Research Article

Assessment of scapular muscle strength and force couple ratios in stroke patients: A cross sectional study

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ABSTRACT
Introduction: This study aimed to quantify the differences in individual scapular muscle strength in both the arms along with obtaining force couple ratio of scapula stabilisers in order to gain values in terms of strength of muscles.
Materials and Methods: A quantitative cross sectional study in 30 stroke patients to assess the muscle strength of the serratus anterior, rhomboids, upper, middle and lower trapezius (in both shoulders) using a suspension scale was done. The muscle force couple ratios were calculated.
Result: 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 non affected arm is greater than the affected arm. The middle trapezius strength is lowest in affected arm (0.574kgf) and lower trapezius strength is lowest in non affected arm (0.767kgf). The mean force couple ratio for upper trapezius versus lower trapezius was higher in the affected side (10.08) and non affected side (7.74).The remaining force couples were similar for both the arms.
Conclusion: The study concluded that overall muscle strength of the scapula stabilisers 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 found to be greater in both arms which shows considerable incoordination between the muscles.
Keywords: Muscle strength, Scapula, Stroke, Force couple

1. 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].
It has been found that the scapular stabilizers are frequently compromised by muscle weakness due to which the paretic arm might alter scapular position. Such weakness exacerbates upper extremity motor deficits. For the

upper limbs to operate well, it is necessary to be able 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 to provide stability due to their anatomy and biomechanics. The serratus anterior muscle helps stabilize and move the scapula during elevation of the arm. It attaches from first 9 ribs till medial border of 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 own axis of movement are known as force couples [7]. The upper trapezius muscle combined with 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 scapula laterally around chest wall while the lower trapezius resists maintaining position of 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 in order to assess the recovery of muscle strength and the effectiveness of interventions [10].Various techniques to measure 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 isolated strength of muscle it is important to consider muscle balance within the force couples since the balance can reveal about the functional status of the movement [7]. Along these lines, the purpose of this study was to quantify the differences in individual scapular muscle strength in both the arms along with obtaining the force couple ratio of the scapula stabilizers in order to gain values in terms of strength of muscles and create strengthening regimens in the rehabilitative process.

2. Materials and Methods

This was a cross sectional, quantitative study conducted on 30 hemi paretic stroke patients at Dr. D. Y. Patil Vidyapeeth, Pimpri, Pune. The study span was 6 months extending from 1st August 2022 to 10th January 2023.The sampling method was a purposive method and by considering mean and 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. The software used was G*Power. However, 30 individuals (instead of minimum 19) were considered since a larger sample size can improve the precision and reliability of the results. The inclusion criteria included patients with age above 20 years old with having suffered 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 having any musculoskeletal condition such as frozen shoulder, tendinitis prior to stroke. The institutional ethical approval was taken from Dr. D. Y.Patil College of Physiotherapy, Pimpri, Pune (DYPCPT/ISEC/20/2022). 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 was performed prior to the testing procedure. Study tools included suspension scale, two non-elastic belts and a kettle bell.

2.1. Outcome Measure

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

2.2. 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 arm. 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 was 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 acromioclavicular joint. The belt was attached to a suspension scale which was stabilized to the other end with a kettle bell and another belt. 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 distal forearm region. The belt was attached to a suspension scale which was stabilized to the other end with a kettle bell and another belt. 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: Patient was in prone lying position. A belt was placed on distal forearm region. Patient’s arm was placed in 45° of abduction, thumb pointing down. Other end of the belt was attached to suspension scale which was stabilized to the other end with a kettle bell and another belt. Maximum isometric contraction was held for a count of 10 (Figure 3).
- Middle trapezius: Patient was in prone lying position. A belt was placed on distal forearm region. Patient’s arm was placed in 90° of abduction, thumb pointing up. Other end of the belt was attached to suspension scale which was stabilized to the other end with a kettle bell and another belt. Maximum isometric contraction was held for a count of 10 (Figure 4).
- Lower trapezius: Patient was in prone lying position. A belt was placed on distal forearm region. Patient’s arm was placed in 145° of abduction, thumb pointing up. Other end of the belt was attached to suspension scale which was stabilized to the other end with a kettle bell and another belt. Maximum isometric contraction was held for a count of 10 (Figure 5).

