Research Article

# Assessing Scapular Muscle Strength and Force Couple Ratios in Stroke Patients: A Cross-Sectional Study

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**Citation** Khandare Sh, Bhavsar DK. Assessing Scapular Muscle Strength and Force Couple Ratios in Stroke Patients: A Cross-sectional Study. Journal of Modern Rehabilitation. 2024; 18(3):301-309. http://dx.doi.org/10.18502/jmr.v18i3.16416

http://dx.doi.org/10.18502/jmr.v18i3.16416

**Article info:**
**Received:** 31 Jan 2023
**Accepted:** 07 Jun 2023
**Available Online:** 01 Jul 2024

**Keywords:**
Muscle strength; Scapula; Stroke; Force couple

## ABSTRACT

**Introduction:** This study quantifies the differences in individual scapular muscle strength in both arms along with obtaining a force couple ratio of scapula stabilizers to gain values in terms of the strength of muscles.

**Materials and Methods:** A quantitative cross-sectional study was done on 30 stroke patients to assess the muscle strength of the serratus anterior, rhomboids, and upper, middle, and lower trapezius (in both shoulders) using a suspension scale. Meanwhile, the muscle force couple ratios were calculated.

**Results:** The results showed significant strength differences between both arms for upper trapezius (P=0.0020), serratus anterior (P=0.018), rhomboids (P=0.001), middle trapezius (P=0.0068), and no difference for lower trapezius (P=0.1746). The mean muscle strength in the non-affected arm is greater than the affected arm. The middle trapezius strength is lowest in the affected arm (0.574 kgf) and the lower trapezius strength is lowest in the non-affected arm (0.767 kgf). The mean force couple ratio for upper trapezius versus lower trapezius was higher in the affected side (10.08) and the non-affected side (7.74). The remaining force couples were similar for both arms.

**Conclusion:** Overall muscle strength of the scapula stabilizers is greater in the non-affected arm than in the affected arm. The strength of the force couple between the upper and lower trapezius is greater in both arms which shows considerable incoordination between the muscles.

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## Introduction

Stroke is defined as paralysis or weakness on one side of the body contralateral to the site of the lesion [1]. Stroke patients frequently exhibit a combination of muscle weakness or imbalance, decreased postural control, muscle spasticity, poor voluntary control, and body misalignment [2]. Occlusion of the middle cerebral artery is the most common cause of stroke. The upper extremities are more involved in middle cerebral artery syndrome. Upper limb functional impairment is a common consequence of a stroke, affecting approximately 80% of stroke survivors [3].

The scapular stabilizers are frequently compromised by muscle weakness because the paretic arm might alter the scapular position. Such weakness exacerbates upper extremity motor deficits. For the upper limbs to operate well, it is necessary to control movement and maintain scapular posture. At the glenohumeral joint, the scapula provides dynamic stability with controlled movement [2]. The scapular muscles are responsible for providing stability due to their anatomy and biomechanics. The serratus anterior muscle helps stabilize and move the scapula during the elevation of the arm. It attaches from the first 9 ribs to the medial border of the scapula and produces simultaneous scapular upward rotation, posterior tilting, and external rotation [4, 5]. The upper trapezius supports the shoulder against gravity, elevates the scapula, and assists in upward rotation and adduction of the scapula when standing upright. The middle trapezius primarily adducts the scapula, while the lower trapezius depresses and upwardly rotates the scapula. The rhomboid minor and major muscles downwardly rotate the scapula, causing simultaneous elevation and adduction [4, 6, 7].

