



Effects of dynamic scapular muscle exercises on grip strength in young adults

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Abstract

Introduction: The functions of the upper extremities are executed by proximal stability and distal functional movements. The muscles surrounding the scapula provide proximal stability for the upper extremity and act as a fix when the distal part is moving. The purpose of this study was to determine the effects of dynamic scapular exercises on grip strength in young adults so as to discuss the efficacy of proximal stability (scapular stability) on distal function (hand grip strength) and also to discuss the available literature most closely pertaining to the kinetic chain theory with regard to scapular muscle strength so that the proposed approach can lead to improvements in individuals with grip strength issues.

Materials and Methodology: Thirty male individuals between the ages of 18-29 were included in this study. The intervention involved dynamic scapular muscle strengthening exercises targeting the Scapular Stabilizing muscles over duration of 4 weeks (thrice a week). Pre and post intervention grip strengths were measured using a sphygmomanometer. The mean of three reading was recorded for data calculations.

Results: Pre-intervention and Post-intervention grip strengths were compared using the paired t-test and the results were extremely significant with $p < 0.0001$.

Conclusion: Dynamic Scapular muscle strengthening exercises significantly increased grip strength in young adults.

Keywords: grip strength, scapula, kinetic chain, proximal segments, distal segments

Introduction

The most important functions of the upper extremity for independent and smooth activities of daily living are the functions of the hand. A representative function of the hand is to hold something. The strength of the fingers when holding something is known as grip strength and it is an important index in the evaluation of motor function of the hand [1].

It is widely accepted that grip strength provides an objective index of the functional integrity of the upper extremity. Physical and occupational therapists commonly measure grip strength to monitor the success or failure of their treatment programs, besides, grip strength serves to be an important contributor to quality of life, functional ability, and independence [2].

Also, grip strength is an important component in the proper execution of daily living activities as well as in various sports movements [3].

Dynamic upper extremity dominant tasks such as throwing, hitting, and serving occur as the result of the integrated, multisegmented, sequential joint motion, and muscle activation system known as the kinetic chain, in upper extremity dominant tasks, the energy development and output follows a proximal to distal sequencing. Proper utilization of the kinetic chain allows maximal force to be developed in the core which can then be efficiently transferred to the arm during these actions. In order for the tasks to be effective and efficient, the kinetic chain links (the different body segments)

must have optimal amounts of muscle flexibility, strength, proprioception, and endurance as well as the ability to perform the task consistently on a repetitive basis. Impairment of one or more kinetic chain links can create dysfunctional biomechanical output leading to pain and/or injury [4].

The functions of the upper extremities are executed by proximal stability and distal functional movements. The muscles surrounding the scapula provide proximal stability for the upper extremity and act as a fix when the distal part is moving. The scapula also acts as an axis, transmitting the power and high energy of the lower extremities and trunk to the upper extremities. Therefore, the upper extremities which play an important role in functional performance of daily living activities, will work better when the stability of scapula is secured [1].

In that context, Alexander *et al.* demonstrated that coordinated control of the shoulder girdle muscles is necessary to properly position the hand for delicate manipulation [3, 5].

When the scapula fails to perform its stabilization role, shoulder complex function is inefficient causing impairment in the kinetic chain link of the upper extremity which can result not only in decreased neuromuscular performance but also may predispose the individual to injury of the upper quarter [6].

It is important that the clinician have a thorough understanding of the muscles that control the scapula and normal scapular mechanics. The scapulothoracic articulation

is one of the least congruent joints in the body. No actual bony articulation exists between the scapula and thorax, which allows tremendous mobility in many directions including protraction, retraction, elevation, depression, anterior/posterior tilt, and internal/external and upward/downward rotation. When describing scapular positions, the point of reference is the glenoid.

The scapular stabilizing muscles are

Serratus Anterior

The serratus anterior is an important scapular stabilizing muscle. It originates from the first eight ribs and courses along the rib cage to insert along the anterior medial aspect of the scapula. Due to the multiple attachment sites, the primary role of the serratus anterior is to stabilize the scapula during elevation and to pull the scapula forward and around on the thoracic cage. Three-dimensional studies have shown that the serratus anterior contributes to all components of 3-D scapular movements during arm elevation, which includes upward rotation, posterior tilt, and external rotation ^[6].

