The Effect of Imagery Exercises on Activation of Shoulder Muscles

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Introduction: To identify the effect of imagery exercises on activity of the shoulder muscles. **Materials and method:** A sample of 23 healthy participants (17 females and 6 males), with no history of shoulder injury, participated in the present study. Surface bipolar electrodes were applied over the supraspinatus, infraspinatus, posterior deltoid, middle deltoid, anterior deltoid, and pectoralis major. Participants performed six imagery exercises: flexion, extension, abduction, adduction, external rotation, and internal rotation. Root mean square of myoelectric activity of shoulder muscles was calculated for statistical analysis. The RMS during rest was used as an offset and also to normalize the activity of each muscle during imagery exercises. **Results:** Performing the imagery exercises resulted in significant activation of the shoulder muscles ($P< 0.01$). In the case of the supraspinatus muscle, significant difference ($P< 0.05$) was found among exercise types but no significant value was seen for infraspinatus muscle. In flexion, abduction, adduction, and internal rotation imagery exercises, the correlation observed between muscles activation was significant ($P<0.01$). **Discussion:** Supraspinatus highly activated in exercises including elevation of the arm. Activation of infraspinatus in all exercises suggest its important stability role in glenohumeral joint.

Key words: Imagery exercise; Motor control; Re-education; Rotator cuff; Electromyography

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Introduction

Proper activity of rotator cuff is essential for normal shoulder function. These muscles reduce shearing force by compressing humeral head into glenoid fossa (1). Also, through blending to the joint capsule, tendons of these muscles tighten the capsule and increase their efficiency (1-4). The neuromuscular system plays an important role in motor control of rotator cuff muscles. This system controls and adjusts the muscle activity using the received inputs from mechanoreceptors and higher parts of CNS (5). The previous studies showed that rotator cuff muscles activate before activation of prime mover muscles to stabilize the glenohumeral joint. This anticipatory activation of rotator cuff muscles is the strategy of neuromuscular system (6). In shoulder injuries, neuromuscular mechanism is disrupted. After occurrence of injury and the resultant pain, due to two factors of properioceptive inhibition by pain and differentiation caused by increased neutral zone or tissue rupture, activation of rotator cuff muscles decreases. Neural inhibition of rotator cuff muscles occurs as decreament of sensorimotor input to these muscles (7-9). As previously mentioned, the source of this decrement is at the level of both mechanical receptors and spinal cord. As such neural inhibition occures, motor control of rotator cuff muscles becomes disrupted (5). This motor control disruption includes increment of the onset latency of rotator cuff muscles, abbreviated activation period, increment of activation intensity, and decrement of activation intensity of prime mover muscles (10-12). The shoulder pain causes increment in the onset latency of rotator cuff muscles and increment in the onset latency of the subscapularis muscle related to the infraspinatus muscle in the late cocking phase (13). In shoulder impingement, it is reported that activation intensity of rotator cuff and deltoid decreases (14). In the long run, motor control disruption may change the motor plan in the motor cortex. It is reported that over-use, disuse, and injury can also lead to alternation in cortical representation.

Mental practice and imagery exercises can help in restoration of motor control of muscles (15-17). In the first stages of rotator cuff rehabilitation, exercises are prescribed with the goal of prevention or removal of neural inhibition and improvement of motor control. Sensorimotor and Reactive Neuromuscular Training, which worked based on mechanoreceptors excitation and increment of properioception flow to muscles, can be beneficial to improvement of muscles activity. In these exercises, properioceptive inputs path through spinal cord and after making adjustment can affect the efferent inputs to muscles (11,18). Imagery exercises are imagination or thinking about doing a movement without actually doing any observable movement. Imagery exercises can be beneficial in motor learning, especially in the first stages. Pathway of imagery exercises is similar to a voluntary contraction but at the end of the pathway, muscles contract minimally. Neural commands are sent from supplementary motor cortex and travel through corticospinal tract until they reach the muscles. This site of motor cortex, therefore, has an important role in motor learning (19). After shoulder surgeries, the shoulder muscles are prone to neural inhibition due to pain and immobility. In this condition, performance of imagery exercises may be helpful in prevention or decrement of neural inhibition and disruption of motor control.

