>
<td>0.38</td>
<td>0.7</td>
</tr>
<tr>
<td>D.I. (months)</td>
<td>8.8 ±2.34</td>
<td>8.07 ±1.97</td>
<td>0.48</td>
<td>0.63</td>
</tr>
<tr>
<td>Hemiparetic Side</td>
<td>3 Rt - 7 Lt</td>
<td>2 Rt – 11 Lt</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sex (M/F)</td>
<td>1 F - 9 M</td>
<td>1 F - 12 M</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

D.I.: Duration of Illness, SD: standard deviation, P: probability, S: significance, NS: non-significant (P > 0.05), Rt: Right, Lt: Left, M: Male, F: Female.

II. The Isokinetic Peak Torque Measurement

The determined peak torque values for the shoulder abductors and external rotators were compared within the same group and between the two groups.

i) Within Groups:

The mean values of the peak torque of the shoulder abductors in group G1 showed a significant difference in the paired t-test between pre- (23.36±9.94) and post-testing (25.13±9.28) phases where the t-value and p-value were (4.12) and (0.003), respectively. The percentage of improvement was 7.57%.

For group G2, the mean value of shoulder abductors peak torque showed a highly significant difference in the paired t-test between the pre-testing (23.93± 8.74) and the post-testing (33.66±7.91) phases where the t-value and p-values were (20.01) and (0.0001), respectively. The percentage of improvement was 40.66%.

The shoulder external rotators peak torque in group G1 showed a significant difference in the paired t-test between pre- (9.72±4.8) and the post-testing (11.68±5.14) phases with a t-value of (7.5) and a p-value of (0.0001), respectively. The percentage of improvement was 20.16%.
In group G2, the peak torque of shoulder external rotators showed a highly significant difference in the paired t-test between the pre- (9.42±4.8) and the post-testing (16.94±6.3) phases where the t-value and p-value were (10.88) and (0.0001), respectively. The percentage of improvement was 79.83 %.

The results of the shoulder abductors and external rotators peak torque in both the pre- and post-testing phases are listed in Table (2) for groups G1 and G2.

Table (2): Comparison between the pre- and the post-testing phases for the shoulder abductors and external rotators peak torque for group G1 and group G2.

<table>
<thead>
<tr>
<th>Paired t-test</th>
<th>Shoulder abduction peak torque</th>
<th>Shoulder external rotation peak torque</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>G1</td>
<td>G2</td>
</tr>
<tr>
<td>Mean</td>
<td>pre-testing</td>
<td>post-testing</td>
</tr>
<tr>
<td></td>
<td>23.36</td>
<td>25.13</td>
</tr>
<tr>
<td>SD</td>
<td>±9.94</td>
<td>±9.28</td>
</tr>
<tr>
<td>Imp %</td>
<td>7.57%</td>
<td>40.66%</td>
</tr>
<tr>
<td>t-value</td>
<td>4.12</td>
<td>20.01</td>
</tr>
<tr>
<td>p-value</td>
<td>0.003*</td>
<td>0.0001**</td>
</tr>
<tr>
<td>S</td>
<td>S</td>
<td>HS</td>
</tr>
</tbody>
</table>

SD: standard deviation, Imp %: Improvement percentage, P: probability, S: significance, *S: significant (p < 0.05), **HS: Highly Significant (P < 0.001).

ii) Between Groups:

Comparison of the mean values of the shoulder abductors peak torque showed no significant difference in the independent t-test results of the pre-testing phase between group G1 and G2 where the t- and p-values were (0.14) and (0.88), respectively. On the post-testing phase, there was a significant difference in the post-testing values where the t-value and p-values were (2.37) and (0.02), respectively. The results of the test indicated a higher improvement of significant value in group G2.
Comparison of the mean values of the shoulder external rotators peak torque showed no significant difference in the independent t-test results of the pre-testing phase between group G1 and G2 where the t-value and p-value were (0.14) and (0.88), respectively. On the post-testing phase, there was a significant difference in the post-testing values where the t-value and p-values were (2.14) and (0.04), respectively. The results of the test indicated a higher improvement of significant value in group G2.

The results of the independent t-test for the shoulder abductors and external rotators peak torque between groups G1 and G2 were revealed in Table (3) and illustrated in Fig. (4.1) and Fig. (4.2) for the pre- and post-test phases, respectively.

Table (3): Comparison of the mean values of the shoulder abductors and external rotators peak torque between G1 and G2 in the pre- and the post-testing phases.

<table>
<thead>
<tr>
<th>Independent t-test</th>
<th>Shoulder abductors peak torque</th>
<th>Shoulder external rotators peak torque</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>t-value</td>
<td>0.14</td>
<td>2.37</td>
</tr>
<tr>
<td>p-value</td>
<td>0.88</td>
<td>0.02*</td>
</tr>
<tr>
<td>S</td>
<td>NS</td>
<td>S</td>
</tr>
</tbody>
</table>

P: probability, S: significance, NS: non-significant (p>0.05), *S: significant (p<0.05).
III. The Peak Force Measurement: the Lafayette MMT System

The peak force values of the supraspinatus, upper trapezius and serratus anterior muscles were compared within the group itself and between the two groups.
i) Within Groups:

The results of the paired t-test for the peak forces of the studied muscles, supraspinatus, upper trapezius and serratus anterior, in the pre- and the post-testing phases are demonstrated in Tables (4a-4b) for groups G1 and G2.

The mean value of the peak force of the supraspinatus muscle in the control group, group G1, showed a significant difference in the paired t-test between the pre- (1.28± 0.47) and the post-testing (1.49±0.4) phases where the t-value and the p-value were (4.58) and (0.001), respectively. The percentage of improvement was 16.4%. In the study group, group G2, the paired t-test showed a highly significant difference between the pre- (1.39± 0.54) and the post-testing (2.20±0.47) phases with a t-value of (9.23) and a p-values of (<0.0001). The percentage of improvement was 58.57%.

The mean value of peak force of the upper trapezius muscle in group G1 showed a highly significant difference in the paired t-test between the pre- (2.34± 0.38) and the post-testing (2.59±0.36) phases where the t- and p-values were (5.83) and (0.0002), respectively. The percentage of improvement was 10.68 %. In group G2, there was a highly significant difference in the paired t-test between pre- (2.28± 0.49) and post-testing (3.4±0.57) where the t-value and the p-value were (6.92) and (<0.0001), respectively. The percentage of improvement was 49.14 %.

The mean value of the peak force of serratus anterior muscle in group G1 showed a significant difference in the paired t-test between the pre- (2.35± 0.69) and the post-testing (2.54±0.62) where the t-value and p-value were (6.04) and (0.0002), respectively. The percentage of
improvement was 8.08%. For group G2, there was a highly significant difference in the paired t-test between the pre- (2.31± 0.72) and the post-testing (3.11±0.61) phases where the t- and the p-values were (11.84) and (0.0001), respectively. The percentage of improvement was 34.67%.

Table (4a): Comparison between the pre- and the post-testing phases of the peak force mean values of the supraspinatus and upper trapezius muscles for group G1 and group G2.

<table>
<thead>
<tr>
<th>Peak Force</th>
<th>Supraspinatus</th>
<th>Upper trapezius</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>G1</td>
<td>G2</td>
</tr>
<tr>
<td>Paired t-test</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>1.28</td>
<td>1.49</td>
</tr>
<tr>
<td>SD</td>
<td>±0.47</td>
<td>±0.44</td>
</tr>
<tr>
<td>% Imp</td>
<td>16.4 %</td>
<td>58.57%</td>
</tr>
<tr>
<td>t-value</td>
<td>4.58</td>
<td>9.23</td>
</tr>
<tr>
<td>p-value</td>
<td>0.001*</td>
<td>&lt;0.0001***</td>
</tr>
<tr>
<td>S</td>
<td>S</td>
<td>ES</td>
</tr>
</tbody>
</table>

SD: standard deviation, % Imp: Percentage of improvement, P: probability, S: significance, *S: Significant (P < 0.05), **HS: Highly significant (P < 0.001), ***ES: Extremely significant (P < 0.0001).

Table (4b): Comparison between the pre- and the post-testing phases of the peak force mean values of the serratus anterior muscle for group G1 and group G2.

<table>
<thead>
<tr>
<th>Peak Force</th>
<th>Serratus anterior</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>G1</td>
</tr>
<tr>
<td>Paired t-test</td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>2.35</td>
</tr>
<tr>
<td>SD</td>
<td>±0.69</td>
</tr>
<tr>
<td>% Imp</td>
<td>8.08 %</td>
</tr>
<tr>
<td>t-value</td>
<td>6.04</td>
</tr>
<tr>
<td>p-value</td>
<td>0.0002**</td>
</tr>
<tr>
<td>S</td>
<td>HS</td>
</tr>
</tbody>
</table>

SD: standard deviation, % Imp: Percentage of improvement, P: probability, S: significance, *S: Significant (P < 0.05), **HS: Highly significant (P < 0.001), ***ES: Extremely significant (P < 0.0001).

ii) Between Groups:

Comparison of the mean values of the peak force of the supraspinatus muscle showed no significant differences in the
independent t-test values of the pre-testing phase between the two groups. The t-value and the p-value were (0.51) and (0.6), respectively. On the other hand, the results of the post-testing phase showed significant differences between the two groups (P < 0.05) with t- and p-values of (3.82) and (0.001), respectively. The results of the test indicated a higher improvement of significant value in group G2.

Comparison of the mean values of the peak force of the upper trapezius muscle showed no significant difference in the independent t-test values of the pre-testing phase among the two groups where the t-value and the p-values were (0.29) and (0.77), respectively. For the post-testing phase, there was a significant difference (P < 0.05) between the two groups where the t-value and p-value were (3.93) and (0.0008), respectively. The results of the test indicated a higher improvement of significant value in group G2.

Comparison of the mean values of the peak force of the serratus anterior muscle, between groups G1 and G2, showed no significant difference in the independent t-test value in the pre-testing phase, and the t- and p-values were (0.11) and (0.91), respectively. In the post-testing phase, there were significant differences (P < 0.05) between the two studied groups where the t-value and p-value were (2.22) and (0.03), respectively. The results of the test indicated a higher improvement of significant value in group G2.