Rhomboids

The rhomboids (major and minor) function to stabilize the medial border of the scapula. The rhomboids are very active in scapular adduction or retraction, which can be defined as backward rotation of the scapula toward the vertebral column. The rhomboid minor originates from the spinous process of the seventh cervical and first thoracic vertebrae and inserts into the medial border of the scapula near the base of the scapular spine. The rhomboid major originates from the second through fifth thoracic vertebrae and inserts into the medial scapular border of the scapula just below the insertion of the minor.

Trapezius (Upper fibres/ Middle Fibres/ Lower Fibres)

The trapezius takes origin from the medial third of the superior nuchal line, external occipital protuberance, nuchal ligament, and spinous processes of C7 to T12 vertebrae and attach distally at the lateral third of the clavicle, acromion and spine of the scapula. The trapezius functions include upward rotation and elevation for the upper trapezius, retraction for the middle trapezius, and upward rotation and depression for the lower trapezius

Pectoralis minor

The pectoralis minor is an anterior muscle that takes origin from the axial skeleton (second through sixth ribs) and inserts into the medial aspect of the coracoid process of the scapula. Pectoralis minor functions to perform several movements abduction, depression, downward rotation and anterior tilt of the scapula ^[6]. With normal physiologic movement, the scapular muscles act in concert with one another ^[7].

Most of the abnormal biomechanics and overuse injuries that occur about the shoulder girdle, elbow and the wrist can be traced to alterations in the function of the scapular-stabilizing muscle. Weakness of the scapulothoracic muscles most commonly being the serratus anterior and lower trapezius, potentially leads to abnormal movement and abnormal positioning of the scapula, disturbances in scapulohumeral rhythm, and generalized upper quarter dysfunction ^[8].

The purpose of this study was to determine the effects of dynamic scapular exercises on grip strength in young adults so as to discuss the efficacy of proximal stability (scapular stability) on distal function (hand grip strength) and also to discuss the available literature most closely pertaining to the kinetic chain theory with regard to scapular muscle strength so that the proposed approach can lead to improvements in individuals with grip strength issues.

Materials and Methods

An experimental study was designed with ethical clearance approval, which included 30 voluntary male participants. Healthy male volunteers between the ages of 18-29 were recruited to participate in this study. To participate, the volunteers should be having complete ROM at the shoulder, elbow and the wrist. Exclusion criteria included any individual with injury, pain or any symptomatic neurologic, orthopedic or musculoskeletal dysfunction. An individual was also excluded if he performed any sport activity on a competitive level or more frequently than thrice a week. Prior to the exercises, consent of the participant was taken & the investigator clarified & confirmed all pertinent questions, including inclusion and exclusion criteria, questions regarding age, sex, height, weight, smoking habits, types of exercise, frequency of exercise, level of athletic competition, and history of illnesses and injuries.

Following completion of the intake form and interview, subjects performed warm up exercises which included active exercises of the upper extremity. After the warm up, subjects performed Stretching exercises focusing on the Pectoralis minor, Pectoralis Major and the Posterior shoulder capsule. (Hold time 10 seconds/ 6 repetitions)^[6]

Initially the participants were given a Thera band of a lower resistance and the level of resistance was increased gradually within the duration of intervention (3 sessions a week/ 4 weeks)

After completing stretching exercises, strengthening exercises commenced focusing on scapular stability muscles -

- Dynamic Hugs - Arms at 60 abduction, elbow at 45 flexion and shoulder internally rotated 45 (target muscle - Serratus anterior) ^[6] (Fig 1 & 2)



Fig 1

Fig2

- Cheerleader Exercises - (Target Muscle - Rhomboids and Lower Trapezius). These exercises include horizontal

abduction and PNF D2 Flexion/Extension pattern ^[6] (Fig No. 3-6)



Fig 3

Fig 4

Fig 5

Fig 6

Before and after the intervention, grip strength was recorded using a sphygmomanometer which measures force in units of mm Hg. The sphygmomanometer cuff was evenly rolled, forming a circumference to conform with a normal functional hand position for grip. A rubber band was placed around each end of the cuff to hold it in position. The cuff was inflated to 20 mmHg, which was the starting position for measurement of each subject ^[9].