Materials and Method

Participants

A total of 23 healthy participants, including 17 females and 6 males (mean age: 30.7, range: 18-55 years; height: 165.5, range, 155-184 cm; body mass, 61.6 kg, range, 44-90 kg), volunteered to take part in the present study. Participants had no regular sport activity, no history of shoulder, scapular, neck, and thoracic pain, or shoulder arthroscopy or surgery. Physical examination was conducted by a trained sports physiotherapist. Empty-can, speed, lift-off, and resisted external rotation tests were performed to investigate any sign of musculotendinous injuries and sulcus sign, apprehension, and load, and shift tests were carried out to assess any sign of joint instability.

The project was approved by the Ethical Committee at Shahid Beheshti University of Medical Sciences, Tehran (Code #149).

Procedure and Measurement Techniques

A methodological study was performed on 11 participants to assess the reliability of the dependent variables. All the trials were performed on a single day with a 1-hour interval. The Intra-Class Correlation (ICC) was run to calculate the reliability of the data. The ICC ranged from 0.70 for infraspinatus adduction test to the highest value of 0.98 for supraspinatus imagery adduction test. The reliability evaluation showed good to excellent results.

As for the main study, upon arrival to the laboratory, physical assessment was performed on each participant and the participants were asked to complete the personal information form. Then they were informed about the study procedure and signed the consent form.

Next, electromyography recording was done. In the present study, surface electromyography (Datalog, Biometerics, UK) with bipolar surface electrodes with inter detection area of 2 cm was used. Sampling rate was 1000/s and sensitivity was adjusted to 300 mv based on the pilot study. Because of the limitation of surface EMG, only supraspinatus and infraspinatus muscles could be recorded among rotator cuff muscles. Subscapularis muscle could only be recorded by positioning the electrodes under scapular bone and teres minor, since due to its small size and vicinity with other muscles and the possibility of cross talk phenomen, it is inaccessible with surface electrode. In each exercise, electerical activity of supraspinatus, infraspinatus, and prime mover of that movement was recorded.

Participants were instructed to sit on an armchair with proper height. They were asked to sit with proper thoracic and lumbar curve and maintain this posture during the test. The dominant arm was positioned on the armrest in slight abduction and neutral rotation.

Electrodes were then placed based on the Johnson method (20), except for the supraspinatus muscle, as in pilot and sonographic studies we found that it is easier to record this muscle where it is more superficial. So, the electrode was placed on one-third of the lateral end of this muscle parallel to its fibers.

To record infraspinatus activity, electrodes were placed in the middle of scapular fossa, 3 cm lateral to medial border, and to record pectoralis major activity, electrodes were placed medial to the humeral head. Anterior deltoid was recorded thorugh placing the electrodes 1 cm lateral to the coracoid process. Also, to record middle deltoid, electrodes were placed at the mid-range of acromion and deltoid tubercle and, finally, to record posterior deltoid, the electrodes were placed inferior to the posterior side of glenoid.

After placing the electrodes, we started the recording. After a four-second delay, verbal command was given and participants performed one of the exercises for 10 seconds. After 10 seconds, the command for relaxation was given to the participant and after a four-second delay, the recording procedure was stopped.

In the present study, we asked participants to think and imagine that they were doing physiologic shoulder movement instead of imagination of compressing the humeral head into glenoid to investigate activation of shoulder muscles, especially rotator cuff. Participants were instructed to think they were only moving their arms to one direction without any visible muscles contraction and movement. They were instructed to think of moving their arms upward frontally for flexion, moving upward laterally for abduction, pulling posteriorly for extension, pushing to the chest for adduction, moving back the hand laterally for external rotation, and nearing palm of the hand to the abdomen for internal rotation. During the test, the examiner checked the participants for any visible muscles contraction or arm movement.