All the muscles described above work in harmony to produce normal physiological movements through balanced action according to the line of pull which is known as the anatomical force couples. Thus, two equal forces acting in opposing directions to rotate a part about its axis of movement are known as force couples [7]. The upper trapezius muscle combined with the lower trapezius forms the upper force couple [7]. The elevation and depression motions of the upper and lower components, respectively, balance each other out while simultaneously producing scapular upward rotation [6]. The serratus anterior and lower trapezius act in conjunction as the serratus anterior pulls the scapula laterally around the chest wall while the lower trapezius resists maintaining the position of the deltoid tubercle [8]. The middle trapezius and serratus anterior work together to produce upward rotation of the scapula [6]. By stabilizing the medial or vertebral border of the scapula to the thorax, the rhomboid muscles help prevent excessive internal rotation of the scapula at the acromioclavicular joint and offset the lateral translation component of the serratus anterior muscle [5].

After a stroke, there is a low-tone flaccid stage with no voluntary control, followed by a spastic stage. There are significant changes in the glenoid fossa angle in the first flaccid stage due to hypotonia of the trapezius, serratus anterior, and rhomboid muscles, which cause scapular descending revolution, depression, and protraction, which may prompt, thus adding to subluxation. The tone of the flexor is predominant in the upper extremity during the spastic stage, causing scapular withdrawal in retraction and depression with adduction at the shoulder [9]. Reliable outcome measures are required to assess the recovery of muscle strength and the effectiveness of interventions [10]. Various techniques to measure the strength of muscles are available. One such technique is the isometric strength measurement where peak torque generated by a muscle is measured which is an indicator of maximal strength and is a reliable method [10, 11]. Along with testing the isolated strength of muscle, it is important to consider muscle balance within the force couples since the balance can reveal the functional status of the movement [7]. Accordingly, this study quantifies the differences in individual scapular muscle strength in both arms along with obtaining the force couple ratio of the scapula stabilizers to gain values in terms of the strength of muscles and create strengthening regimens in the rehabilitative process.

## Materials and Methods

This was a cross-sectional, quantitative study conducted on 30 hemi-paretic stroke patients at Health Center of Dr. D. Y. Patil Vidyapeeth, Pimpri, Pune. The study span was 6 months, from August 1, 2022, to January 10, 2023. The sampling was done via a purposive method. Considering Mean±SD of affected and non-affected arm's isometric shoulder abduction to be 47.4±15.8 and 32.0±16.5, respectively, according to isometric and isokinetic muscle strength in the upper extremity can be reliably measured in persons with chronic stroke [10], at 95% confidence interval power of 80% the minimum sample size was calculated to be 19 individuals. We used the G*Power software, in this study. Nonetheless, 30 individuals (instead of a minimum of 19) were considered since a larger sample size can improve the precision and reliability of the results. The inclusion criteria were patients with age above 20 years old, suffering from a unilateral stroke at least 6 months earlier, upper extremity spasticity in the range of 1 to 2 (modified Ashworth scale), upper limb Brunnstrom recovery stages above 4, and having a mini-mental state score higher than 24 out of 30. Patients were excluded if they had any difficulty in communicating or understanding test instructions, complete motor disability of the upper extremity, any upper limb fracture or dislocation, and any musculoskeletal condition, such as frozen shoulder, or tendinitis before stroke. The institutional ethical approval was taken from Dr. D. Y. Patil College of Physiotherapy, Pimpri, Pune. The nature of the study was explained and informed consent was taken from the patients meeting the inclusion criteria. Demographic data and basic neurological examination were performed before the testing procedure. The study tools included a suspension scale, two non-elastic belts, and a kettlebell.

## Outcome measure

A suspension scale was used to measure the isometric strength of scapular muscles. The device could measure strength ranging from 10 g to 50 kg and has an accuracy of 5 g (0-10 kg) or 10 g (10-50 kg). The tool is a valid and reliable measure with established values [12].