The American Society of Hand Therapists' standardized arm position for hand strength testing was utilized. For the arm to be tested, the elbow was flexed to 90°. The forearm and wrist were in neutral positions, and the fingers were flexed as needed for a maximal contraction. Demonstration of maximum hand grip performance was given prior to the first session, and re-instruction was given prior to the other session as needed. One minute or greater were allowed between each grip measurement. The mean score among three trials of grip strength measurement was recorded for data calculations ^[9].

Results

Thirty normal healthy male college-age subjects with no history of orthopedic trauma of their upper extremity volunteered to participate in this study. Age of the participants was within the range of 19.20-24.6 with the mean of 22.34 (SD: 1.822)

Pre-intervention and Post-intervention Grip strength values were obtained and compared using the paired t-test and the results were significant with $p < 0.0001$

The following table and Fig depicts the pre-intervention and post-intervention hand grip strength mean values –

Table 1

Scapular Strength Training	Grip Strength (in mm Hg) (mean) (SD)	p value
Pre-Intervention	200.44(10.059)	$p < 0.0001$
Post-Intervention	263.63(14.965)	

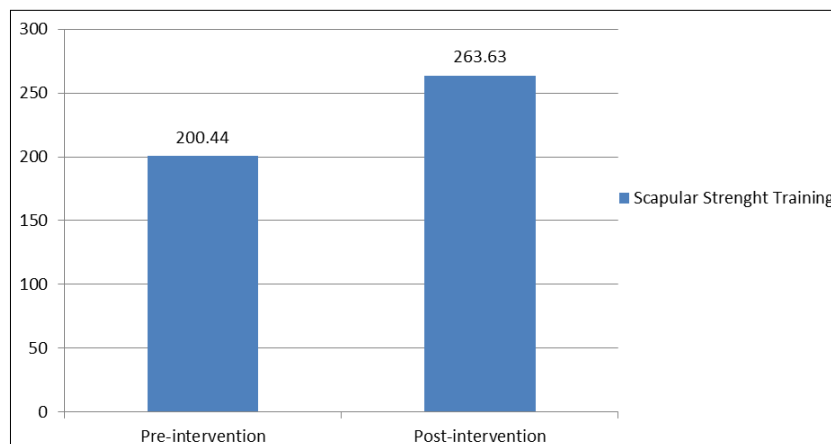


Fig 1: Scapular Strength Training

Discussion

The need of this study was to signify the role of proximal musculature on the distal segments and its functioning. It is well documented in the literature that a proximal to distal

muscle activation pattern occurs during functional tasks ^[4, 10]. For example it is known that contraction of the trunk musculature and deep cervical flexors occurs before upper extremity movement. Furthermore, during reaching tasks,

shoulder activity occurs before activation of the extensor carpi radialis and flexor carpi radialis. Hirashima and others found a sequential muscle activation pattern from the scapular protractors to the shoulder, and then down to the elbow extensors in 9 healthy male throwing athletes. In addition, during a reaching task, the scapulothoracic musculature activates during the first 5-15% of the arm movement cycle. To that end, the peak scapulothoracic muscle activation appears to be before onset of the anterior deltoid, biceps, and triceps musculature^[10].

Studies have confirmed that grip strength being a distal function is associated with the amplitude of shoulder muscle activation- the proximal component. In addition, with disuse of the hand, shoulder muscle activity decreases over time. As it relates to the scapular muscles influence on hand function, Naidler-Steinhart and Katz-Leurer found that control of the upper trapezius muscle influenced the speed of hand writing tasks in healthy individuals^[10, 11].

As mentioned earlier, in various upper extremities and lower extremities dominant tasks, the energy development and output follows a proximal to distal sequencing termed as kinetic chain. Changes in the position of various segments of the kinetic chain can affect the function of the distal component to a significant extent^[4].

For example, Grip strength itself, being an important functional task of the upper extremity shows variability with changes in position of the wrist, forearm, going proximally towards the elbow, shoulders and ultimately the trunk^[12-16].

Pryce² studied the effects of wrist joint position on grip strength. The elbow joint was maintained at 90° flexion during the measurements. He found no significant difference in grip strength with test angles of (1) 0° and 15° wrist extension, (2) 0° and 15° ulnar deviation, and (3) any combination of these positions. He, however, obtained significantly lower grip strength scores when the wrist was positioned in 15° flexion and 30° ulnar deviation^[12].