Figure 1, Illustrating Upper trapezius testing

Figure 2, Illustrating Serratus anterior testing

Figure 3, Illustrating Rhomboids testing **Figure 4,** Illustrating Middle trapezius testing

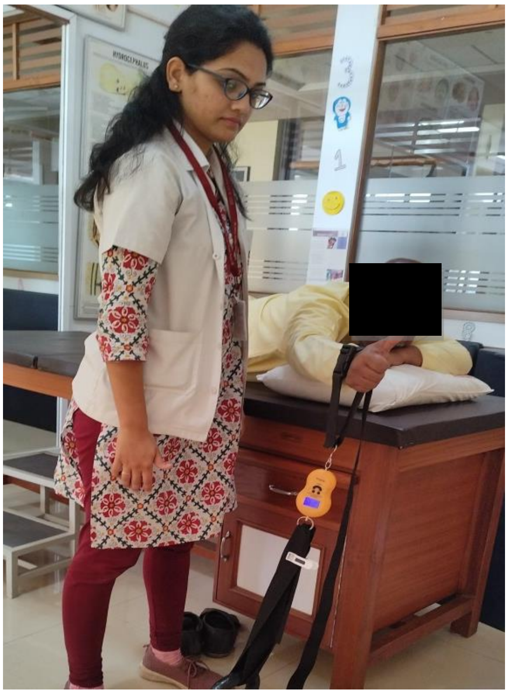

Figure 5, Illustrating Lower trapezius testing

2.3. Statistical Analysis

Statistical analyses were performed using MedCalc for Windows, version 20.211 (MedCalc Software, Ostend, Belgium) and descriptive analysis was done. Demographic data and clinical characteristics were presented as frequencies, means and standard deviations (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, minimum, maximum and SD. 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. Wilcoxon test for paired samples was employed for the comparison between the affected and non affected sides' muscle strength. Statistical significance was set at 5% and p-values less than 0.05 were considered statistically significant.

3. Results

3.1. Patient Demographics

In Table 1, the demographic and clinical characteristics of the 30 participants (4 women and 26 men) were presented. Their mean age was 52 years (SD-15) and the mean BMI was 23.84 kg/m^2(SD-2.59). 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 Modified Ashworth scale. The Brunnstrom recovery stages varied between 4, 5, and 6 in 3, 17 and10 participants respectively.

Table 1. Demographic and clinical characteristics of the patients

Characteristics	
Age, mean (SD) (years)	52 (15)
Gender	
1. Male	26(86.66%)
2. Female	4(13.33%)
BMI, mean (SD) (kg/m^2)	23.84 (2.59)
Recovery stage; mean	5
1. Stage 4	3(10%)
2. Stage 5	17(56.6)
3. Stage 6	10(33.33%)
Spasticity	
1. Grade 1-	11(36.66%)
2. Grade 1+	12(40%)
3. Grade 2-	7(23.33%)
Dominance	
1. Right	30
2. Left	0
Paretic side	
1. Right affected	11 (37%)
2. Left affected	19(63%)

3.2. Strength Measurements

Table 2 shows upper trapezius strength (mean) is found to be the greatest in both the arms followed by serratus anterior muscle.There is decreased strength in rhomboids, middle and lower trapezius muscles in both arms among which middle trapezius strength is lowest in affected arm and lower trapezius strength is lowest in non affected arm. Here, the P values show significance for individual muscle strength. The strength of 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 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 non-affected arm. However, the strength of upper trapezius (p=0.1892) is statistically not significant for non-affected arm.

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

Muscle	**Minimum**	**Maximum**	**Mean**	**SD**	**P value**
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.