Data Processing

In the present study, data was analyzed running Root Mean Square (RMS). First, RMSs for both activity and rest period were calculated. Then, RMS of rest period was subtracted from that of activity period. Finally, the result was normalized with RMS of rest period as follows:

$d=RMS_{exercise}-RMS_{rest}$

Normalized 'd'$=(d/RMS_{rest})$

Statistical Analysis

For data analysis, SPSS (v. 14) was used. To investigate the

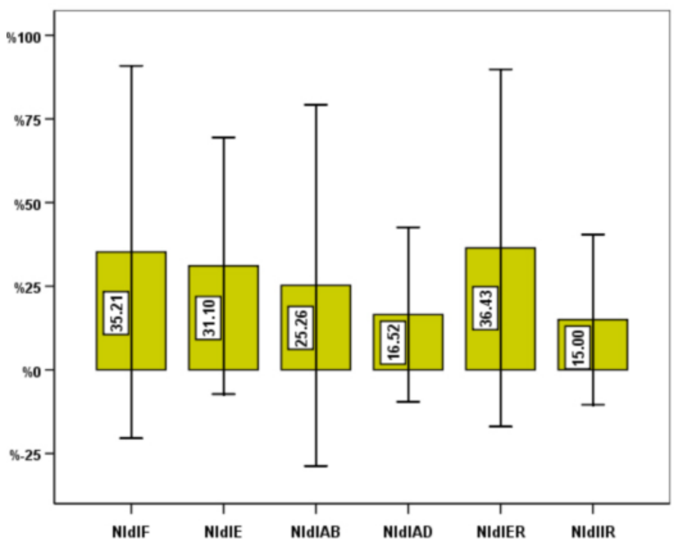

Figure 1. The normalized infraspinatus activity during different imaginary exercises

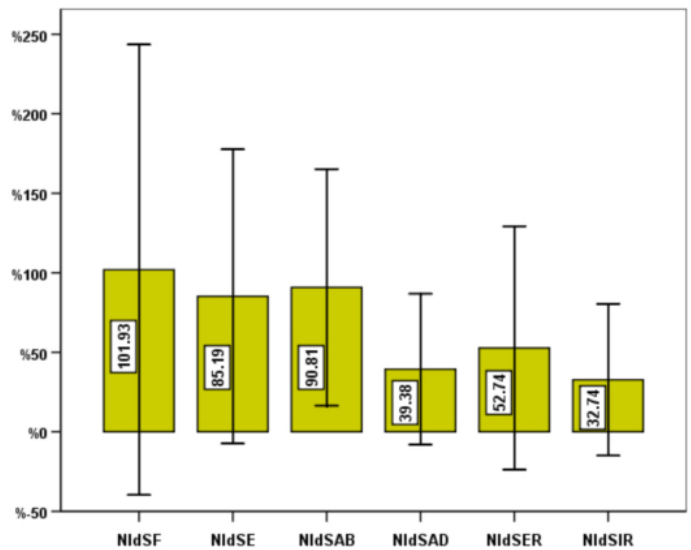

Figure 2. The normalized supraspinatus activity during different imaginary exercises

effects of exercises on muscles activation, paired t-test and to compare the effects of the types of exercises on muscles activity repeated measures ANOVA were run. Also, pearson correlation coefficient was performed to find any correlation between activation of different muscles.

Results

Imagination exercises resulted in significant activation of shoulder muscles (*P*<0/01). A significant difference (*P*<0/05) was found comparing the effects of the types of exercise on the activity of supraspinatus muscle; however, in the case of infraspinatus muscles, no significant difference was found (Figures 1 and 2).

Imagination of flexion, abduction, extension, external rotation, adduction, and internal rotation induced the most activity in supraspinatus, and in the case of infraspinatus, external rotation, flexion, extension, abduction, adduction, and internal rotation induced the most activity, respectively (Figures 3-8).