A summary of the results of the independent t-test for the peak force of the studied muscles between group G1 and group G2 is given in Table (5). These results are also illustrated in Fig. (4.3) and Fig. (4.4) for the pre- and the post-testing phases, respectively.
Table (5): Comparison of the peak force of the three scapular muscles between groups G1 and G2 in the pre- and post-testing phases.

<table>
<thead>
<tr>
<th>Independent t-test</th>
<th>Supraspinatus</th>
<th>Upper trapezius</th>
<th>Serratus anterior</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
</tr>
<tr>
<td>t-value</td>
<td>0.51</td>
<td>3.82</td>
<td>0.29</td>
</tr>
<tr>
<td>p-value</td>
<td>0.6</td>
<td>0.001*</td>
<td>0.77</td>
</tr>
<tr>
<td>S</td>
<td>NS</td>
<td>S</td>
<td>NS</td>
</tr>
</tbody>
</table>

P: probability, S: significance, NS: non-significant (P>0.05), *S: Significant (P<0.05), **HS: Highly Significant (P<0.001).

Fig. (4.3): The pre-test mean values of the peak force of the supraspinatus, upper trapezius (UT) and serratus anterior (SA) muscles between the groups; G1 and G2.

Fig. (4.4): The post-test mean values of the peak force of the supraspinatus, upper trapezius (UT) and serratus anterior (SA) muscles between groups; G1 and G2.
IV. The 2D Postural Assessment "CorelDraw Software"

1) The Scapular alignment: resting upward rotation angle:

i) Within Groups:

The mean value of the scapular upward rotation angle in the control group, group G1, showed an extremely significant differences in the paired t-test between the pre- (31.34±4.16) and the post-testing (33.31±3.77) phases where the t-value and the p-value were (6.742) and (<0.0001), respectively. The percentage of improvement was 6.27%.

The mean value of the scapular upward rotation angle showed also an extremely significant differences in the paired t-test between the pre- (30.41±2.98) and the post-testing (36.58±2.42) phases in the study group, group G2. The t- and p-value were (9.848) and (<0.0001), respectively with a percentage of improvement of 20.55%. For both groups, G1 and G2, the results of the paired t-test of the resting scapular upward rotation angle are given in Table (6) for groups G1 and G2.

Table (6): Comparison between the pre- and post-testing phases of the scapular upward rotation angle for group G1 and group G2.

<table>
<thead>
<tr>
<th>Paired t-test</th>
<th>G1</th>
<th>G2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>pre-testing</td>
<td>post-testing</td>
</tr>
<tr>
<td>Mean</td>
<td>31.34</td>
<td>33.31</td>
</tr>
<tr>
<td>SD</td>
<td>±4.16</td>
<td>±3.77</td>
</tr>
<tr>
<td>% Imp</td>
<td>6.27%</td>
<td></td>
</tr>
<tr>
<td>t-value</td>
<td>6.74</td>
<td></td>
</tr>
<tr>
<td>p-value</td>
<td>&lt;0.0001***</td>
<td>&lt;0.0001***</td>
</tr>
<tr>
<td>S</td>
<td>ES</td>
<td>ES</td>
</tr>
</tbody>
</table>

SD: standard deviation, %Imp: Percentage of improvement, P: probability, S: Significance, ***ES: Extremely significant (P < 0.0001).
ii) Between Groups:

Comparison of the mean values of scapular upward rotation angle showed no significant difference in the pre-testing phase where the t-value and the p-value were (0.62) and (0.54), respectively, while for the post-testing phase; there was a significant difference with a t-value of (2.53) and a p-value of (0.01), respectively. The results of the test indicated that the reduction of the spinal angle is higher and of significant value in group G2 compared to G1.

The results of the independent t-test for the scapular upward rotation angle are illustrated in Table (7) and Fig. (4.5).

<table>
<thead>
<tr>
<th>Independent t-test</th>
<th>Scapular Upward Rotation Angle</th>
<th>Pre-test</th>
<th>Post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>t-value</td>
<td>0.62</td>
<td>2.53</td>
<td></td>
</tr>
<tr>
<td>p-value</td>
<td>0.54</td>
<td>0.01*</td>
<td></td>
</tr>
<tr>
<td>S</td>
<td>NS</td>
<td>S</td>
<td></td>
</tr>
</tbody>
</table>

P: probability, S:significance, NS: non-significant(P>0.05), *S:significant (P<0.05).

Fig. (4.5): The mean values of the resting scapular upward rotation angle for the pre- and the post-testing phases between the groups; G1 and G2.
2) **The Spinal lateral deviation angle results:**

i) **Within Groups:**

The mean value of the spinal lateral deviation angle, in group G1, showed an extremely significant difference in the paired t-test between the pre- (7.32± 2.2) and the post-testing phases (5.48±2.33) where the t-value and the p-value were (15.18) and (<0.0001), respectively. The percentage of improvement was (25.13%).

The mean value of the spinal lateral deviation angle, in group G2, showed an extremely significant difference in the paired t-test between the pre- (7.65± 2.08) and the post-testing (3.76±1.77) phases with t-value (9.26) and p-value (<0.0001), respectively. The improvement percentage was (50.76 %). The results of the paired t-test of the spinal lateral deviation angle are demonstrated in **Table (8)** for groups G1 and G2.

<table>
<thead>
<tr>
<th></th>
<th>G1</th>
<th>G2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>pre-testing</td>
<td>post-testing</td>
</tr>
<tr>
<td>Mean</td>
<td>7.32±2.2</td>
<td>5.48±2.33</td>
</tr>
<tr>
<td>SD</td>
<td>±2.2</td>
<td>±2.33</td>
</tr>
<tr>
<td>% Imp</td>
<td>25.13%</td>
<td>50.76%</td>
</tr>
<tr>
<td>t-value</td>
<td>15.18</td>
<td>9.26</td>
</tr>
<tr>
<td>p-value</td>
<td>&lt;0.0001***</td>
<td>&lt;0.0001***</td>
</tr>
<tr>
<td>S</td>
<td>ES</td>
<td>ES</td>
</tr>
</tbody>
</table>

SD: standard deviation, % Imp: Percentage of improvement, P: probability, S: significance, ***ES: Extremely significant (P < 0.0001).

ii) **Between Groups:**

Comparison of the mean value of the spinal lateral deviation angle showed no significant differences in the independent t-test value of the pre-testing phase where the t-value and the p-value were (0.37) and
(0.71), respectively. On contrary, the results of the post-testing phase revealed significant differences with a t-value of (2.29) and a p-value of (0.03). The results of the test indicated a higher improvement of significant value in group G2.

The results of the independent t-test of the spinal lateral deviation angle are summarized in Table (9) and are plotted in Fig. (4.6).

Table (9): Comparison of the spinal lateral deviation angle between groups G1 and G2 in the pre- and post-treatment.

<table>
<thead>
<tr>
<th>Independent t-test</th>
<th>Spinal Lateral Deviation Angle</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-test</td>
</tr>
<tr>
<td>t-value</td>
<td>0.37</td>
</tr>
<tr>
<td>P-value</td>
<td>0.71</td>
</tr>
<tr>
<td>S</td>
<td>NS</td>
</tr>
</tbody>
</table>

P: probability, S: significance, NS: non-significant (P > 0.05), *S: Significant (P < 0.05).

Fig. (4.6): The mean value of lateral spinal deviation angle in the pre- and post-testing phases between the groups; G1 and G2.

V. The Motor Assessment Scale (MAS) Results:

The MAS was used to assess the items that are mainly concerning the transferring activity from side lying to sitting, balanced sitting, upper
limb functions and hand movements (see; Appendix III, items 2, 3, 6, and 7).

A summary of the results of the paired t-test, for each studied item of the MAS, of the pre- and the post-testing phases is given in Table (10) for groups G1 and G2. The unpaired t-test results are listed in Table (11). Figures (4.7) and (4.8) illustrate the results of this part of the study for the pre- and the post-testing phases, respectively.

1) Upper limb (UL) functions

i) Within Group:

The mean value of the UL function in group G1 showed no significant difference in the paired t-test between the pre- (4.6±0.69) and the post-testing (4.8±0.42) phases where the t- and p-values were (1.50) and (0.16), respectively. The percentage of improvement was 4.34%.

The mean value of the UL function in group G2 showed an extremely significant difference in the paired t-test between the pre- (4.53±0.51) and the post-treatment (5.61±0.50) where the t- and p-values were (6.062) and (< 0.0001), respectively. The improvement percentage was 23.84%.

ii) Between Groups:

Comparison of the mean value of the upper limb function between the groups; G1 and G2, indicated no significant differences in the independent t-test values of the pre-testing phase where the t-value and the p-value were (0.2427) and (0.81), respectively. For the post-testing phase, there was a highly significant difference between the two groups where the t-value and the p-value were (4.10) and (0.0005), respectively.
The results of the test indicated a higher improvement of significant value in group G2

2) **Hand movement**

i) **Within Group:**

The mean value of the hand movement in group G1 showed no significant difference in the paired t-test between the pre- (4.4±0.69) and the post-testing (4.6±0.51) phases where the t-value was (1.50) and the p-value was (0.16). The percentage of improvement was 4.5%.

The mean value of the hand movements in group G2 showed highly significant difference in the paired t-test between the pre- (4.30±0.48) and the post-testing (5.46±0.51) phases where the t-value and p-values were (5.19) and (0.0002), respectively. The percentage of improvement was 26.97%.

ii) **Between Groups:**

Comparison of the mean value of the hand movements between groups G1 and G2 showed no significant difference in the independent t-test values of the pre-testing phase where the t-value and the p-value were (0.71) and (0.37), respectively. For the post-testing phase, there was a highly significant difference between the groups where the t-value and the p-values were (3.95) and (0.0007), respectively.

3) **Transfer from side lying to sitting position**

i) **Within Group:**

The mean value of motor performance during transfer from side lying to sitting position in group G1 showed significant difference in the paired t-test between the pre- (4.7±0.94) and the post-testing (5.3±0.67)
phases where the t-value and the p-value were (3.674) and (0.005), respectively. The percentage of improvement was 12.76%.