Similarly, Kraft and Detels² studied 20 healthy subjects and did not find a significant difference when the wrist joint was positioned in 0°, 15°, or 30° extension, but obtained significantly ($p < .05$) lower scores when the wrist was held in 15° flexion^[13].

Mathiowetz and associates⁷ tested the grip strength of 29 female college students with the elbow joint flexed at 90° in one test and fully extended in another. The subjects remained seated during both measurements. They obtained a significantly ($p < .05$) higher grip strength in the 90° elbow flexed position than in the fully extended position^[14].

On the contrary, Kuzala and Vargo²² evaluated the effects of four different elbow positions (0°, 45°, 90° and 135° of flexion) on grip strength measurements in 46 physical therapy students (16 men and 30 women). Subjects in the sitting position were asked to maintain shoulder adduction while holding their forearm parallel to the mark on a poster, indicating the four test positions. The highest mean grip strength measurement was recorded when the elbow was fully extended. Grip strength scores decreased as the elbow was positioned in greater degrees of flexion; that is, 135° of flexion yielded the weakest grip strength score^[15].

Chwen-Yng Su *et al.* studied the influence of shoulder position on grip strength in three different shoulder positions

(0°, 45°, 90° and 135° of flexion) the highest mean grip strength score was obtained when the shoulder was flexed at 180° with the elbow fully extended. Grip strength decreased as the shoulder was positioned in lesser degrees of flexion: 0° of flexion with elbow flexed at 90° had the lowest score. This finding indicated that shoulder joint angle does affect grip strength performance^[15].

Teraoka²³ examined grip strength of subjects standing, sitting, and supine, with the elbow joint held in full extension during the tests. He found that grip strength was higher for subjects who stood than for those who sat for all age groups and for both sexes. Also, he reported higher grip strength for subjects sitting than for those who were supine. Similar results were reported by Balogun and colleagues. In that study, standing produced greater grip strength as compared to sitting, regardless of whether the elbow was positioned at 90° flexion or in full extension. The authors suggested that the synergistic effect of the muscles of the lower extremities may have enhanced the maximal grip force in standing^[16].

In a comprehensive review, Veeger and van der Helm discussed that hand movement is dependent on three-dimensional mobility of the shoulder complex, which in turn is dependent on coordination of the trunk muscles, thereby signifying the interplay between the distal and the proximal segments^[3].

Alizadehkhayat *et al.* found that a standardized hand grip task in a neutral position activated supraspinatus and infraspinatus. Grip strength has been shown to be correlated with the strength of the upper extremity, general strength of the body and as an objective measure of upper extremity function. Nascimento *et al.* and Manadlidis and O'Brien found a statistically significant and positive relationship between isometric hand grip strength and isokinetic peak torque and work measures of the shoulder stabilizing muscles. The relationship has been proposed as a result of the requirement of a stable proximal shoulder girdle to enable optimal recruitment of the distal muscles, and the force transmitted along the myofascial pathways^[17].

Kwasniewski compared bilateral rotator cuff strength in patients with a unilateral hand or wrist disorder using a hand held dynamometer and reported a statistically significant decrease in elevated external rotation strength. Kwasniewski stated that it was unclear whether there is a causal relationship. Similarly, Bud off found an increased prevalence of rotator cuff weakness of the limb with an associated hand or wrist disorder^[17].

Scapula acts as a base for various muscle attachments. The muscles of the rotator cuff attach along the entire surface of the scapula and are responsible for glenohumeral stability compressing the humeral head into the socket. Kibler describe these muscles working in this manner as compressor cuff. Now, if the scapular stability muscles (Rhomboids, Trapezius, Serratus Anterior, Pectoralis minor) are inefficient to maintain scapular stability then, an instable scapula may lead to altered length- tension relationship of the rotator cuff muscles, inefficient rotator cuff contractions leading to rotator cuff tendinitis or compression of the rotator cuff muscles and altered glenohumeral stability and since rotator cuff function correlates strongly with hand grip strength^[17], it may also lead to reduced hand grip strength.

