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Effect of Fatigue Exercise on Scapular Stability

Potsangbam Nandita[1], Niraj Kumar[2], Onkar Singh[3]

Abstract

Introduction: The scapula is a flat blade lying along the thoracic wall. It is central in proficient shoulder activity providing a stable base from which glenohumeral (GH) mobility occurs [1]. Any abnormal biomechanics and physiology occurring around the shoulder create abnormal scapular position and motions termed as scapulothoracic dyskinesis [13,8] 'floating scapula' or lateral scapular slide [4]. As rotator cuff functions to depress the humeral head within the glenoid cavity where as scapula rotators position the glenoid in proper place for stability with arm motion [6,4]. Fatigue represents the decline in muscle tension(force) capacity with repeated stimulation hence muscular fatigue worsen or impair joint position sensibility and deterioration in muscle conductivity, contractile and elastic properties [8]. *Need for the study:* The study was undertaken to determine the effect of fatigueness on scapular positioning after exercise and to understand the importance of using fatigue as rehabilitation tool for safe return of athlete to competitive performance level. *Methodology:* There are two groups *Group A*- Right side Dominant shoulder of the same 30 individuals assessed with LSST, MVIC and were given exercise in D2 flexion pattern i.e. shoulder flexion, adduction and external rotation till fatigueness. *Group B*- left side non-dominant shoulder of the same 30 individuals assessed with LSST, MVIC and given exercise in D2 flexion pattern i.e. shoulder flexion, adduction and external rotation till fatigueness. *Limitations:* 1. The study comprises of a small sample size. 2. The study could not be able to do over the overhead throwing athlete. 3. In my study I checked the lateral scapular slide immediately 1min. after the exercise but could not recheck it again after few min or hours in the same day. 4. I neither compare nor correlate the results with the actual muscle activity and power of the muscular, which are responsible for abnormal scapular position. *Scope of Future Study:* 1. Further studies can be done in a well set up laboratory with the usage of Biodex dynamometer for accurate estimation of isometric strength at various degrees 2. Future study can be done on population having proprioceptive loss due to some injury or degeneration. 3. The effect of exercise on scapular stability can be seen for longer period of time i.e., 30 min-1hr or any particular time of the day. 4. Further studies can be done to correlate among larger group of subjects. *Conclusion:* The study concluded that a fatigue induced strength deficit of the shoulder musculature can have an adverse affect on scapular positioning by allowing the scapula to glide more laterally during functional activities. It also come to the conclusion that increase displacement of scapula as a result of fatigue of the shoulder girdle could interfere with normal coordination and joint stability thus can impair function around the shoulder girdle. Thus rotator cuff strengthening has been an obvious treatment for various pathologies.

Keywords: LSST; MVIC and D2 Flexion Pattern; Strain Gauge; Goniometer; Wrist Cuff; Stationary Frame; Hooks And Inch-Tape.

Introduction

The scapula is a flat blade lying along the thoracic wall. It is central in proficient shoulder activity providing a stable base from which glenohumeral (GH) mobility occurs [1].

Author Affiliation: [1]Associate Professor and Head [2]Associate Professor [3]Demonstrator, Dept. of Physiotherapy, Shri Guru Ram Rai Institute of Medical & Health Sciences, Patel Nagar Dehradun, Uttrakhand.

Corresponding Author: Niraj Kumar, Associate Professor Shri Guru Ram Rai Institute of Medical & Health Sciences, Patel Nagar Dehradun, Uttrakhand.

E-mail: drnirajkumar25@gmail.com

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As rotator cuff functions to depress the humeral head within the glenoid cavity where as scapula rotators position the glenoid in proper place for stability with arm motion. All these groups of muscles are defined by agonists and antagonist working together as force couples providing not only the dynamic glenohumeral stability but also maintain optimal length tension relationship. The appropriate force couples include the upper and lower trapezes working together with rhomboids, paired with the Serratus anterior. Their motor activation patterns are specific for different desired activities. These muscles work together to coordinate the balance of movement between the shoulder joint thereby maintaining scapulohumeral rhythm, which is in the ratio of 2:1 throughout the full range of elevation. When musculature weak or fatigued, scapulohumeral rhythm compromised and shoulder dysfunction results.[6,4,7,5].

Any abnormal biomechanics and physiology occurring around the shoulder create abnormal scapular position and motions termed as scapulothoracic dyskinesis [13,8] 'floating scapula' or lateral scapular slide [14].

Hypothesis

There will be decrease in isometric strength of scapular stabilizer muscles and increase in lateral scapular slide due to exercise induced fatigue.

Purpose of the study

1. To establish the profile of fatigueness in the scapular stabilizers.
2. To determine the net effect of fatigueness and recurrent microtrauma to the shoulder.
3. To compare the onset of fatigueness after a set of exercise and its induction in strength deficit of shoulder musculature on scapular positioning in the dominant and non-dominant limb pre and post exercise.
4. To determine the effect of exercise on the lateral scapular slide in the dominant and non-dominant limb pre and post exercise.

Objectives

1. To determine fatigueness as an intrinsic factor for shoulder instability or pain.
2. To encourage clinicians, coaches and therapists to understand the importance of using fatigue as rehabilitation tool for the safe return of athlete to competitive performance level.