The mean value of motor performance during transfer from side lying to sitting position in group G2 showed an extremely significant difference in the paired t-test between the pre- (4.6 ± 0.48) and the post-testing (5.76±0.34) phases in which the t- and p-values were (6.06) and (<0.0001), respectively. The percentage of improvement was 25.12%.

ii) Between Groups:

Comparison of the mean value of motor performance during transfer from side lying to sitting position between group G1 and G2 showed no significant difference in the independent t-test of the pre-testing phase where the t- and p-values were (0.025) and (0.98), respectively. Also on the post-testing phase, there was no quite significant difference between the groups where the t-value and p-value were (2.02) and (0.056), respectively.

4) Balanced sitting

i) Within Group:

The mean value of the sitting balance performance in group G1 showed significant difference in the paired t-test between the pre- (4.5±0.52) and the post-testing (5.1±0.56) phases where the t- and p-values were (3.674) and (0.005), respectively. The percentage of improvement was 13.33 %.

The mean value of the sitting balance performance in group G2 showed extremely significant difference in the paired t-test between pre (4.53±0.66 ) and post(5.69± 0.48) testing where the t-value and p-value
were (6.04) and (<0.0001), respectively. The percentage of improvement was 25.60%.

**ii) Between Groups:**

Comparison of the mean value of the sitting balance performance between group G1 and G2 showed no significant difference in the independent t-test value of the pre-testing phase where the t-value and p-value were (0.15) and (0.88), respectively. While on the post-testing phase, there was a significant difference between the groups where the t-value and p-value were (2.71) and (0.01), respectively. The results of the test indicated a higher improvement of significant value in group G2.

Table (10): Comparison between the pre- and the post-testing phases of the Motor Assessment Scale (MAS) for group G1 and group G2.

<table>
<thead>
<tr>
<th>G1</th>
<th>MAS</th>
<th>UL Function</th>
<th>Hand Movement</th>
<th>Side lying-sitting</th>
<th>Balanced Sitting</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean 4.60</td>
<td>4.80</td>
<td>4.40</td>
<td>4.60</td>
<td>4.7</td>
</tr>
<tr>
<td></td>
<td>SD ±0.69</td>
<td>±0.42</td>
<td>±0.69</td>
<td>±0.51</td>
<td>±0.94</td>
</tr>
<tr>
<td></td>
<td>% Imp 4.34%</td>
<td>4.5%</td>
<td>12.76%</td>
<td>13.33%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>t-value 1.50</td>
<td>1.50</td>
<td>3.764</td>
<td>3.674</td>
<td></td>
</tr>
<tr>
<td></td>
<td>p-value 0.16</td>
<td>0.16</td>
<td>0.005*</td>
<td>0.005*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>NS</td>
<td>NS</td>
<td>S</td>
<td>S</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>G2</th>
<th>MAS</th>
<th>UL Function</th>
<th>Hand Movement</th>
<th>Side lying-sitting</th>
<th>Balanced Sitting</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean 4.53</td>
<td>5.61</td>
<td>4.30</td>
<td>5.46</td>
<td>4.69</td>
</tr>
<tr>
<td></td>
<td>SD ±0.51</td>
<td>±0.50</td>
<td>±0.48</td>
<td>±0.518</td>
<td>±0.48</td>
</tr>
<tr>
<td></td>
<td>% Imp 23.84%</td>
<td>26.97%</td>
<td>25.12%</td>
<td>25.60%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>t-value 6.062</td>
<td>5.19</td>
<td>6.06</td>
<td>6.04</td>
<td></td>
</tr>
<tr>
<td></td>
<td>p-value &lt;0.0001***</td>
<td>0.002**</td>
<td>&lt;0.0001***</td>
<td>&lt;0.0001***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>S</td>
<td>ES</td>
<td>HS</td>
<td>ES</td>
<td>ES</td>
</tr>
</tbody>
</table>

UL: Upper Limb, Side lying-sitting: Transfer from side lying to sitting position, SD: standard deviation, %Imp: Percentage of improvement, P: probability, S: significance,*S: Significant (P < 0.05), NS: Non significant (P > 0.05), **HS: Highly significant (P < 0.001), ***ES: Extremely significant (P < 0.0001).
Table (11): Comparison of the Motor Assessment Scale (MAS) between G1 and G2 groups in the pre- and the post-testing phases.

<table>
<thead>
<tr>
<th>Independent t-test</th>
<th>UL function</th>
<th>Hand Movement</th>
<th>Side lying – sitting</th>
<th>Balanced sitting</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pre-testing</td>
<td>post-testing</td>
<td>pre-testing</td>
<td>post-testing</td>
<td>pre-testing</td>
</tr>
<tr>
<td>t-value</td>
<td>0.24</td>
<td>4.10</td>
<td>0.71</td>
<td>3.95</td>
</tr>
<tr>
<td>P-value</td>
<td>0.81</td>
<td>0.0005**</td>
<td>0.37</td>
<td>0.0007**</td>
</tr>
<tr>
<td>S</td>
<td>NS</td>
<td>HS</td>
<td>NS</td>
<td>HS</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>pre-testing</td>
<td>post-testing</td>
<td>pre-testing</td>
<td>post-testing</td>
<td>pre-testing</td>
</tr>
<tr>
<td>t-value</td>
<td>0.025</td>
<td>2.02</td>
<td>0.15</td>
<td>2.71</td>
</tr>
<tr>
<td>P-value</td>
<td>0.98</td>
<td>0.056</td>
<td>0.88</td>
<td>0.01*</td>
</tr>
<tr>
<td>S</td>
<td>NS</td>
<td>NS</td>
<td>NS</td>
<td>S</td>
</tr>
</tbody>
</table>

UL: Upper Limb, Side lying-sitting: Transfer from side lying to sitting position, P: probability, S: significance,*S: Significant (P < 0.05), NS: Non-significant (P > 0.05),**HS: Highly significant (P < 0.001).

Fig. (4.7): The pre-test mean values of the Motor Assessment Scale (MAS) for the upper-limb (UL) function, hand movement, side lying to sitting (side to sit), and sitting balance between groups; G1 and G2.
Fig.(4.8): The post-test Mean values of the Motor Assessment Scale (MAS) for the upper-limb (UL) function, hand movement, side lying to sitting (side to sit), and sitting balance between groups; G1 and G2.

VI. Correlation between the spinal lateral deviation angle and the shoulder girdle muscle strength

The correlation analysis between the peak force of the supraspinatus muscle and spinal lateral deviation angle revealed that there is a highly significant negative correlation where the r-value, r, is (-0.67) and an associated probability p-value, p, is (0.0004). Fig (4.9) represents the results of this correlation analysis.

The correlation analysis between the peak force of the serratus anterior muscle and spinal lateral deviation angle revealed that there was an extremely significant negative correlation where r = -0.88 which is associated with p < 0.0001. This correlation is given in Fig (4.10).

The correlation analysis between the peak force of the upper trapezius muscle and spinal lateral deviation angle revealed that there was
an extremely significant negative correlation where $r = -0.83$ and $p < 0.0001$. Fig (4.11) shows the results of this correlation analysis.

Table (12) summarizes the results of the correlation analysis of the spinal lateral deviation angle and the shoulder girdle muscle strength for the studied muscles.

Table (12): Correlation analysis between mean value of each of the three scapular muscles peak force and the lateral spinal deviation angle.

<table>
<thead>
<tr>
<th>The Correlation Coefficient</th>
<th>Supraspinatus</th>
<th>Serratus Anterior</th>
<th>Upper Trapezius</th>
</tr>
</thead>
<tbody>
<tr>
<td>r-value</td>
<td>-0.67</td>
<td>-0.88</td>
<td>-0.83</td>
</tr>
<tr>
<td>p-value</td>
<td>0.0004***</td>
<td>&lt; 0.0001***</td>
<td>&lt;0.0001***</td>
</tr>
</tbody>
</table>

r-value: correlation coefficient, p-value: probability, S: significance, **HS: Highly significant (P < 0.001), ***ES: Extremely significant (P < 0.0001).

Fig. (4.9): Correlation analysis between the supraspinatus muscle peak force and spinal lateral deviation angle.
Fig. (4.10): Correlation analysis between the peak force of serratus anterior (SA) muscle and spinal lateral deviation angle.

Fig. (4.11): Correlation analysis between the upper trapezius (UR) muscle peak force and the spinal lateral deviation angle.

VII. Correlation between the resting scapular upward rotation angle and the spinal lateral deviation angle:

The correlation analysis between the resting scapular upward rotation angle and spinal lateral deviation angle revealed that there was highly significant negative correlation where the r value equals (-0.68) and had an associated probability value of (0.0003). Table (13) and Fig (4.12) demonstrate these results.
Table (13): Correlation analysis between the resting scapular upward rotation angle and spinal lateral deviation angle.

<table>
<thead>
<tr>
<th>correlation coefficient</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>r-value</td>
<td>-0.68</td>
</tr>
<tr>
<td>p-value</td>
<td>0.0003**</td>
</tr>
<tr>
<td>S</td>
<td>HS</td>
</tr>
</tbody>
</table>

r-value: correlation coefficient, p-value: probability, S: significance, **HS: Highly significant (0.0001 < P < 0.001).

Summary of the Results

The results of Shoulder girdle muscles strength

The mean values of the peak torque of the shoulder abductors and external rotators showed a significant difference on the post-testing for both group, where the percentage of improvement was (7.57%, 20.16%) for group G1 and (40.66%, 79.83%) for group G2, respectively. The independent t-test value indicated higher improvement of significant value in G2 compared to G1.
In addition, the mean value of peak force of supraspinatus, upper trapezius and serratus anterior muscles, for group G1, showed a significant difference on the post-testing phase in both groups with an improvement percentage of 16.4%, 10.68%, and 8.08%, respectively, while for group G2 the improvement percentage was 58.27%, 49.12%, and 34.67% for the three studied muscles, respectively. The independent t-test value indicated higher improvement of significant value in G2 compared to G1.

**The results of postural alignment**

The mean value of the resting scapular upward rotation angle showed a significant increase on the post-testing phase in both groups where the percentage of improvement was 6.27% for group G1 and 20.55% for group G2. The independent t-test value indicated higher improvement of significant value in G2 compared to G1.