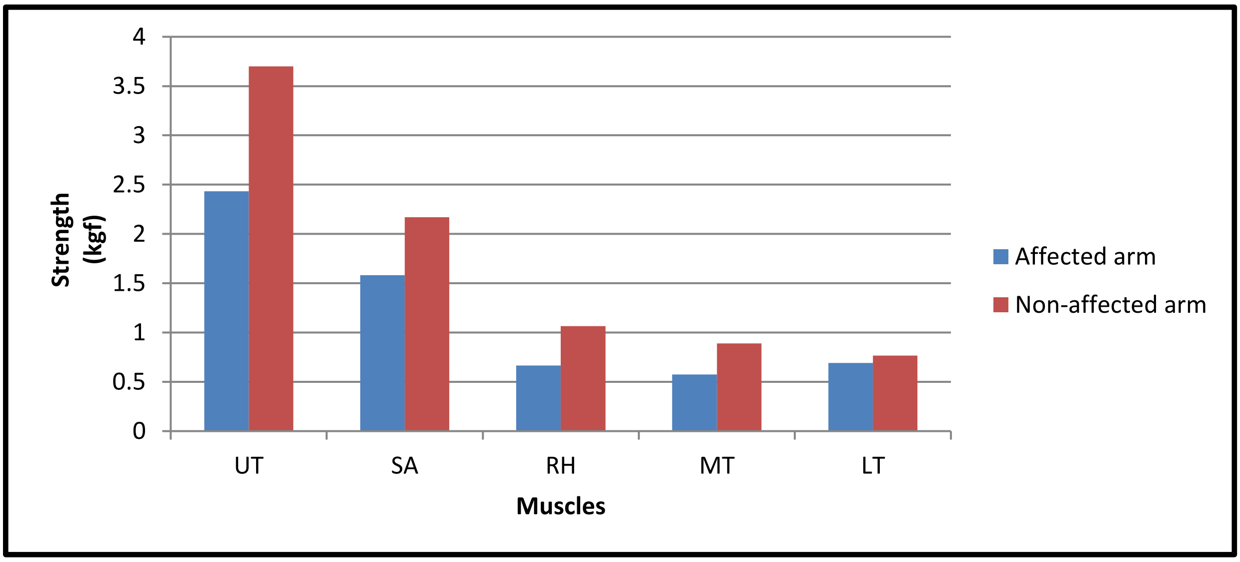

Figure 6. Illustrating muscle strength for both arms**. Abbreviations**: UT; upper trapezius, LT; lower trapezius, MT; middle trapezius, SA; serratus anterior, RH; rhomboids

3.3. Force couple ratio Measurements

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

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

Ratio	**Minimum**	**Maximum**	**Mean**	**SD**	**P value**
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.

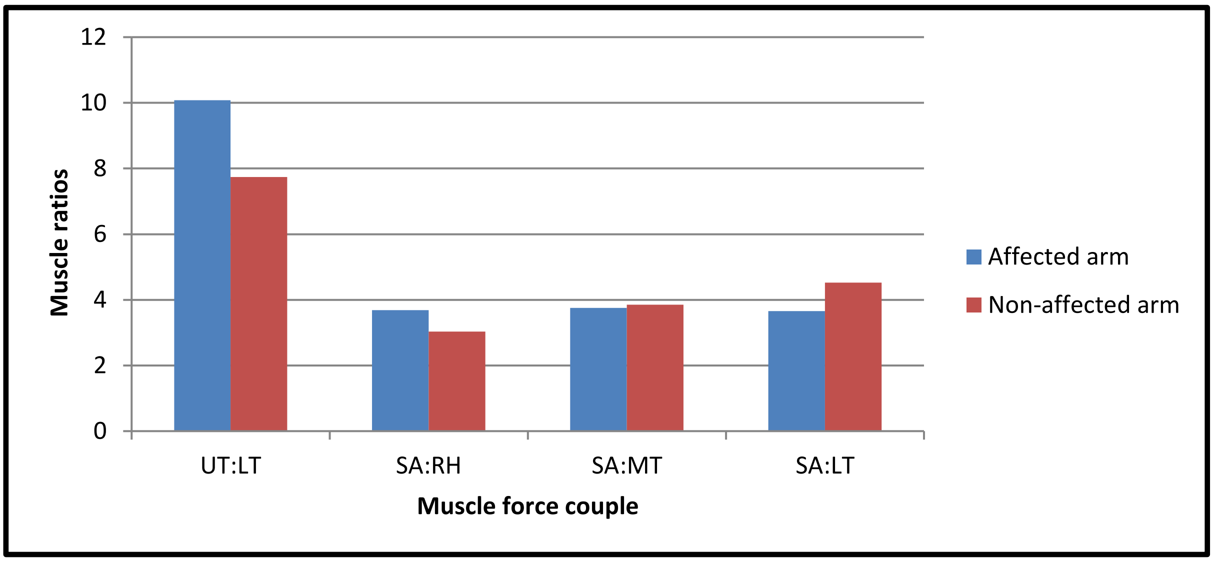

Figure 7. Illustrating muscle force couple ratios for both arms**. Abbreviations**: UT, upper trapezius; LT, lower trapezius; MT, middle trapezius; SA, serratus anterior; RH, rhomboids.