Sporrong *et al.* found that the electromyographic activity of rotator cuff musculature (most significantly the supraspinatus) increased significantly during isometric handgrip tasks, particularly in positions of shoulder flexion/abduction, and that biceps brachii activity also increased during handgrip. It has been suggested that this may cause changes in activity of the shoulder muscles and potentially changes in 'internal loading' of the shoulder [17].

Similarly, Tae-Won Yun and Byoung-Hee Lee studied the effects of hand grip strength on the muscle activation of shoulder joint in breast cancer patients. The muscle activity of the upper trapezius, the lower trapezius, the supraspinatus, and the serratus anterior muscle was compared on the basis of grip strength intensity. This study showed an increase in shoulder muscle activation with increasing hand grip strength thereby correlating the influence of proximal function on the distal function [18].

There are many evidences and examples where impairment in one of the proximal links of the kinetic chain leads to dysfunction or injury in the distal segment. Also the distal injuries can be traced to the alteration in the function of the proximal segments not only in the upper extremity but also in the lower extremity as well.

To that end, impairments of the cervical spine and shoulder have been reported in patients with Lateral epicondylitis such that Serratus Anterior, Lower trapezius, Middle trapezius strength are all diminished in LE. These findings imply that the proximal upper quarter should be considered in the rehabilitation of patients with LE [10].

Research illustrates that shoulder and elbow angles have significant effects on handgrip strength. However, not much attention has been given to the quality of shoulder girdle stabilization in this context. Specifically, shoulder girdle stabilization is not defined by one static position but by the quality of muscle coordination, strength, endurance in all possible joint positions [3].

In that context, fatigue of the scapular stabilizers has been shown to produce kinematic alterations of the elbow in throwing athletes, in a healthy population. This study implies that scapular muscle fatigue i.e. less scapular muscle endurance could predispose individuals to injuries in the elbow region by altering elbow kinematics. Another investigator found that induced pain at the upper trapezius appears to produce an increase in wrist extensor EMG activity in healthy individuals. Clinically, overuse of the upper trapezius and underuse of the lower trapezius, could result in upper trapezius pain. Because upper trapezius pain can result in increased activity of the common wrist extensors, the clinically observed trapezius imbalance may be an indirect link to an overuse wrist extensor injury [10].

As mentioned earlier, strength and endurance of the proximal muscles can contribute to the functioning of the distal component, with regard to it, Thomson and Mitchell investigated the effect of repetitive exercise on the scapular stabilizers by studying the ability of the scapular musculature to stabilize the scapula after fatiguing exercise in the proprioceptive neuromuscular facilitation (PNF) D2 pattern as measured by the lateral scapular slide (LSS) test. Their results suggest that a fatigue-induced strength deficit of the shoulder musculature can have an adverse effect on scapular

positioning by allowing the scapula to glide more laterally during functional activities [6].

The effect of fatiguing exercise on shoulder muscles has also been studied by Carpenter *et al* and Voight *et al*, who investigated the effects of exercise and muscle fatigue on shoulder proprioception. Both groups found a significant decrease in joint kinesthesia, measured using the time threshold to detection of passive movement after fatiguing exercise. They hypothesized that a decrease in position sense as a result of fatigue of the shoulder girdle musculature could interfere with normal coordination and joint stability, thus impairing function around the shoulder girdle and ultimately the upper quarter [6].

Not only scapular kinetics have an influence on upper extremity function but also scapular kinematics i.e. Scapular position plays a vital role in upper extremity function. The ideal position of the scapula is a vital element in upper extremity function in ADL. When the scapula is in its ideal position, not only does it allow the shoulder joint to move smoothly, but it also provides stability to the shoulder joint, because the rotator cuff muscles will exert maximum strength on the glenohumeral joint. If the scapula was located in a position in which it is difficult to provide stability for the shoulder joint, pain in the shoulder and upper extremity and dysfunction would occur. Therefore, the adjustment of the scapula to its ideal position is vital for smooth upper extremity function [1].