The mean value of the spinal lateral deviation angle showed a significant reduction on the post-testing phase in both groups where the percentage of improvement was (25.13%) for group G1 and (50.76%) for group G2. The independent t-test value indicated higher improvement of significant value in G2 compared to G1.

**The results of motor functional performance:**

Both groups showed a significant difference during transfer from side lying to sitting position on the post-testing phase where the p-value was (0.005) for group G1 and (<0.0001) for group G2. For the sitting balance, both groups showed significant difference for the post-testing phase where p-value was (0.005) for group G1 and (<0.0001) for group G2. For the upper extremity, only group G2, showed an extremely
significant difference in the UL functions where the t-value and p-value were (6.062) and (<0.0001), respectively. In addition, it showed a highly significant difference in the hand movements where the t-value and p-value were (5.19) and (0.0002), respectively.

**Correlation analysis:**

The correlation between the strength of supraspinatus muscle and the spinal lateral deviation angle was a highly significant negative with the r = -0.67 and p = 0.0004. On the other hand, an extremely significant negative correlation was obtained between the spinal lateral deviation angle and the strength of both muscles; the serratus anterior and the upper trapezius with the r-values (-0.88) and (-0.83), respectively. Both muscles have similar p-value < 0.0001.

Moreover, the results indicated a highly significant negative correlation between the scapular upward rotation angle and the spinal lateral deviation angle with an r-value of (-0.68) and a p-value of (0.0003), respectively.
Chapter V

Discussion
CHAPTER V
DISCUSSION

The present study was conducted to investigate the role of shoulder girdle strengthening in improving the postural alignment in patients with stroke in both static posture and functional activities. The study was also aiming to find whether there is a correlation between the shoulder girdle muscles strength and spinal alignment. The study was held in the outpatient clinic in the Faculty of Physical Therapy at Cairo University, between December 2010 and January 2012.

The isokinetic peak torque of shoulder abductors and external rotators in addition to the scapular muscles peak force, using the dynamic Lafayette Manual Muscle Tester (MMT), were assessed to measure the shoulder girdle muscles strength. The 2D postural assessment of both resting scapular upward rotation and spinal lateral deviation angles was applied using the Corel Draw Graphics Suite (X5) software from sitting position.

The functional performance of the trunk and upper limbs (ULs) were assessed using the Motor Assessment Scale (MAS) for all participants. The present study had focused on assessing the postural control at both shoulder girdle and trunk levels in functional tasks (see, items 2, 3, 6 and 7 in Appendix VI) that often performed during the daily life activities.

All the measurement outcomes were assessed in the pre- and post-testing phases of the study; after applying a selective strengthening program to the shoulder girdle muscles, for successive six weeks.
Twenty-three patients completed the treatment program. All patients were diagnosed as having stroke caused by cerebro-vascular accident (CVA) with illness duration between six and twelve months post-stroke and age range between 45 and 60 years old. Patients were divided into two groups; the control group (G1, 10 cases) and the study group (G2, 13 cases).

In the pre-testing phase, statistical analysis showed insignificant differences in physical characteristics and measurement outcomes between the groups. Most of the patients showed a pre-testing score ranged from four (4/6) to five (5/6) on the MAS, in both groups.

The resting scapular upward rotation angle was specifically measured in the present study because it reflects the strength of studied scapular muscles; the trapezius, serratus anterior, and supraspinatus muscles. The three muscles work together to keep the normal resting position of the scapula in both elevation and upward rotation orientation (as described previously in chapter II).

**Genthons et al. (2007)** reported that sitting position eliminates the effect of unequal weight shifting on the lower limbs (LLs) so that the body segments to be controlled in sitting position are less than standing. For this reason, sitting position was chosen for measuring the scapular and spinal angles in the present study.

Regarding the treatment program, all participants received preparatory stretching of scapular muscles, resisted exercises of the shoulder abductors and external rotators, and active trunk control exercises. Resisted exercises of the supraspinatus, upper trapezius, and serratus anterior muscles were specifically applied to the study group.
Home routine and general instructions on proper sitting and standing posture were also given to all patients in both groups.

The duration of the applied strengthening program in the present study is based on the findings of Weinstein et al. (2004) who recommended a period of four to six weeks of strengthening training program for patients with stroke to gain changes in the muscle strength and functional performance levels. The same duration of the training program is commonly reported in literature reviewing the effectiveness of different strengthening methods following stroke (Badics et al, 2002, Bourbonnais et al., 2002, Ada et al., 2006).

Although measuring the effect of stretching exercises on scapular alignment was out of the scope of the present study; pectoralis major, teres major, lattisimus dorsi, and rhomboids muscles were all stretched at the beginning of the treatment sessions for both groups.

Kuechle et al. (1997) found that tightness of pectoralis major, latissimus dorsi, teres major has a depressor moment arms and downward pull on the scapula resulting in asynchronous motion. The authors reported that stretching these four muscles should be incorporated in the program of scapular stability before starting the strengthening exercises.

Trunk control exercises were also involved in the present treatment program to facilitate scapular muscles. Magarey and Jones (2003) showed that spinal dissociated movement and awareness of natural posture facilitate scapular control re-training.

In a review study on the dynamic stability of the scapula and the role of rehabilitation programs, Mottram (1997) reported that shoulder external rotation is more important than internal rotation in providing
stability to the shoulder joint. That is why the strengthening of external rotators was incorporated together with abductors in the present study.

Based on Mottram (1997) review, manual resisted exercises primarily re-educate the stability and control around the scapula to improve the postural alignment. Therefore, manual resisted exercises were only considered in the present study rather than any other types of strengthening interventions.

The results of the pre-testing phase, of the present study, showed that shoulder external rotators were weaker than abductors. Ryerson and Levit (2003) revealed that the motor recovery of shoulder external rotators and upward rotators after stroke is less frequent comparing to other shoulder muscles groups. Another factor that could explain the lower external rotators strength is the age of the participants in the present study (45-60 years old). The findings of Helen and Susan (2011) also support this report. In that, the authors investigated the effect of aging on muscle strength of old healthy men with age range between 50 and 60 years old, and found that shoulder abductors were stronger than external rotators. The results were attributed to the postural changes that occurred with aging. As thoracic kyphosis disturbs the scapular mobility towards the midline, shoulder external rotators would be in a mechanically disadvantage position and cannot properly being activated.

The improvement of the shoulder muscles strength, in the present study, after applying the strengthening treatment program is supported by the results of Bourbonnais et al. (2002). The present results for shoulder abductors and external rotators are 5% and 44% higher than Bourbonnais et al. (2002) results, respectively. The difference in results between the two studies can be attributed to the different age range of the patients
participated in Bourbonnais et al. (2002) study (20 -70 years old) and that in the present thesis (45 – 60 years old). Moreover, differences in the methods of resisted exercises could be another factor. In the previous study, shoulder training exercises were applied to patients statically at a fixed angle of 30° of shoulder abduction while in the present study each muscle was trained selectively through the whole available range of motion.

The normal synergist coactivation reported by Cael (2010) between shoulder girdle muscles, working at both glenohumeral and scapulothoracic levels, together with neurophysiologic effect of resisted exercises could explain the significant improvement in the strength of shoulder abductors, external rotators, supraspinatus, upper trapezius, and serratus anterior muscles found in the study group when compared to the control group. Folland and Williams (2007) and Falvo et al. (2010) found that resisted exercises may enhance the recruitment, firing rate, and synchrony at the level of motor neuron by enhancing the neural adaptation.

Among the studied muscles, the shoulder external rotators in the present study gained the highest percentage of improvement in both groups. This result could be explained by the synergist coactivation of shoulder external rotators during scapular muscles strengthening plus the involvement of shoulder external rotation at different activities of daily living (ADL). This explanation is based on the results of Escamellia et al. (2009), who investigated the normal coactivation between the shoulder muscle groups during different exercises. The results revealed that the shoulder abductors and external rotators, mainly the supraspinatus and the infraspinatus, showed an increased firing activity
by 61% and 20%, respectively, during serratus anterior muscle strengthening through forward pushing exercise.

The synergist coactivation between different shoulder muscles might be also a plausible explanation for the higher percentage of improvement of the shoulder abductors and external rotators found to be (40.66%, 79.83%) for G2 and (7.57%, 20.16%) for G1, in the present study, despite that both groups received the same strengthening program for the mentioned muscles. This explanation might also be acceptable for explaining the improvement of the supraspinatus, upper trapezius, and serratus anterior muscles strength in the control group, despite these muscles were not trained for this group.

The reported differences in the recruitment pattern between the supraspinatus, upper trapezius and serratus anterior muscles that were discussed by Kronberg et al., 1990, Ihashi et al., 1998, David, 2000, Mosely et al., 2002, Cool et al., 2007, and Cael, 2010 could explain the high improvement that occur in the strength of those muscles in both groups. The serratus anterior was reported to be utilized mainly during shoulder elevation and pushing activities by the ULs while the supraspinatus and trapzius muscles were involved at different ranges of shoulder movements and during ADL of different demands of muscles activation.

The results of Prange et al. (2010) showed that the coactivated synergist pattern between the shoulder girdle muscles in patients with mild and moderate stroke were nearly similar to that detected in healthy subjects. The authors reported that the difference of muscle coactivation between the healthy subjects and stroke patients were mainly related to the amount of muscle firing recoded by the Electromypography (EMG).
As all patients participated in the present study were stroke with mildly involved motor control level, the finding of Gerdienke et al. (2010) can support the explanation of significant improvement in the strength of all studied muscles, based on the normal synergist coactivation.

The results of the present study also showed significant improvement in the resting scapular upward rotation angle in both groups. The improvement can be attributed to the relation between scapulothoracic stability and trapezius-serratus anterior force coupling described by Voight et al (2000) (see also Fig. 2.8, P.g. 18, Chapter II).

Because the supraspinatus, trapezius and serratus anterior muscles are postural muscles as reported by Horsley (2005), strength improvement shown in the present study can influence the postural stability of both the shoulder girdle and the proximal trunk.