In flexion imagery exercise, the correlation was significant (*P*<0.01) between supraspinatus, infraspinatus, and anterior Deltoid. In abduction, the correlation was also significant (*P*<0.01) between supraspinatus and middle Deltoid. In adduction, too, the correlation was significant (*P*<0.01) between infraspinatus and Pectoralis major, and finally, in internal rotation, the observed correlation was significant (*P*<0.01) between supraspinatus, infraspinatus, and Pectoralis major.

Discussion

In the current study, the imagery exercise was implemented to evaluate the increase in the electrical activity of periarthicular muscles of the shoulder joint. The results showed that performance of imagery exercises resulted in activation of both rotator cuff and prime mover muscles, although activation of prime mover muscle was very low.

The recent studies showed that imagery exercise could activate the muscles and even increase their strength. Brain *et al.*used imagery exercise to minimize the wrist-hand immobilization-induced muscle weakness and found that imagery exercise attenuated the loss of strength and voluntary activation by 50% and also eliminated the prolongation of the cortical silent period that represent the corticospinal inhibition (21). In another study, Ranganathan *et al.* (2004) studied the effect of 12 weeks of imagery exercise on the increase of the strength in the little finger abductor and elbow flexor muscles (22). They reported 35% increase in the finger abductor strength and 13.5% increase in elbow flexor muscles compared with those of the control group.

The cortex is a critical determinant of muscle strength/weakness and a high level of corticospinal inhibition is an important neurophysiological factor regulating force generation. It has been shown that the weakness induced by immobilization results in an increase in intracortical inhibition (23) and increases in strength following exercise would decrease intracortical inhibition (24), while mental imagery of muscle could increase the strength (22).

In the present study, activation intensity of supraspinatus during imaginary abduction muscle was greater than that during imaginary flexion prime mover muscles except in flexion, adduction, and internal rotation imagery test. This is in contrast to the reported results by David and Magarey (2000) who found that infraspinatus activity was greater than that of supraspinatus during throwing activity (25). The major difference between the present study and the study cited is the fact that during throwing action, high level of muscular activation is needed and this

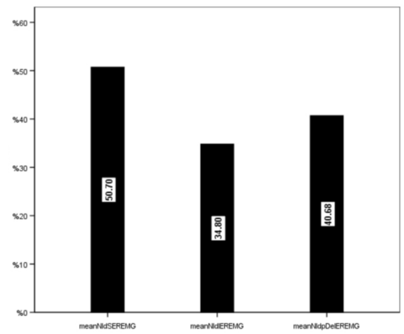

Figure 3. The mean normalized activity of different muscles during imaginary external rotation

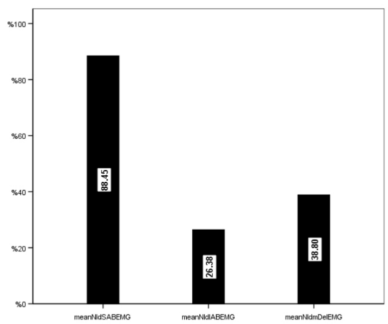

Figure 4. The mean normalized activity of different muscles

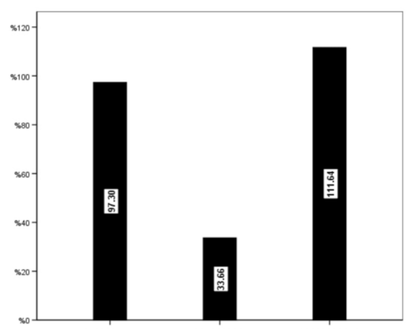

Figure 5. The mean normalized activity of different muscles

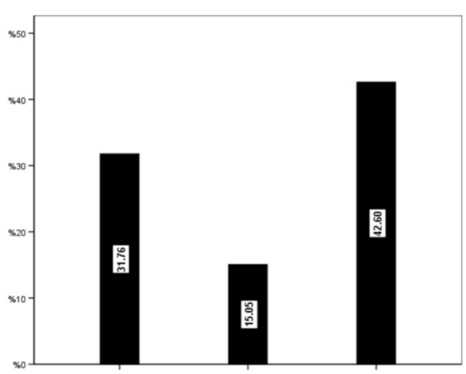

Figure 6. The mean normalized activity of different muscles during imaginary internal rotation