## Study procedure

The muscle strength of the serratus anterior, the upper, middle, and lower trapezius, and the rhomboids (in both shoulders) was determined in kilogram-force (kgf) using a suspension scale and separately measured for affected and non-affected arms. Next, the ratios of the force couples, upper trapezius versus lower trapezius, serratus anterior versus rhomboids, serratus anterior versus middle trapezius, and serratus anterior versus lower trapezius of the scapulae were calculated for affected and non-affected arm. Each muscle was tested twice and in the same order as follows:

- Upper trapezius: A non-elastic belt was placed around the lateral part of the shoulder over the acromioclavicular joint. The belt was attached to a suspension scale which was stabilized to the other end with a kettlebell and another belt. The patient was asked to stand and then instructed to shrug the shoulder. Maximum isometric contraction was held for a count of 10 (Figure 1).

- Serratus anterior: A non-elastic belt was placed around the distal forearm region. The belt was attached to a suspension scale which was stabilized to the other end with a kettlebell and another belt. The patient was asked to stand and then instructed to maximally protract the shoulder in 130° of sagittal flexion. Maximum isometric contraction was held for a count of 10 (Figure 2).

- Rhomboids: The patient was in the prone lying position. A belt was placed on the distal forearm region. The patient's arm was placed in 45° of abduction, thumb pointing down. The other end of the belt was attached to a suspension scale which was stabilized to the other end


**Figure 1.** Illustrating upper trapezius testing

JMR


**Figure 2.** Illustrating serratus anterior testing

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**Figure 3.** Illustrating rhomboids testing


**Figure 4.** Illustrating middle trapezius testing

with a kettlebell and another belt. Maximum isometric contraction was held for a count of 10 (Figure 3).

● Middle trapezius: The patient was in the prone lying position. A belt was placed on the distal forearm region. The patient's arm was placed in 90° of abduction, thumb pointing up. The other end of the belt was attached to the suspension scale which was stabilized to the other end with a kettlebell and another belt. Maximum isometric contraction was held for a count of 10 (Figure 4).

● Lower trapezius: The patient was in the prone lying position. A belt was placed on the distal forearm region. The patient's arm was placed in 145° of abduction, thumb pointing up. The other end of the belt was attached to a suspension scale which was stabilized to the other end with a kettlebell and another belt. Maximum isometric contraction was held for a count of 10 (Figure 5).

## Statistical analysis

Statistical analyses were performed using the MedCalc software for Windows, version 20.211 (MedCalc Software, Ostend, Belgium), and descriptive analysis was done. Demographic data and clinical characteristics were presented as frequencies, Mean±SD, minimum, and maximum. The Shapiro-Wilk was utilized to test the data distribution of numerical variables. All muscle strength measurements were presented as Mean±SD, minimum, and maximum. Similar analyses were performed using the strength ratios wherein force ratios were calculated by averaging the strength values obtained during the three trials on each side and then by dividing the mean strength for the paretic side and the non-paretic side. The Wilcoxon test for paired samples was employed for the comparison between the affected and non-affected sides' muscle strength. The statistical significance was set at 5% and $P<0.05$ were considered statistically significant.


**Figure 5.** Illustrating lower trapezius testing

# Results

## Patient demographics

The demographic and clinical characteristics of the 30 participants (4 women and 26 men) are presented in Table 1. The Mean±SD of their age was 52±15 years and the mean body mass index was 23.84±2.59 kg/m$^2$. All participants were right-handed and the dominant hand was affected in 37% and non-dominant in 63% of the participants. Spasticity varied between grade 1, 1+, and 2 in 11, 12, and 7 participants respectively according to the modified Ashworth scale. The Brunnstrom recovery stages varied between 4, 5, and 6 in 3, 17, and 10 participants, respectively.

## Strength measurements

Table 2 shows upper trapezius strength (mean) is the greatest in both arms followed by the serratus anterior muscle. There is decreased strength in rhomboids, and middle, and lower trapezius muscles in both arms among which middle trapezius strength is lowest in the affected arm and lower trapezius strength is lowest in the non-affected arm. Here, the values of P show significance for individual muscle strength. The strength of the upper trapezius (P=0.0406), serratus anterior (P<0.0001), rhomboids (P<0.0001), middle trapezius (P=0.0010), and lower trapezius (P<0.0001) is significant for the affected arm. Similarly, the strength of serratus anterior (P=0.0003), rhomboids (P=0.0280), middle trapezius (P<0.0001), and lower trapezius (P=0.0001) is significant for a non-affected arm. However, the strength of the upper trapezius (P=0.1892) is statistically not significant for the non-affected arm (Figure 6).