Improved scapular alignment may also enhance the strength of the shoulder muscles. Mottram (1997) and Cools et al. (2004) discussed the role of trapezius-serratus anterior force coupling in enhancing the proper scapular positioning and providing a mechanical advantage to the muscles working at the shoulder level to generate sufficient tension.

Improved scapular alignment after applying a program of resisted exercises was also found by Alizadeh et al. (2009). The authors investigated the effect of six weeks of successive exercise program on the realignment of protracted scapula in neurologically unimpaired subjects. Their results revealed an improvement in the scapular position by 70% in the study group versus the control group. The improvement was correlated to the improved strength of scapular elevators mainly the trapezius muscle. Results of group B in the present study (20.55 %)
showed less improvement in comparison with the previous study (70%). This can be attributed to the differences in the response between hemiparetic and normal subjects, treatment emphasis and dose of treatment program.

The changes in the resting scapular position reported in the present study can also be explained by the role of active exercises in providing the proprioceptive and cutaneous input that enhanced the postural control (Mosely et al., 1992).

The pushing forward exercise applied to the study group, in the present work, might have a great impact on the shoulder girdle muscles strength, endurance, scapular position and dynamic stability as reported by Lunden et al. (2009).

**Shim et al. (2010)** explained the role of pushing forward exercise, as a closed kinetic chain (CKC) exercise, in providing postural stability through promoting proprioception and facilitating muscle co-contraction. Forward pushing exercise was also reported to activate the trunk muscles bilateral which in turn facilitate the symmetrical alignment of the trunk. In addition, the authors discussed changes in the cortical feed-forward processing that could also affect the postural control.

The variation in the percentage of strength improvement of the shoulder muscles obtained in the present study may provide an explanation for the better improvement of scapular alignment in the study group compared to the control group.

In the present work, spinal lateral deviation alignment was significantly improved in both groups. **Gomes et al (2006)** published a case study that supports the effect of shoulder girdle posture on spinal
alignment in patients with stroke. Only positional stretching exercises, known as Global Postural Re-education (GPR), were applied to the tight scapular and pelvis girdle muscles. The improvement of scapular position and spinal lateral deviation in the previous report were less than that reported in the present study. Variations in the study design and the treatment procedures are the reasons for obtaining such results. Moreover, measuring spinal alignment from standing position in the previous report, instead of sitting, did not eliminate the effect of unequal weight distribution of lower limbs on spinal alignment. Gomes et al. (2006) contributed the improvement in spinal alignment to the effect of the GPR technique in providing better scapular and pelvic alignment.

Although the findings reported by Gomes et al. (2006) cannot be generalized, they were reported in the present study because they highlight the role of manual exercise program in providing a real measurable change in the lateral spinal deviation in patients with stroke.

To our knowledge, there is no published evidence to support the influence of shoulder muscle strength on spinal alignment in patients with stroke. The present study is the first concerning measuring the resting angular alignment of the spine following a selective shoulder girdle strengthening treatment program.

Mottram (1997) and Williams et al., (1995) found that scapulothoracic joint stability, provided mainly by the trapezius-serratus anterior coupling, is considered as an important part of providing core stability of the trunk. They also showed that each part of the body has a unique influence on core stability. This interaction between different body segments is known as the postural kinetic chain. 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 (Horsley, 2005).

In the present study, the improved spinal alignment in G2 (50.76%) compared to G1 (25.13%) might be explained by the higher improvement of the scapular muscles strength, that specifically trained in G2 (the study group). Trunk control exercises may also influence the spinal alignment through enhancing the symmetry between both sides of the trunk as reported by McClure (2011).

Moreover, results of the present study showed a significant improvement in the functional performance of G2 while for G1 the improvement was obtained only in the items concerning transfer from side lying to sitting and balanced sitting.

The upper limb (UL) and hand functions were significantly improved in G2 for almost all the patients except two cases. For the first case, the patient had a lower muscle strength level than other patients in the same group during the pre-testing phase. As a consequence, the stability required at the shoulder girdle to hold the limb weight was insufficient to perform the tasks of higher scoring described on the functional scale (MAS). Therefore, the patient did not gain higher score on the UL or hand movement functions.

For the second case, the patient usually depends on using the non-affected right UL in the ADL. This may explain the unchanged functional scoring level on the post-testing phase despite the improvement in the muscle strength. The same patient showed also less improvement in hand movements for the same reason. The report of Feys et al (1998) could support this explanation; in which the authors revealed the limited improvement of the UL functional performance to the possibility of using
one side during the UL function. While for the lower limb, LL, the functional activities require bilateral use of both sides during standing or walking.

Generally, the significant improvement in the UL and hand movement functions reported for G2 could be explained by the high improvement in proximal stability at the shoulder girdle, scapular and spinal alignment. The results of the present study are supported by the results obtained by Shim et al. (2010). The authors studied the effects of shoulder girdle strengthening on motor performance and reported a significant effect of shoulder stability on UL and the hand functions.

The improvement of the scapular alignment might also have an impact on the upper limb and the hand functions. Raine et al. (2009) showed that maintaining the appropriate alignment of shoulder on trunk facilitates the controlled practice and creates a demand for the anticipated postural adjustments (APAs) needed for the ADL. Stable and properly aligned scapula allows the initiation of hand movement through prepositioning of the proximal segments of the UL.

According to Urquhart et al (2005), body posture can influence the coordination between trunk and ULs during functional activities and dramatically disturb the efficient reaching and grasping. In addition, the results of Woodenbury et al (2009) proved that stable trunk provides a reference point for the extremities to move freely. The author studied the effect of constrained trunk on the functional performance of reaching in patients with stroke and found significant improvement in both pattern of reaching and hand function.

Improvement in the UL functional performance following strengthening exercises was discussed by Weinstein et al. (2004). The
authors evaluated the short and long term effects of strengthening interventions (resisted exercises and functional training exercises) versus spontaneous recovery in acute stroke patients with different motor recovery levels. Manual resisted exercises reported to statistically improve the shoulder muscle strength and functional performance of the UL in patients with stroke than spontaneous recovery. The authors attributed the improvement of functional performance on the Fugl-Meyer scoring to the increased shoulder flexors and extensors strength and sufficient duration of successive therapy.

The results of the present study are contradictory to the findings of Van der Lee et al (1999). The use of "forced arm use" intervention combined with resisted and functional exercises was compared, in the previous report, to the traditional "Bobath therapy" that focused on the bimanual activities in two groups. After six weeks, there was no significant difference between both groups regarding the upper extremities functions measured by the Fugl-Meyer scale. The author explained the results to the presence of some sensory deficits. The differences between the results of the present study and that of Van der Lee et al (1999) can be argued to be due to differences in the patients criteria such as the long illness duration (average 3 years) and the presence of sensory deficits.

In the present study, the significant improvement in the performance of both groups during changing the position from side lying to sitting can be attributed to the improvement in the shoulder girdle strength that enhanced the forward weight shifting required during transfer activities and so made the movement easier and faster. Falvo et al (2010) found that strengthening training allows the motor tasks to be performed with less relative effort and enhanced neural efficiency.
In addition, the CKC exercises, forward pushing, used with G2 may enhance the core stability, improve motor performance and thus make the movement more efficient (Calais-Germain, 1993).

The daily practice of bed mobility in the ADL may explain the similarly in the performance of transfer activity of patients participated in the present study in both groups (p = 0.056). Through the study only two patients of G2 did not show difference in the post-test scoring level during transfer from side lying to sitting. This can be attributed to being dependent and not properly following instructions, despite showing some clinical differences.

Balanced sitting showed also significant improvement in both groups. Raine et al. (2009) reported that realigning and activation of the shoulder complex facilitate the postural activity especially during transfer from one postural set to another through holding the weight of the limb. Therefore, improvement in both of sitting balance and transferring from side lying to sitting for participants in the present study can be explained by the improved proximal stability at shoulder and upper trunk levels. Trunk control exercises were also reported to improve the trunk stability and functional sitting balance in patients with stroke (Karthikbabu et al, 2011), but this was out of the scope of the present study.

Generally, patients of G2 showed higher improvement for sitting balance (p <0.0001) in comparison to those of G1 (p=0.005). This difference can be attributed to the amount of improvement in both shoulder girdle strength and postural alignment. Only five patients, a patient in G2 and four patients in G1, did not improve their score in the post-testing phase of the sitting balance. Fears from falling down during reaching the floor from sitting restricted the patient mobility required for
a higher score. In addition, those patients did not properly follow the given instructions for proper seating positions when at home. Moreover, the low percentage of improvement in the shoulder girdle muscles strength for the four patients in G1 can be added to the reasons for acquiring unvaried score.

The outcomes of the present study represented a significant negative correlation between the supraspinatus (r = -0.67, p=0.0004), serratus anterior (r = -0.88, p<0.0001), and upper trapezius (r = -0.83, p<0.0001) muscles strength and postural alignment of the trunk. In addition, the results showed a significant negative correlation between the scapular alignment and spinal alignment (r = -0.68, p=0.0003). This correlation can be explained by the contribution of the three muscles, as postural muscles, in providing postural stability; in which the trapezius and serratus anterior are considered as superficial trunk muscles. This explanation can be supported by the results of Okada et al. (2011) who reported a significant correlation between the spinal stability and the strength of trunk flexors and extensors (the superficial and deeper trunk muscles) in healthy subjects.

In addition, Cael (2010) report could give a reasonable explanation to the extremely significant correlation between the trunk alignment and trapezius -serratus anterior in comparison to the supraspinatus muscle. The author discussed that the upper trapezius and serratus anterior muscles are normally involved in different neck and spinal movements; side bending, extension and rotation plus their activation during shoulder movements. On the other hand, the supraspinatus works only at the shoulder level.
According to the results of the present work, the suggested null hypothesis can be rejected as there is a significant difference between the pre- and the post-test phases for spinal alignment in both of G1 and G2 groups. In addition, there is a statistical difference between both groups in the post-test phase for both shoulder girdle strength and spinal alignment. For the functional outcomes, the null hypothesis can be rejected G2 while the hypothesis is acceptable for G1 for some of the functional tasks that did not show a statistical improvement on the MAS, for instance; the UL and hand movement functions.