3.4. Strength Differences Measurement

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

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

Strength differences	**Mean**	**SD**	**P value**
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.

4. Discussion

The purpose of this study was to evaluate 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 upper trapezius and serratus anterior is greater for affected and non affected arm as compared to the rhomboids, middle and lower trapezius muscles. Furthermore, the strength of middle trapezius is lowest in the affected arm and strength of lower trapezius is lowest in the non affected arm.

While considering force couple ratios it is found that 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 to those of previous research that have 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. In order to provide stability and mobility of the scapula at rest and during shoulder movements, these muscles must interact efficiently (Paine RM, Voight, 1993). 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 in order 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, Oliver et al physiologically, both the strength of the individual muscles and muscle groups as well as the muscular balance within force couples should be taken into account. 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.

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 in order to assess strength improvement (Richard W. Bohannon, 2007). A study conducted by Bertrand et al proved 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 necessitates the need to include scapular muscle strengthening exercise. 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 stabilisers will help patients with hemiparesis have better shoulder function and experience less pain and disability.

Our study had its limitations. There were unequal number of male and female participants in the study due to which strength differences were not measured separately for male and female.

5. Conclusion

In an era when there is a call for a 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 about the scapular stabilizers in the study can be utilized to create strengthening programs in the stroke rehabilitation process.

Ethical consideration

This research was approved by the ethical committee of Dr. D.Y Patil College of Physiotherapy**,** Pimpri, Pune
Ethical code –DYPCPT/ISEC/20/2022

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Authors' Contribution

Supervision – Dr. Shilpa Khandare
Methodology, Data collection, original draft writing and editing – Dr. Dharti Bhavsar

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Conflict of interest

The authors declared no conflict of interest.

7. References

1. O'Sullivan SB. *Physical Rehabilitation*. 5th ed. Philadelphia, PA: F.A. Davis Company; 2007. p. 471-474
2. Park S-E, Kim Y-R, Kim Y-Y. Immediate effects of scapular stabilizing exercise in chronic stroke patient with winging and elevated scapula: A case study. J Phys Ther Sci. 2018;30(1):190-3.
3. Jadhav R, Pazare S. Effect of scapular kinesiotaping as an adjunct to dynamic neuromuscular stabilization exercises on upper extremity functions in stroke patients. Int J Health Sci Res. 2022;12(1):13-22.
4. Paine RM, Voight M. The role of the scapula. J Orthop Sports Phys Ther. 1993;18(1):386-91.
5. Levangie PK, Norkin CC, Lewek MD. *Joint Structure & Function: A comprehensive analysis*. Philadelphia, PA: F.A. Davis Company; 2019. p. 259-261.
6. Oatis CA. *Kinesiology: The mechanics and pathomechanics of human movement*. Philadelphia, PA: Wolters Kluwer; 2017.
7. Briel S, Olivier B, Mudzi W. Scapular force: Couple ratios in healthy shoulders - an observational study reflecting typical values. S Afr J Physiother. 2022;78(1).
8. Johnson G, Bogduk N, Nowitzke A, House D. Anatomy and actions of the trapezius muscle. Clin Biomech. 1994;9(1):44-50.
9. Mahmoud LS, Aly SM. The effect of Scapular Dyskinesia on the scapular balance angle and upper extremity sensorimotor function in stroke patients with spasticity. Bull Fac Phys Ther. 2020;25(1).
10. Ekstrand E, Lexell J, Brogårdh C. Isometric and isokinetic muscle strength in the upper extremity can be reliably measured in persons with chronic stroke. J Rehabil Med. 2015;47(8):706-713.
11. Nascimento LR, Teixeira-Salmela LF, Polese JC, Ada L, Faria CD, Laurentino GE. Strength deficits of the shoulder complex during isokinetic testing in people with chronic stroke. Braz J Phys Ther. 2014;18(3):268-275.
12. Ueda A, Mitani Y, Koda H, Omine T, Inada R, Konishi N, et al. Verification of shoulder external rotators strength measurement using a suspension scale. Cureus. 2022.
13. Tang L, Chen K, Ma Y, Huang L, Liang J, Ma Y. Scapular stabilization exercise based on the type of scapular dyskinesis versus traditional rehabilitation training in the treatment of periarthritis of the shoulder: Study protocol for a randomized controlled trial. Trials. 2021;22(1).