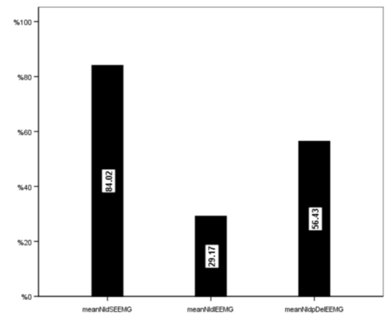

Figure 7. The mean normalized activity of different muscles during imaginary extension

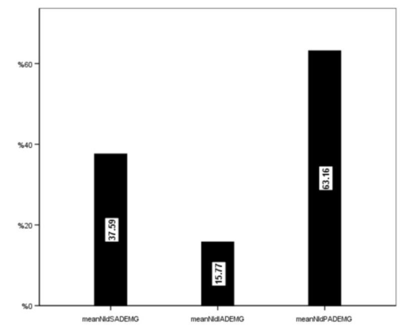

Figure 8. The mean normalized activity of different muscles during imaginary adduction

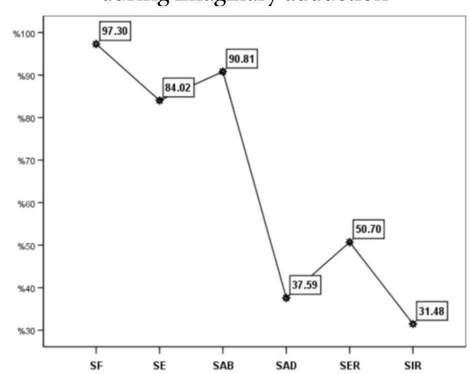

Figure 9. The mean normalized activity of supraspinatus during different imaginary exercises

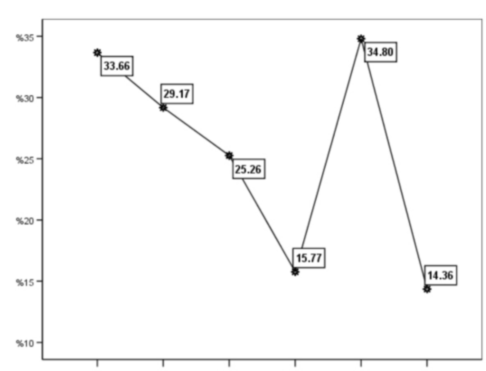

Figure 10. The mean normalized activity of infraspinatus during different imaginary exercises

pattern of muscular activity and also their motor role could be completely different from imagery exercise where no moment and movement happens in the joint. Greater activation intensity of supraspinatus in the present study with respect to the prime movers may be representative of the important role of this muscle in decision period and before starting a movement to control athrokinematic motions.

In the case of flexion imagery exercise, lesser activation of supraspinatus, as compared to that of anterior deltoid, may be because of smaller possibility of subluxation in the joint during flexion, where anterior deltoid is the prime mover, as compared with that during abduction, where middle deltoid is the prime mover.

Lesser activation of supraspinatus, as compared to pectoralis major, in adduction and internal rotation imagery exercises may be because of lesser dynamic joint stability needed to provide by supraspinatus in these exercises.

Activation intensity of infraspinatus was lesser than that of supraspinatus and prime movers in all imagery exercises. This finding can be attributed to proper line of action of this muscle which obviates the need to intensive activation.

Statistically, the factor of the types of imagery exercises affected supraspinatus activation; however, for infraspinatus, the types of imagery exercises had no significant effect on activation of this muscle. This finding may indicate the important task of infraspinatus in the function of glenohumeral joint disregarding the direction of movement.

Imagery exercises which induced most relative activation in supraspinatus muscle are shown in Figure 9.