Finally and within the obtained results, preliminary evidence was provided to highlight the role of shoulder girdle muscle strength in influencing the postural alignment of the upper trunk in hemiparetic patients with stroke during both resting position and functional activities. The results also suggested that a relatively uncomplicated exercise program, which focused on the shoulder girdle muscles, was effective in enhancing the strength of scapular muscles and realigning both of the scapula and upper trunk during resting positions.
Chapter VI

Summary, Conclusion and Recommendations
CHAPTER VI

SUMMARY, CONCLUSION, AND RECOMMENDATIONS

The present study was conducted at the out-patient clinic of the Faculty of Physical therapy at Cairo University from December 2010 to January 2012. The purpose of the study was to investigate the effect of shoulder girdle strengthening on the lateral deviation of the trunk in patients with stroke during a static position (sitting) and dynamic activities. In addition, the study aimed at examining whether there is a correlation between the shoulder girdle muscles strength and the trunk alignment.

Twenty-three hemiparetic patients of similar physical characteristics were participated in the study. Participants were randomly assigned into two groups of pre-test and post-test control design. The peak torque of shoulder muscles and the peak force of scapular muscles, the resting scapular upward rotation angle, the spinal lateral deviation angle, and the motor performance were all measured during the pre- and the post-test phases of the study. Patients in both groups received a successive six weeks of shoulder girdle strengthening program as following:

The Control Group (G1): included 10 patients (1 female and 9 male). They received the preparatory stretching exercises for the pectoralis major, latissimus dorsi, rhomboidis major and minor, and teres major muscles. Besides, the active resisted exercises for the shoulder abductors and shoulder external rotators, and active trunk control exercises were applied.

The Study Group (G2): included 13 patients (1 female and 12 male) and received the same protocol applied to G1 in addition to
selective active resisted exercises for the supraspinatus, serratus anterior, and upper fibers of trapezius muscles.

**Findings**

**The analysis of data revealed the following:**

1. The resisted exercises produce a significant difference in the peak torque of shoulder external rotators and abductors in both groups with profound improvement in G2.

2. The resisted exercises produce a significant difference in the peak force of the supraspinatus, upper trapezius, and serratus anterior muscles in both groups with tremendous improvement in G2.

3. The shoulder girdle strengthening exercises, focused mainly on the scapular muscles, reduced the lateral spinal deviation angle in the static sitting posture by a factor of 50.76% for G2 and 25.13% for G1. In addition, the applied protocol showed a pronounced effect on the resting scapular upward rotation angle in G2 (20.55%) compared to (6.27%) in G1.

4. The strength of the scapular muscles; supraspinatus, serratus anterior and upper fibers of trapezius, was significantly correlated with the trunk postural alignment.

5. The impact of the strengthening exercises of the shoulder girdle, focusing on the scapular muscles, was of significant importance in improving the functional motor performance of the sitting balance in both groups while for the upper extremity functions the improvement was significant only in G2.
Conclusion

Within the limitation of the presented study, we conclude that:

1. The strengthening of shoulder girdle muscles is efficient in improving the postural alignment of both spine and scapula in the frontal plane in patients with stroke.

2. The shoulder-trunk postural interaction should be considered as an important key during all stages of post-stroke rehabilitation.

3. Strengthening exercises have a valuable impact on improving the functional motor performance in patients with stroke.

Implementations

The findings of the present study could be implemented in the followings:

The manual resisted shoulder girdle strengthening exercises could be utilized in integration with the postural correction protocol when designing a physical therapy program for patients with stroke.

Recommendations

The shoulder-trunk interaction needs further studies; to clarify the effect of shoulder girdle muscles strength on the trunk alignment.

Within the study limitations, the digital photogrammetry and Corel Draw Graphic software can be recommended as a non invasive method for evaluating and following up the postural alignment regularly post-stroke.
Moreover, the present study gives rise to some additional research topics as follows:

1. Investigating the effect of shoulder girdle alignment on the spinal alignment of hemiplegic patients in standing position, walking, and other different functional activities.

2. Following up the long-term effects of shoulder girdle muscle strengthening programs on the muscle strength, posture, level of balance, and functional outcomes after chronic stroke.

3. Using the 3D analysis system in providing a full view on the trunk alignment in patients with stroke.

4. Differentiating between the contribution of shoulder muscle strength and flexibility in providing proper postural alignment.

5. Measuring the influence of the improvement of shoulder girdle alignment on pelvis obliquity in patients with stroke.

6. Comparing the effect of both the pelvic alignment to that of the shoulder on the body posture in patients with stroke during static positions and dynamic activities.

7. Evaluating the impact of postural alignment on functional performance in patients with stroke of various illness duration, age categories, motor deficits, and perceptual impairments.

8. Investigating the correlation between the postural alignment and the different types of sensory deficits in patients with stroke.

9. Comparing the postural control level in patients with right sided hemiparesis to that in patients with left.
10. Studying the correlation between the trunk postural control level, the location and the size of the cerebral infarction in both static positions and dynamic activities in patients with stroke.


12. Investigating the effect of properly designed seating system on the postural alignment in patients with stroke during different stages of motor recovery.


14. Comparing between the normal mechanical and the patho-mechanical interdependency of the proximal and distal segments alignment of the human body during static position and dynamic activities in neurologically impaired patients.

15. Comparing between the normal and the pathological differences of the anticipatory postural adjustments at different neural levels in neurologically impaired patients during the activities requiring compound shoulder-hand movements and those requiring isolated hand movement.

16. Measuring the normal resting upward scapular rotation and its relation to hand dominance, different physical characteristics, and age categories throughout the Egyptian society.
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Appendices
Appendix I
Consent Form

موافقة على الاشتراك في بحث طبي
كلية العلاج الطبيعي - جامعة القاهرة

عنوان البحث: تأثير تقوية عضلات الحزام الكتفي على استقامة الجذع في مرضى السكتة الدماغية

اسم الباحث: أمينة محمد عبد الحميد عوض

الغرض من البحث: يهدف البحث إلى دراسة تأثير البرنامج العلاجي لتقوية عضلات الحزام الكتفي على الانحناء الجانبي لقؤام الجذع عند مرضى السكتة الدماغية.

الخطوات:

1. يتم أخذ ثلاث قياسات من المريض قبل بدء البرنامج العلاجي وتشمل القياسات: قياس القوة العضلية للحزام الكتفي باستخدام أجهزة متخصصة وقياس لزاوية الدوران العلوي لعظمة اللوح وأيضاً زاوية الانحناء الجانبي للجذع وذلك من خلال تصوير المريض من وضع الجلوس ويتم أيضاً قياس المهارات الحركية للجذع و الطرفين العلويين للمريض باستخدام اختبار حركي مخصص لذلك بححد مهارات المريض الحركية وفقاً لدرجات محددة.

2. يتم تطبيق برنامج علاجي يشمل مجموعة من التمرينات البدوية لتقوية عضلات الحزام الكتفي لمدة 6 أسابيع متناوبة باجمالي 18 جلسة علاجية.

3. يتم إعادة القياسات المذكورة بعد انتهاء المدة العلاجية للبرنامج.

الأخطار: تكاد لا تذكر طبقاً لمعايير الأمان والجودة المتتذجة في البحث العلمي. مصداقية البحث: نتائج هذا البحث يمكن نشرها ولن يتم نشر أي معلومات شخصية عن المريض إلا بموافقة كتابية منك.

المسؤولية العلاجية والمادية في حالات الطوارئ: ستقدم الإسعافات الأولية لمريض على مسؤولية الباحث وأي إصابة تلحق بالمريض أثناء البحث ستبقى على عاتقنا.
الموافقة الشخصية: بعد مراجعة وفهم كل ما جاء في هذا الاقرار قررت أنا المشاركة في الدراسة البحثية بدون إجبار من أحد علماء باتي قد استفيد وقد لا استفيد من نتائج هذه الدراسة ليستفيد آخرون وقد أعطيت نسخة من هذا الاقرار.

الاسم: 
التاريخ: 
توقيع: 

Appendix II
Patient Evaluation Sheet

I- HISTORY
A-Personal history

<table>
<thead>
<tr>
<th>Name</th>
<th>Sex</th>
<th>Serial Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Weight</td>
<td>Occupation</td>
</tr>
<tr>
<td>Diagnosis</td>
<td>Height</td>
<td>Address</td>
</tr>
<tr>
<td>Duration of illness</td>
<td>Special habits</td>
<td>Marital state</td>
</tr>
</tbody>
</table>

Date of evaluation (pretest)
Date of reevaluation (posttest):

B-Present history

Onset: .................................................................
Course: ..............................................................
Duration: ...........................................................

C-Past/medical history

DM: ................................................................. HT:

Fever: .............................................................. Trauma: ............
Previous similar attack: ........................................
Others: .............................................................

Previous rehabilitation history: ............................................................
History of any interventions: .................................................................
Medications: ................................................................

D-Family history

EXAMINATION

II- Neurological Evaluation

(1) Mental state assessment
State of consciousness .................................................................
Orientation ..............................................................
Memory .................................................................
Mode .................................................................
Behavior .................................................................
Intelligence .................................................................

(2) Speech assessment:
-aphasia: ..................-dysarthria: ...........

(3) Motor system
A-by inspection
-Muscle contour: .................................................................
-Involuntary movement: .................................................................

B- Neumotor assessment
-Muscle tone assessment (MAS): .................................................................
Shoulder region muscle tone assessment:

Shoulder Flexors: .................................................................
Shoulder Adductors: .............................................................
Shoulder internal rotators: ......................................................

-Clonus:

-Reflexes Assessment

1-physiological deep reflex
- Biceps reflex (C5-C6): - ..............................................................
- Triceps reflex (C6-C7): - ..............................................................
- Brachioradiates reflex (C5-C6); - ....................................................

2-Pathological deep reflex
- Supraspinatus reflex (C3-C4): ......................................................
- Finger reflex (C5-T1): - ..............................................................
- Adductor reflex (L4): - ..............................................................
- Patellar reflex (L2-L3-L4): .........................................................

3-Superficial reflex
- Planter reflex (S 1, 2) ..............................................................