There are many examples of proximal muscle activation providing interactive moments that allow efficient distal segment function. They either provide maximal force at the distal end, similar to the cracking of a whip, or they provide precision and stability to the distal end. Maximum force at the foot segment in kicking is developed by the interactive moment resulting from hip flexion. Maximum shoulder internal rotation force to rotate the arm is developed by the interactive moment developed by trunk rotation. A 23%-24% increase in maximal rotator cuff activation occurs when the scapula is stabilized by the trapezius and rhomboid muscles. Similarly, in the lower extremities 26% more activation can occur in the ankle as a result of proximal muscle activation [19]. Jeongok Yang *et al.* conducted a research to determine the effects of adjusting the scapula into its ideal position through active scapular protraction on the muscle activation and function of the upper extremity by measuring the grip strength. The results showed that positioning the scapula in the ideal position improved the muscle activation of the upper extremity muscles by increasing the grip strength [1].

Cho also studied how positioning the scapula in an ideal position through passive protraction affected the function of the upper extremity and ADL of chronic stroke patients. Her results show that the upper extremity function and ADL of the group that had scapular setting improved more than those of the group that did not receive scapular setting. Hence, when the scapula is in its ideal position, upper extremity function is improved and also the function of the upper extremity works better when the stability of the scapula is secured [1, 20].

Postural stability is a prerequisite for movement. It involves the entire musculoskeletal system, through an arrangement of regional interdependence and precise coordination (feed-forward mechanism) of muscles stabilizing the trunk.

Therefore, achieving optimal trunk stabilization, which serves to be the most proximal segment of the body, should be the first step when training optimal movement or strength.^[3] In addition, the distal muscle activity can be more directed towards precision and control, rather than power generation, when proximal muscle activation is maximum^[19].

Based on the above discussions, we know that how strength, endurance and co-ordination between the scapular stability muscles (Trapezius, Serratus Anterior, Rhomboids) is essential not only for efficient and smooth movement along the whole upper quarter but also in maintaining an ideal position of the scapula which serves to be an essential kinetic chain link for the proper functioning of the shoulder, elbow, wrist and hand. Similarly in this study, dynamic scapular muscle strengthening exercises were performed which led to strength gains in scapular muscles (Trapezius, Serratus Anterior, Rhomboids) and the strength gains of these muscles had a significant influence to the distal segment, hand, by increasing the grip strength thereby concluding that proximal muscle strength gain can induce distal muscle strength gain indirectly attributed to the fact, that when scapular muscles stabilize the scapula in its ideal position and anchoring the scapula strongly on the thoracic cage, then the length-tension relationship of the upper extremity muscles would be balanced resulting in optimum force production, efficient force transmission and minimal force wastage by reducing the compressive, translatory and shearing forces at the joints of the upper quarter kinetic chain.

Also, Thomas *et al.* Used only general resistance training of upper extremities and still found significant gains in hand.^[21, 3]

Most of the abnormal biomechanics and overuse injuries that occur about the shoulder girdle elbow and wrist can be traced to alterations in the function of the scapular stabilizing muscles^[6, 10]. Scapular muscle weakness and rotator cuff insufficiency would likely cause a destabilized shoulder girdle. An inefficient and destabilized shoulder girdle, according to the kinetic chain theory, places more demand on the musculature of the elbow and wrist to initiate energy transfer that is required for functional movement^[10].

In our daily life, the shoulder joint activity or muscular strength of the upper extremity and hand grip strength is very important. Since the functional movements of the hand are affected by the proximal part of the upper extremity, injury to the proximal part of the upper extremity can result in dysfunction, without any injury of the distal part of the upper extremity^[1].

Since the proximal segments, here, the scapula and its muscles, play a crucial role in proper functioning and execution of movements in the upper quarter and serve as a key prerequisite for securing functional movements and proper stability of the upper limbs^[18], assessment and rehabilitation of the scapulothoracic joint and its surrounding muscles should be involved in treating any upper quarter dysfunction.

The subjects of this study were normal adults, hence there could be a few difficulties in generalizing the results of this study to patients and also a larger sample size should be required for the same. Also, in this study only hand grip strength was used as an index of upper extremity function

whereas other strength indices such as pincer strength were not taken into consideration.

No studies have directly investigated the influence of scapular muscle performance on patients with various upper extremity pathologies such as Lateral Epicondylitis, De quernians Tenosynovitis and other overuse injuries in the upper quarter.

Therefore, future studies are needed to describe the effects of both scapular muscle strength and endurance in a working population who develop upper quarter disorders or to study the effects of scapular muscle training on the function of upper extremity so as to provide a clinical basis for the treatment of patients.