## Force couple ratio measurements

Table 3 shows that the mean force couple ratio for upper trapezius versus lower trapezius was higher in the affected side, as well as the non-affected side. The remaining force couples are nearly similar for both arms (Figure 7).

## Strength differences measurement

Table 4 shows that there are significant strength differences for the upper trapezius, serratus anterior, rhomboids, and middle trapezius for both arms whereas no significant difference is found for the lower trapezius muscle for both arms.

# Discussion

This study evaluated scapular muscle strength and force couple ratios in stroke patients. The study's findings revealed that the muscle strength of the scapula stabilizers is greater in the non-affected arm as compared to the affected arm. Muscle strength of the upper trapezius and serratus anterior is greater for affected and non-affected arms as compared to the rhomboids, middle and lower trapezius muscles. Furthermore, the strength of the middle trapezius is lowest in the affected arm, and

**Table 1.** Demographic and clinical characteristics of the patients

| Characteristics | | Mean±SD/No. (%) |
|---|---|---|
| Age (y) | | 52±15 |
| Gender | Male<br>Female | 26(86.66)<br>4(13.33) |
| BMI (kg/m$^2$) | | 23.84±2.59 |
| Recovery stage (mean)<br>1. Stage 4<br>2. Stage 5<br>3. Stage 6 | | 5<br>3(10)<br>17(56.6)<br>10(33.33) |
| Spasticity | Grade 1-<br>Grade 1+<br>Grade 2- | 11(36.66)<br>12(40)<br>7(23.33) |
| Dominance | Right<br>Left | 30(100)<br>0(0) |
| Paretic Side | Right affected<br>Left affected | 11(37)<br>19(63) |

SD: Standard deviation; BMI: Body mass index.

**Table 2.** Individual strength (kgf) in affected and non-affected arms (n=30)

| Muscle | | Minimum | Maximum | Mean±SD | P |
|---|---|---|---|---|---|
| Affected arm | UT | 0.373 | 6.507 | 2.4335±1.6472 | 0.0406 |
| | SA | 0.31 | 7.11 | 1.5825±1.5203 | <0.0001 |
| | RH | 0.055 | 3.3 | 0.6653±0.6572 | <0.0001 |
| | MT | 0.095 | 1.72 | 0.5743±0.4626 | 0.0010 |
| | LT | 0.04 | 4.335 | 0.6922±0.8513 | <0.0001 |
| Non-affected arm | UT | 0.155 | 8.495 | 3.7008±2.1128 | 0.1892 |
| | SA | 0.305 | 6.24 | 2.1701±1.615 | 0.0003 |
| | RH | 0.165 | 2.51 | 1.0662±0.7059 | 0.0280 |
| | MT | 0.22 | 4.165 | 0.8886±0.8226 | <0.0001 |
| | LT | 0.106 | 2.705 | 0.7677±0.6464 | 0.0001 |

Abbreviations: UT: Upper trapezius; LT: Lower trapezius; MT: Middle trapezius, SA: Serratus anterior; RH: Rhomboids. JMR

**Table 3.** Force couple ratio in affected and non-affected arms (n=30)

| Ratio | | Minimum | Maximum | Mean±SD | P |
|---|---|---|---|---|---|
| Affected arm | UT: LT | 0.27 | 125.75 | 10.08±22.96 | <0.0001 |
| | SA: RH | 0.31 | 19.05 | 3.69±3.94 | <0.0001 |
| | SA: MT | 0.32 | 10.6 | 3.75±3.17 | 0.0030 |
| | SA: LT | 0.2 | 17.77 | 3.66±3.54 | <0.0001 |
| Non-affected Arm | UT: LT | 0.49 | 41.11 | 7.74±7.90 | <0.0001 |
| | SA: RH | 0.4 | 16.67 | 3.03±3.51 | <0.0001 |
| | SA: MT | 0.12 | 17.39 | 3.85±3.93 | <0.0001 |
| | SA: LT | 0.53 | 15.58 | 4.52±4.44 | <0.0001 |