(4) Sensory assessment

<table>
<thead>
<tr>
<th>Sensory assessment</th>
<th>Intact</th>
<th>Delayed</th>
<th>Decreased</th>
<th>Exaggerated</th>
<th>Impaired</th>
<th>Lost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Superficial sensation</strong></td>
<td></td>
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<tr>
<td>pain</td>
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<td>touch</td>
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<tr>
<td><strong>Deep sensation</strong></td>
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<tr>
<td>Joint position</td>
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<tr>
<td>Joint movement</td>
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<tr>
<td>vibration</td>
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<tr>
<td>Muscle sense</td>
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<tr>
<td>Nerve sense</td>
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<td><strong>Cortical sense</strong></td>
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<td>Tactile localization</td>
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<td>2 points discrimination</td>
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<tr>
<td>Stereognosis</td>
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<tr>
<td>Graphethesia</td>
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<tr>
<td>Paragnosis</td>
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(5) Coordination assessment:
-Non equilibrium assessment:

<table>
<thead>
<tr>
<th>Coordination challenge</th>
<th>Intact</th>
<th>Mild Impairment</th>
<th>Moderate Impairment</th>
<th>Sever Impairment</th>
<th>Impossible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finger to finger</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Finger to nose</td>
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<tr>
<td>Romberg test</td>
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</tbody>
</table>
- Equilibrium assessment:

(6) Trunk balance assessment (Levels of Trunk Control):

<table>
<thead>
<tr>
<th>Level</th>
<th>Pretest</th>
<th>Posttest</th>
</tr>
</thead>
<tbody>
<tr>
<td>Level 1: static sitting</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level 2: sitting while doing active UL activity</td>
<td></td>
<td></td>
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<tr>
<td>Level 3: sitting while doing UL and trunk activity</td>
<td></td>
<td></td>
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<tr>
<td>Level 4: powerful thrust</td>
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<td></td>
</tr>
</tbody>
</table>

III- Musculoskeletal assessment

- Skeletal deformity: .................................................................
- Shoulder stability: .................................................................

1. Shoulder pain assessment: Numeric Rating Scale (NRS)

<table>
<thead>
<tr>
<th>None</th>
<th>Mild</th>
<th>Moderate</th>
<th>Severe</th>
</tr>
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<tbody>
<tr>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
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<tr>
<td>8</td>
<td>9</td>
<td>10</td>
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</tbody>
</table>

2. Shoulder complex Muscle testing:

<table>
<thead>
<tr>
<th>Muscle Group</th>
<th>Pre-test</th>
<th>Post-test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoulders abductor group</td>
<td>Lafayette Manual Muscle Tester (MMT)</td>
<td>isokinetic</td>
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<tr>
<td>Shoulder ext. rot. group</td>
<td>supraspinatus</td>
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</table>

Postural assessment: using Corel Draw program

<table>
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<tr>
<th>Angle</th>
<th>Pre-test</th>
<th>Post-test</th>
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<td>Resting scapular Upward Rotation angle</td>
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<td>Spinal lateral deviation angle</td>
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## Appendix III

### Line Cancellation Task (Masur, 2004)

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<th>Patient Name</th>
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### Appendix IV

**Modified Ashworth Scale - Bohannon and Smith (1987)**

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<th>Score</th>
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<tr>
<td>0</td>
<td>No increase in tone.</td>
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<tr>
<td>1+</td>
<td>Slight increase in muscle tone, manifested by a catch and release or minimal resistance at the end of the ROM when the affected part(s) is moved in flexion or extension.</td>
</tr>
<tr>
<td>1</td>
<td>Slight increase in muscle tone, manifested by a catch, followed by minimal resistance throughout the remainder (less than half) of the ROM.</td>
</tr>
<tr>
<td>2</td>
<td>More marked increase in muscle tone through most of the ROM, but affected part(s) easily moved.</td>
</tr>
<tr>
<td>3</td>
<td>Considerable increase in muscle tone, passive movement difficult.</td>
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<tr>
<td>4</td>
<td>Affected part(s) rigid in flexion or extension.</td>
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Appendix V


<table>
<thead>
<tr>
<th>Stage</th>
<th>Description</th>
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<tr>
<td>1</td>
<td>Stage of initial flaccidity&quot;</td>
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<tr>
<td>2</td>
<td>Developing spasticity</td>
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<tr>
<td>3</td>
<td>Basic limb synergy stage</td>
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<tr>
<td>4</td>
<td>Isolated joint movements stage</td>
</tr>
<tr>
<td>5</td>
<td>Out-of-synergy stage</td>
</tr>
<tr>
<td>6</td>
<td>Near normal stage</td>
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<table>
<thead>
<tr>
<th>Stage</th>
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<tr>
<td>1</td>
<td>The patient is completely flaccid with no voluntary movement at all.</td>
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<td>2</td>
<td>Basic limb synergy develops but with no voluntary movement in which the spasticity, hyper-reflexia, synergies appear.</td>
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<td>3</td>
<td>Spasticity and basic limb synergy are marked, in which the voluntary movements are possible but only in synergies.</td>
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<td>4</td>
<td>A voluntary isolated control is possible, corresponding to decline of spasticity and synergies. Four movement combinations deviate from basic limb synergies and become available, which are: placing the hand behind the body, alternative pronation-supination with the elbow at 90° flexion and elevation of the arm to a forward horizontal position.</td>
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<td>Increasing voluntary control out-of-synergy with coordination deficits is developed. Voluntary movements can be performed as arm raising to a side horizontal position, alternative pronation-supination with the elbow extended and bringing hand over the head.</td>
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<tr>
<td>6</td>
<td>Movement control and coordination are nearly normal.</td>
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## Appendix VI

**Motor Assessment Scale (Carr et al., 1985)**

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<th>Task/scoring (1-6)</th>
<th>Pretest</th>
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<td></td>
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<td>2 Supine to sitting over side of bed</td>
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</tr>
<tr>
<td>3 Balanced sitting</td>
<td></td>
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</tr>
<tr>
<td>6 Upper-arm function</td>
<td></td>
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<td>7 Hand movements</td>
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<tr>
<td>9 General tones</td>
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### CRITERIA FOR SCORING OF MOTOR ASSESSMENT SCORE

1. **Supine to side lying onto intact side**
   1. Pulls himself into side lying. (Starting position must be supine lying, not knees flexed. Patient pulls himself into side lying with intact arm, moves affected leg with intact leg.)
   2. Moves leg across actively and the lower part of the body follows. (Starting position as above. Arm is left behind.)
   3. Arm is lifted across body with other arm. Leg is moved actively and body follows in block. (Starting position as above.)
   4. Moves arm across body actively and the rest of the body follows in block. (Starting position as above.)
   5. Moves arm and leg and rolls to side but overbalances. (Starting position as above. Shoulder and arm flexes forward.)
   6. Rolls to side in 3 seconds. (Starting position as above. Must not use hands.)

2. **Supine to sitting over side of bed**
   1. Side lying, lifts head sideways but cannot sit up. (Patient assisted to side lying.)
   2. Side lying to sitting over side to bed. (Therapist assists patient with movement. Patient controls head position throughout.)
   3. Side lying to sitting over side of bed. (Therapist gives stand-by help by assisting legs over side of bed.)
   4. Side lying to sitting over side of bed. (With no stand-by help.)
   5. Supine to sitting over side of bed. (With no stand-by help.)
   6. Supine to sitting over side of bed within 10 seconds. (With no stand-by help.)

3. **Balanced sitting**
   1. Sits only with support. (Therapist should assist patient into sitting.)
   2. Sits unsupported for 10 seconds. (Without holding on, knees and feet together, feet can be supported on floor.)
3 Sits unsupported with weight well forward and evenly distributed. (Weight should be well forward at the hips, head and thoracic spine extended, weight evenly distributed on both sides.)

4 Sits unsupported, turns head and trunk to look behind. (Feet supported and together on floor. Do not allow legs to abduct or feet to move. Have hands resting on thighs, do not allow hands to move onto plinth.)

5 Sits unsupported, reaches forward to touch floor, and returns to starting position. (Feet supported on floor. Do not allow patient to hold on. Do not allow legs and feet to move, support affected arm if necessary. Hand must touch floor at least 10 cm in front of feet.)

6 Sits on stool unsupported, reaches sideways to touch floor, and returns to starting position. (Feet supported on floor. Do not allow patient to hold on. Do not allow legs and feet to move, support affected arm if necessary. Patient must reach sideways not forward.)

4. Sitting to standing
1 Gets to standing with help from therapist. (Any method.)
2 Gets to standing with stand-by help. (Weight unevenly distributed, uses hands for support.)
3 Gets standing. (Do not allow uneven weight distribution or help from hands.)
4 Gets to standing and stands for 5 seconds with hips and knees extended. (Do not allow uneven weight distribution.)
5 Sitting to standing to sitting with no stand-by. (Do not allow uneven weight distribution. Full extension of hips and knees.)
6 Sitting to standing to sitting with no stand-by help three times in 10 seconds. (Do not allow uneven weight distribution.)

5. Walking
1 Stands on affected leg and steps forward with other leg. (Weight-bearing hip must be extended. Therapist may give stand-by help.)
2 Walks with stand-by help from one person.
3 Walks 3 m (10 ft) alone or uses any aid but no stand-by help.
4 Walks 5 m (16 ft) with no aid in 15 seconds.
5 Walks 10 m (33 ft) with no aid, turns around, picks up a small sandbag from floor, and walks back in 25 seconds. (May use either hand.)
6 Walks up and down four steps with or without an aid but without holding on to the rail three times in 35 seconds.

6. Upper-arm function
1 Lying, shoulder girdle with arm in elevation. (Therapist places arm in position and supports it with elbow in extension.)
2 Tying, hold extended arm in elevation for 2 seconds. (Physical therapist should place arm in position and patient must maintain position with some external rotation. Elbow must be held within 20 degrees of full extension.)
3 Flexion and extension of elbow to take palm to forehead with arm as in 2. (Therapist may assist supinator of forearm.)
4 Sitting, hold extended arm in forward flexion at 90 degrees to body for 2 seconds. (Therapist should place arm in position and patient must maintain position with some external rotation and elbow extension. Do not allow excess shoulder elevation.)
5 Sitting, patient lifts arm to above position, holds it there for 10 seconds, and then lowers it. (Patient must maintain position with some external rotation. Do not allow pronation.)
6 Standing, hand against wall. Maintain arm position while turning body toward wall. (Have arm abducted to 90° with palm flat against the Wall.)