Conclusion

Dynamic Scapular muscle strengthening exercises significantly increased grip strength in young adults

References

1. Jeongok Yang, Joongsok Lee, Bomjin Lee, Sora Jeon, Bobae Han, Dongwook Han *et al.* The Effects of Active Scapular Protraction on the Muscle Activation and Function of the Upper Extremity J Phys. T 600 her. Sci. 2014; 26(4):2014.
2. Joseph A Balogun, Charles T, Akomolufe Luteef Amusa. Grip Strength: Effects of Testing Posture and Elbow Position Arch Phys Med Rehabil, 1991; 72.
3. Alena Kobesovaa, Jan Dzvonika, Pave IKolara, Angie Sardinab, Ross Anandel. Effects of shoulder girdle dynamic stabilization exercise on hand muscle strength Isokinetics and Exercise Science, 2015; 23:21-32.
4. Aaron Sciascia, Robin Cromwell, Kinetic Chain Rehabilitation. A Theoretical Framework, Lexington Clinic, Shoulder Center of Kentucky, 1221 South Broadway, Lexington, KY 40504, USA, 2012.
5. Alexander CM, Miley R, Harrison PJ. Functional modulation of shoulder girdle stability. Exp Brain Res. 2005; 161:417-22.
6. Russ Paine, Michael L. Voight, The Role Of The Scapula, The International Journal of Sports Physical Therapy, 2013; 8(5):618.
7. Russell M Paine, Michael Voight. The Role of the Scapula, JOSPT, 1999; 18.
8. Jason Brumitt, Scapular-Stabilization Exercises: Early-Intervention Prescription, Human Kinetics • Athletic Therapy Today, 11(5):15-18.
9. George F. Hamilton, Carolyn McDonald, Thomas C. Chenier, Measurement of Grip Strength: Validity and Reliability of the Sphygmomanometer and Jamar Grip Dynamometer, J Orthop Sports Phys Ther 1992; 16:215-219
10. Joseph M. Day, Scapular Muscle Assessment In Patients With Lateral Epicondylalgia, Doctor of Philosophy Dissertation, College of Health Sciences, University of Kentucky, 2013.
11. Naider-Steinhart S, Katz-Leurer M. Analysis of proximal and distal muscle activity during handwriting tasks. Am J Occup Ther. 2007; 61(4):392-398.
12. Pryce JC. The wrist position between neutral and ulnar deviation that facilitates the maximum power grip strength. J Biomech 1980; 13:505-2.

13. Kraft GH, Detels PE. Position of function of the wrist, *Arch Phys Med Rehabil*, 1972; 53:272-5.
14. Mathiowetz V, Rennells C, Donahoe L. Effect of elbow position on grip and key pinch strength. *J Hand Surg* 1985; 10A:694-97.
15. Chwen-Yng Su, Jau-Hong Lin, Tsui-Hsien Chien, Kuang-Fang Cheng, Yue-Tung Sung. Grip Strength in Different Positions of Elbow and Shoulder, *Arch Phys Med Rehabil*, 1994; 75.
16. Teraoka T. Studies on the peculiarity of grip strength in relation to body position and aging, *Kobe J Med Sci.*, 1979; 25:1-17.
17. Ian Horsley, Lee Herrington, Rebecca Hoyle, Evie Prescott and Nathan Bellamy, Do changes in hand grip strength correlate with shoulder rotator cuff function? *Shoulder & Elbow*. 2016; 8(2):124-129.
18. Tae-Won Yun, Byoung-Hee Lee, Effects of hand grip strength on shoulder muscle activity in breast cancer patients, *Phys Ther Rehabil Sci*. 2016; 5(2):95-100.
19. Gharote GM, Kapadia HJ, Yeole UL, Panse RB, Pawar PA, Kulkarni SA *et al*. Comparison of core stability in different sportsmen. *Saudi J Sports Med*. 2017; 17:168-73.
20. Cho MA: An effect of scapula setting on upper extremity functions and activities of daily living of chronic stroke patients. Daegu University, Unpublished Master's Thesis, 2011.
21. Thomas EM, Sahlberg M, Svantesson U. The effect of resistance training on handgrip strength in young adults. *Isokinet Exerc Sci*. 2008; 16:125-31.