During flexion, anterior deltoid (the prime mover) tends to pull the humerus head in superior, posterior, and medial directions. During extension and external rotation, posterior deltoid (the prime mover) tends to pull the humerus head in superior, anterior, and lateral rotation directions. During abduction, middle deltoid tends to pull the humerus head in superior direction.

To neutralize the superior pull of deltoid group, supraspinatus steers humerus head downward by attaching to the superior facet of greater tuberosity. Also, supraspinatus has almost horizontalline of action which makes it capable of compressing humerus head into glenoid fossa based on concavity-compression mechanism. Using this mechanism, supraspinatus decreases shearing force and increases joint stability.

Imagery exercises which induced most relative activation in infraspinatus muscle are shown in Figure 10.

Infraspinatus consists of fibers with different arrangements. Superior fibers have almost horizontal direction and seem proper for compressing humerus head into glenoid fossa and can guide external rotation by inserting into the middle facet of greater tuberosity. Inferior fibers have a large capability to pull humerus head inferiorly using their inferiorly and posteriorly line of action. According to findings of the present study, infraspinatus showed great activity in exercises in which decision was made to elevate the arm like flexion, extension, and abduction. The great activation of infraspinatus in these exercises could be for damping the superior pull of deltoid group. Posterior deltoid prime mover muscle of external rotation tends to pull humeral head superiorly and anteriorly. Superior fibers of infraspinatus help to rotate the head externally and compress it into glenoid fossa whereas inferior fibers seem to damp superior pull of posterior deltoid.

During adduction and internal rotation movements, pectoralis major and latissimus dorsi (the prime mover of this movement) cannot produce large translation of humerus head in neutral shoulder position via attachment near the humerus head (both sides of intertubercular groove). So, high activation of supraspinatus and infraspinatus was not necessary in these movements.

The notable finding in the present research was high activation of supraspinatus and infraspinatus in both flexion and extension imagery exercises. Usually, muscles which are highly activated in exercise or movement are silent in contrast exercise or movement. This finding can indicate the important role of this muscle as a local stabilizer to providing dynamic joint stability before and during performing the movement.

Correlation analysis showed relationships in four flexion, abduction, adduction, and internal rotation imagery exercises. The correlation between muscle activation can indicate the co-operation or co-activation of one group to stabilize the joint and to neutralize the unwanted pull of the other muscles.

In flexion imagery exercise, high correlation was observed between supraspinatus, infraspinatus, and anterior deltoid. In flexion, in addition to superior translation of the humeral head, anterior subluxion might occur. Activation of supraspinatus and infraspinatus correlated with anterior deltoid centralize humeral head by pulling it inferiorly and compressing into the glenoid.

In abduction imagery exercise, correlation was noticed between supraspinatus and middle deltoid. Also, activation of supraspinatus correlated with middle deltoid downward steer and centralize humeral head by compressing into the glenoid.

Moreover, in adduction imagery exercise, a correlation was observed between infraspinatus and pectoralis major. In internal rotation imagery exercise, too, a correlation was found between supraspinatus, infraspinatus, and pectoralis major.

Activation of adductor and internal rotator muscles tend to anteriorly and inferiorly sublux the joint. Supraspinatus and infraspinatus, by acting on superolateral and posterior side of humeral head, and also tightening of superior and posterior capsule, maintain humeral head in the center of the glenoid.

Conclusion

The present study showed that imagery exercise are able to activate the shoulder periarthicular muscles to the level that in long training periods could increase the strength of these muscles. These types of exercises can be beneficial in shoulder pathologies where movement or strong muscle contraction are forbidden or immobilization is necessary.

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Conflict of interest:
None

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Authors' contributions:
All authors made substantial contributions to conception, design, acquisition, analysis and interpretation of data.