7. Hand movements
1 Sitting, extension of wrist. (Therapist should have patient sitting at a table with forearm resting on the table. Therapist places cylindrical Object in palm of patient's hand. Patient is asked to lift object off the table by extending the wrist. Do not allow elbow flexion.)
2 Sitting, radial deviation of wrist. (Therapist should place forearm in midpronation supination, i.e., resting on ulnar side, thumb in line with forearm and wrist in extension, fingers around a cylindrical object. Patient is asked to lift hand off table. Do not allow elbow flexion or pronation.)
3 Sitting, elbow into side, pronation and supination. (Elbow unsupported and at the right angle. Three-quarter range is acceptable.)
4 Reach forward, pick up large ball of 14 cm (5-in) diameter with both hands and put it down. (Ball should be on table so far in front of patient that lie has to extend arms fully to reach it. Shoulders must be protracted, elbows extended, wrist neutral or extended. Palms should be kept in contact with the ball.)
5 Pick Lip polystyrene cup from table and put it on table across other side of body. (Do not allow alteration in shape of cup.)
6 Continuous opposition of thumb and each finger more than 14 times in 10 seconds. (Each finger in turn tabs the thumb, starting with index finger. Do not allow thumb to slide from one finger to the other, or to go backwards.)

8. Advanced hand activities
1 Picking up the top of a pen and putting it down again. (Patient stretches arm forward, picks up pen top, releases it on table close to body.)
2 Picking up one jellybean from a cup and placing it in another cup. (Teacup contains eight jellybeans. Both cups must be arms' length. Left hand takes jellybean from cup on right and releases it in cup on left.)
3 Drawing horizontal lines to stop at a vertical line 10 times in 20 seconds. (At least five lines must: touch and stop at the vertical line.)
4 Holding a pencil, making rapid consecutive dots on a sheet of paper. (Patient must do at least 2 clots a second for 5 seconds. Patient picks pencil up and positions it without assistance. Patient must hold pen as for writing. Patient must make a dot not a stroke.)
5 Taking a dessert spoon of liquid to the mouth. (Do not allow head to lower towards spoon. Do not allow liquid to spill.)
6 Holding a comb and combing hair at back of head.

9. General tonus
1 Flaccid limb, no resistance when body parts are handled.
2 Some response felt as body parts are moved.
3 Variable, sometimes flaccid, sometimes good tone, sometimes hypertonic.
4 Consistently normal response.
5 Hypertonic 50 percent of the time.
6 Hypertonic at all times.
# Appendix VII

## Raw Data

### Control (G1) Group

**Patients General Characteristics**

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## Control (G2) Group

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Arabic Summary
وجود علاقة عكسية ذات دلالة احصائية بين قوة عضلات الحزام الكتفي و الانحناء الجانبي للجذع.

الخلاصة:

• يستنتج أن تقوية عضلات الكتف تسهم في تحسن زاوية الانحناء الجانبي للجذع في مرضى السكتة الدماغية.
• تقوية عضلات الكتف تسهم في تحسن الاداء الحركي في مرضى السكتة الدماغية.
عنوان الرسالة
تأثير تقوية عضلات الحزام الكتفي على استقامة الجذع في مرضى السكتة الدماغية

يهدف هذا البحث إلى دراسة تأثير التحسن في قوة عضلات الحزام الكتفي على كل من زاوية انحناء الجذع الجانبي في مرضى السكتة الدماغية من وضع الجلوس. وقد أجريت الدراسة بكلية العلاج الطبيعي – جامعة القاهرة خلال الفترة من ديسمبر 2010 حتى يناير 2012 م.

وقد أجري هذا البحث على 22 مريضا تراوح أعمارهم بين (54-61) عاما بمتوسط (50.9 ± 2.6) عاما، وقسمتهم إلى مجموعتين (مجموعة دراسة و مجموعة ضابطة).

جموعة الدراسة: تكوّنت من 12 مريضا (أنثى و 10 ذكر) وقد تلقت هذه المجموعة برنامج العلاج الطبيعي الذي يشمل تمرينات تقوية عضلات الكتف الاتية: العضلة فوق الشوكة والعضلة شبه المنحرفة العلوية والعضلة المثنائية الأمامية بالإضافة إلى برامج العلاج الطبيعي التقليدي والذي يشمل تمرينات بدوية علاجية لطالة عضلات الكتف وتمرينات علاجية أخرى لتموين العضلات الراقبة الجانبية وعضلات الدوران الخارجي للركض بالإضافة إلى تمرينات اتزان الجذع.

المجموعة الضابطة: تكوّنت من 10 مريضا (أنثى و 9 ذكور) وقد تم تطبيق البرنامج التقليدي فقط لها.

قياس: تم قياس قوة العضلات المذكورة وقياس زاوية كل من الدوران العلوي لعظمة اللوح والانحناء الجانبي للجذع كما تم أيضا قياس مستوى الأداء الحركي لمهارات محددة لاتزان الجذع وطرفين العلويين قبل وبعد تطبيق البرامج العلاجي والذي استمر لمدة ستة أسابيع متتالية للمجموعتين.

وقد أظهرت نتائج الدراسة التالي:

- تحسن ذو دلالة إحصائية في جميع العضلات المختبرة للمجموعتين معا و بشكل ملحوظ.
- ذو دلالة إحصائية بالنسبة لمجموعة الدراسة.
- ذو دلالة إحصائية في زاوية الدوران العلوي لعظمة اللوح في المجموعتين معا مع وجود فروق ذو دلالة إحصائية بين المجموعتين حيث كانت نسبة التحسن للمجموعة الضابطة (72.6%) و مجموعة الدراسة (55.2%).
- تحسن ذو دلالة إحصائية في زاوية انحناء الجذع الجانبي في المجموعتين معا مع وجود فروق ذو دلالة إحصائية بين المجموعتين حيث كانت نسبة التحسن للمجموعة الضابطة (51.1%) و مجموعة الدراسة (35.6%).
- تحسن ذو دلالة إحصائية لمستوى الأداء الحركي لجميع المهن العلوية للمهارات الحركية المختبرة لمجموعة الدراسة، أما المجموعة الضابطة فلم تظهر تحسنًا ذو دلالة إحصائية للمهارات الحركية للطرفين العلويين.
تأثير تقوية عضلات الحزام الكتفي على استقامة الجذع في مرضى السكتة الدماغية

أمينة محمد عبد الحميد عوض - قسم العلاج الطبيعي لاضطرابات الجهاز العصبي العضلي و جراحته.


درجة الماجستير.

المستخلص

بعد الاضطراب في استقامة الجذع لدى مرضى السكتة الدماغية، يتسبب هذا الإضطراب في تمكيني من المريض. وبدأت الدراسات التحريجية والوظيفية بين الحزام الكتفي و الجذع من أهم المقتنيات المدرسية لسنوات عديدة، وعلى الرغم مما هو متعارف عليه من أهمية الاتزان في الجذع و مدى تأثيره على وظائف الحزام الكتفي، غير أن دور الحزام الكتفي في المساعدة في تغيير استقامة الجذع لم يدرس بشكل م👻سح لكثير من الوقت، حيث كان الهدف من هذه الدراسة هو دراسة تأثير التحسن في قوة عضلات حزام الكتف على زاوية الاتزان في الجذع الجانبية في مرضى السكتة الدماغية من وضع الجلوس، كما أننا تأثير ذلك على مستوى الأداء الحركي للمريض.

تم تطبيق البحث فعليا على 22 مريضًا يعانون من السكتة الدماغية لمدة من 6 إلى 02 شهراً، وتم تقسيمهم إلى مجموعتين: مجموعة دراسة و مجموعة ضابطة. وتم تطبيق برنامج علاجي يدوي لمدة 6 أسابيع متتالية لتقوية عضلات حزام الكتف، حيث تم تطبيق التمرينات الآلية للمجموعتين معا: تمارين علاجية لطأ الزاوية، وتدوير عضلات الكتف وتمرينات لقوة العضلات الرافعة الجانبية و عضلات الدوران الخارجي للكتف بالإضافة إلى تمارين اتزان الجذع. وتم تلقيم مجموعة الدراسة تمارين إضافية لكل من العضلة فوق الشوكية وعضلة شبه المنحرفية العلوية، وتم إجراء قياسات قوة عضلات الكتف لقياس مستوى الاتزان الجذع، كما تم إجراء قياسات مستوى الاتزان الجذع و المشكلات الأخرى للمرضى. وقد أظهرت النتائج تحسن ذو دلالة إحصائية في جميع العضلات المختبرة، وأيضاً زاوية انحناء الجذع في المجموعتين غير أن الفرق بين المجموعتين كان له أيضاً دلالة إحصائية حيث كانت نسبة التحسن للمجموعة الضابطة (50 %) و مجموعة الدراسة (72 %) بالنسبة لزاوية انحناء الجذع. كما زادت ذات دلالة إحصائية بالنسبة لمستوى الاتزان الجذع لجميع الممارسين المختبرة لمجموعة الدراسة، أما المجموعة الضابطة فلم تظهر تحسناً ذو دلالة إحصائية بالنسبة للاتزان الجذع للمرضى المصابين. وقد أظهر البحث أيضاً تأثير ذلك على مستوى الأداء الحركي، حيث أظهرت النتائج تحسن ذو دلالة إحصائية في جميع الاتزان الجذع المختبرة.

الكلمات الدالة:
عضلات حزام الكتف - القوة العضلية - اضطرابات الجهاز العصبي.
تأثير تقوية عضلات الحزام الكتفي على استقامة الجذع فى مرضى السكتة الدماغية

توطنة
للحصول على درجة الماجستير فى العلاج الطبيعي

مقدمة من
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بكالوريوس العلاج الطبيعي - 2005
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كلية العلاج الطبيعي
جامعة القاهرة
2012