Abbreviations: UT: Upper trapezius; LT: Lower trapezius; MT: Middle trapezius; SA: Serratus anterior; RH: Rhomboids. JMR

**Table 4.** Comparison between strength (kgf) in the affected and non-affected arm (n=30)

| Strength Differences | Mean±SD | P |
|---|---|---|
| UT | 1.2673±2.0368 | 0.0020 |
| SA | 0.5876±1.6005 | 0.0018 |
| RH | 0.4009±0.585 | 0.0001 |
| MT | 0.3143±0.7268 | 0.0068 |
| LT | 0.07547±0.7581 | 0.1746 |

Abbreviations: UT: Upper trapezius; LT: Lower trapezius; MT: Middle trapezius; SA: Serratus anterior; RH: Rhomboids. JMR

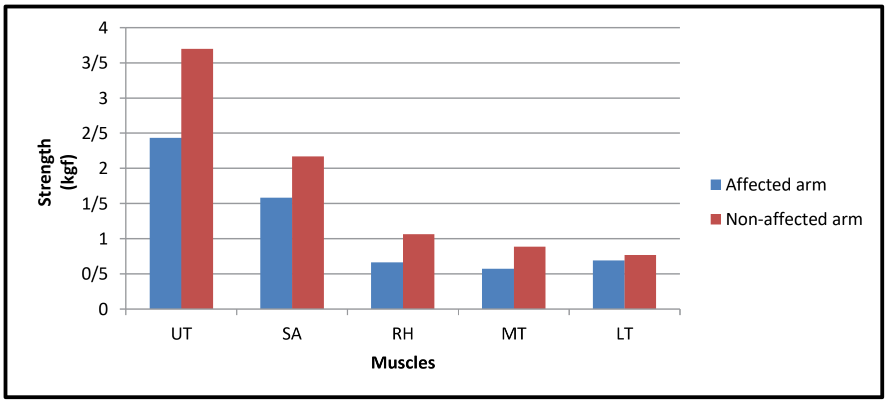


**Figure 6.** Illustrating muscle strength for both arms

JMR

Abbreviations: UT: Upper trapezius; LT: Lower trapezius; MT: Middle trapezius; SA: Serratus anterior; RH: Rhomboids.

the strength of the lower trapezius is lowest in the non-affected arm.

While considering force couple ratios, the mean force couple measurement between the upper and lower trapezius is found to be greatest for both arms as compared to other force ratios which shows that there is considerable incoordination between upper and lower trapezius muscles.

The results of this study can be justified by those of previous research that has shown that there are numerous scapular muscles, with serratus anterior, upper trapezius and rhomboids being the most significant for preserving the position of the scapula. To provide stability and mobility of the scapula at rest and during shoulder movements, these muscles must interact efficiently [4]. Previous research has shown that individuals with scapula dyskinesia exhibit abnormally high levels of activity in the upper trapezius, posterior deltoids, lower trapezius, and rhomboids, as well as abnormally low levels of activity in these muscles. These altered muscle activation patterns are linked to changes in scapular kinematics, such as decreased scapular upward rotation, external rotation, and posterior tilt [13].

According to De Baets, the scapula needs to be properly positioned to produce effective movement of the shoulder. Patients with stroke had a decreased capacity to perform isolated and specific arm motions during motor functional tasks of the upper extremity due to the abnormal nature of scapula humeral muscles and scapula thoracic incoordination.