References

1. Matsen F, Lippitt S. Practical evaluation and management of the shoulder. WB Saunders company. 1994.
2. Hovelius L., Anterior dislocation of the shoulder. PhD thesis. Linko¨ping University No. 139, Linko¨ping, Sweden, 1982.
3. Ovensen J., S. Nielsen, Posterior instability of the shoulder joint, Acta Othop. Scand. 1986; 57:436.
4. Ovensen J., S. Nielsen, Stability of the shoulder joint, Acta Othop. Scand. 1985; 56:149.
5. Myers J, Lephart S. Sensorimotor contribution to shoulder stability: Effect of injury and rehabilitation. Manual Therapy. 2006; 11: 197–201.
6. David g., M.E. Magarey, EMG and strength correlates of selected shoulder muscles during rotations of the glenohumeral joint, Clinical Biomechanics. 2000; 15: 95-102.
7. Myers JB, Lephart SM. The role of the sensorimotor system in the athletic shoulder. Journal of Athletic Training 2000; 35(3):351–63.
8. Myers JB, Lephart SM. Sensorimotor deficits contributing to glenohumeral instability. Clinical Orthopaedics. 2002; 400:98–104.
9. Lephart SM, Henry TJ. Functional rehabilitation for the upper and lower extremity. Ortho Clin N Am. 1995; 26(3):579–92.
10. Barden JM, Balyk R, Raso VJ, Moreau M, Bagnall K. Dynamic upper limb proprioception in multidirectional shoulder instability. Clin Orthop & Related Res. 2004; 420:181–9.
11. Glousman R, Jobe F, Tibone J. Dynamic electromyographic analysis of the throwing shoulder with glenohumeral instability. *Bone Joint Surg Am.* 1988; 70:220-226.
12. Illyés A, Kiss R. Muscle Activity of shoulder joint in patients with multidirectional shoulder instability during pull, forward punch, elevation and overhead throw. Physical Education and Sport. 2005; 3(1): 93–105.
13. Hess SA1, Richardson C, Darnell R, Friis P, Lisle D, Myers P. Timing of Rotator Cuff Activation During Shoulder External Rotation in Throwers With and Without Symptoms of Pain. J Orthop Sports Phys Ther. 2005; 35(12):812-20.
14. Reddy A, Mohr K. Electromyographic analysis of the deltoid and rotator cuff muscles in persons with subacromial impingement. J Shoulder and Elbow Surg. 2000
15. Buonomano DV, Merzenich MM. Cortical Plasticity: from synapses to maps. *Annal Review of Neuroscience* 1998; 21:149- 186
16. Elbert T, Sterr A, Flor H, *et al.* Inputincrease and input-decrease types of cortical reorganization after upper extremity amputation in humans. *Experimental Brain Research* 1997; 117: 161-164
17. Elbert T, Pantev C, Wienbruch C, *et al.* Increased cortical representation of the fingers of the left hand in string players. *Science* 1995; 270:305-307
18. Nyland J. Clinical decisions in theraputic exercise planning and implementation. pearson prentice hall, New Jersy. 2006
19. Shumway-Cook A, Woollacott M. Motor control translating research into clinical practice. 3rd edn. Lippincott Williams-Wilkins. 2007.
20. Pease w, Johnson E, Practical electromyography 4th edn. Lippincot Williams & Wilkins, 2007.
21. Brian C. Clark, Niladri K. Mahato, Masato Nakazawa, Timothy D. Law, James S. Thomas. The power of the mind: the cortex as a critical determinant of muscle strength/weakness. Journal of Neurophysiology. 2014 ; 112 (12): 3219-26.
22. RanganathanVK, SiemionowV, LiuJZ, SahgalV, YueGH. From mental power to muscle power–gaining strength by using the mind. Neuropsychologia. 2004; 42: 944–956.
23. Clark BC, Issac LC, Lane JL, Damron LA, Hoffman RL. Neuromuscular plasticity during and following 3 wk of human forearm cast immobilization. J Appl Physiol. 2008; 105: 868–878.
24. Weier AT, Pearce AJ, Kidgell DJ. Strength training reduces intracortical inhibition. Acta Physiol (Oxf) 2012; 206: 109–119.
25. David g., M.E. Magarey, EMG and strength correlates of selected shoulder muscles during rotations of the glenohumeral joint, Clinical Biomechanics. 2000; 15 : 95-102.