According to Briel et al. [7], physiologically, both the strength of the individual muscles and muscle groups as well as the muscular balance within force couples should be considered. As therapists, it is in our best interests to determine typical muscular strength values. This is especially true for the scapular stabilizers, where only the individual muscles are tested and the force couple ratios are ignored.

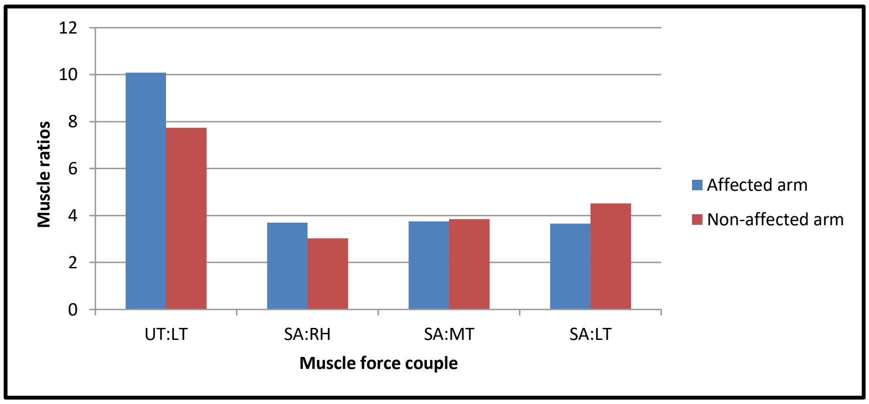


**Figure 7.** Illustrating muscle force couple ratios for both arms

JMR

Abbreviations: UT: Upper trapezius; LT: Lower trapezius; MT: Middle trapezius; SA: Serratus anterior; RH: Rhomboids.

The evaluation of scapular kinematics can be made beneficial by the determination of typical values for the various force couple ratios of the scapular stabilizers. The scapular stabilizing muscles support the scapula both statically and dynamically. As a result, knowing the values of the force couple ratios is critical for rehabilitation and evaluation. The force couple ratios presented here can be used as a guide for rehabilitation by clinicians.

Strength training is recommended to improve motor function in post-stroke patients even years after a stroke, so the reliability of strength measurements must be determined to assess strength improvement [14]. A study conducted by Bertrand et al. [15] confirmed that maximum static strength as well as a strength ratio measurement in hemiparesis patients is reliable. The findings of this study support the concept that strength is a determinant of upper limb function in hemi paretic patients and that the difficulty in providing adequate proximal limb stabilization may limit movements produced at more distal joints.

The present study requires to include scapular muscle strengthening exercises. Additionally, maintaining the force couple of the scapulae, which has been altered as a result of muscle imbalance, and creating targeted exercises based on the strength of the scapula stabilizers will help patients with hemiparesis have better shoulder function and experience less pain and disability.

## Conclusion

In an era when there is a call for more objective, sensitive, and measurable evaluation methods, the findings presented here could aid in the creation of a database for scapular muscle force measurements. The advantage of knowing the values of the scapular stabilizers in the study can be utilized to create strengthening programs in the stroke rehabilitation process.

### Study limitations

This study faced some limitations. There were unequal numbers of male and female participants in the study due to which strength differences were not measured separately for males and females.

## Ethical Considerations

### Compliance with ethical guidelines

This research was approved by the Ethics Committee of Dr. D.Y Patil College of Physiotherapy, Pimpri, Pune (Code: DYPCPT/ISEC/20/2022).

### Funding

This research did not receive any grant from funding agencies in the public, commercial, or nonprofit sectors.

### Authors' contributions

Study supervision: Shilpa Khandare; Methodology, data collection and writing: Dharti Bhavsar.

### Conflict of interest

The authors declared no conflict of interest.

### Acknowledgments

The authors would like to thank Tushar J. Palekar, at Dr. D.Y Patil College of Physiotherapy, Pimpri, Pune for giving us this opportunity to conduct this study.

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