Need for the study

The study was undertaken to determine the effect of fatigueness on scapular positioning after exercise and to understand the importance of using fatigue as rehabilitation tool for safe return of athlete to competitive performance level.

Operational Definitions

Fatigue

It is decline in force during a maximal contraction or duration for which a force can be maintained. It can also be define as a state of increased discomfort and decreased efficiency, power or capacity to respond to stimulation due to prolonged or exercise exertion.

Lateral Scapular Slide test (LSST)

It is use to evaluate scapular stability by comparing the distance between a fixed point on the vertebral column and the scapula on the tested side in various ranges of scapulothoracic and glenohumeral joint.

Flexibility

It deals with a joint or a series of joints used to produce a particular movement. It is both static and dynamic in nature. Flexibility is limited by the ability of the tissues to lengthen quickly.

Isometric strength

It is the static muscle work against maximal resistance at a particular point of the range. The resistance demands the greatest possible increase in intramuscular tension.

Maximum voluntary isometric contraction

It is the maximum amount of tension, which can be generated by scapular stabilizers isometrically without any trick movement.

D2 Diagonal Pattern

These are the diagonal movement i.e. the path in which maximal response of functional relationship can be facilitated.

D2 flexion: - Abduction and External rotation of shoulder

Literature Review

Shoulder Musculature & function

Della Valle CJ et al.,(2001) and Kibler WB,(1998) has reviewed that the shoulder complex muscles can be classified by anatomic and functional groupings. The first anatomic group comprises the trapezius, rhomboids, levator scapulae and Serratus anterior concerned with stabilization and rotation of the scapula. The second group includes extrinsic muscles – the deltoid, biceps and triceps which involved in gross motor functions and movement of the arm and force generation of the hand. The final group includes intrinsic muscles of the rotator cuff –

the subscapularis, the supraspinatus, infraspinatus and teres minor which are responsible for fine motor movements and compression of humerus into shoulder joint [55,57,58,59].

Likewise by Paine R.M, Voight ML in (1993) also mentioned that stability at the scapulothoracic joint depends on the surrounding musculature. When weakness or dysfunction is present, normal scapular positioning and mechanics may become altered and also may predispose the individual to shoulder injury [2].

Shoulder Characteristic in Players

Alfredson et al. (1998) seen that young volleyball players have a higher bone mass in the proximal humerus, distal humerus and distal radius in the dominant compared with non dominant arm and it is more likely a cause effect relationship [32]. Also seen that range of motion was less in dominant side than non dominant side [33,34].

H.K Wang et al. (2001) found active range of internal rotation and concentric rotators strength in dominant arm was significantly less than in non dominant arm but internal rotator were significantly stronger in both concentric and eccentric tests at both testing speeds [35].

Shoulder injuries related with fatigue

Brady L, et al. (2004) proposed a dysfunction mechanoreceptor theory in which muscle fatigue is believe to desensitize the muscle spindle thresholds. This sensitization would serve to decrease afferent feedbacks to the CNS, which is caused by local metabolism interfering at the muscular level, CNS fatigue and neuromuscular fatigue [49].

In 2002, Bryan L, Reinmann & Scott, proposed that joint stability is a phenomenon, which requires the activation and control of dynamic restraints as a result of integration of entire motion control system of body [46]. The motion control is optimized by the proprioceptive information conveyed to all levels of CNS. Hence proprioceptive information is necessary for neuromuscular control of dynamic restraints [47].

Jobe et al. (1989) suggest that mild anterior GH instability is a consequence of the progressive attenuation of the static anterior stabilization structures from repetitive throwing. Also show an injurious cycle ensures, with fatigue of dynamic stabilization leading to further GH anterior translation and encroachment of the coracoacromial arch [62].

Lateral Scapular Slide test (LSST)

Several studies have been performed to determine the reliability and validity of LSST in comparison with radiographic comparison for the validity of LS glide measure was found to have a co-relation coefficient of more than 0.90 [19,29,30].

Kibler has suggested that LSST may be used to monitor the scapular stabilization in any rehabilitation program that involve strengthening exercise [15].

Shoulder Rehabilitation

Lexington Clinic Sports Medicine center unpublished data, 1999 suggested that the PNF D2 pattern exercise can mimic functional directionality and facilitate tripolar conditioning. This exercise can be progressed by using dumbbells, tubing theraband to make it a plyometric exercises [1].

Methodology

Subjects 30 subjects including of boys and girls were included for the study. The study is an experimental study. The study was taken on Sports College, Raipur and SBSPGI, Balawala. There are two groups, Group A- Right side Dominant and Group B- left side non-dominant shoulder of the same 30 individuals. Inclusion criteria Boys and Girls at the age group 20-25 yrs., Overhead throwing sport players, No history of shoulder pain presently or recently, No past history of trauma and surgery undergone, Should not have any cervical pain, neuralgia, elbow pain, wrist pain & neuromuscular disorder, Subjects were excluded history of neuromuscular disorder, History of recent stress fracture or dislocations or subluxation, Non compliance with testing procedures, Hyper trained cervical shoulder, Hyper laxity of shoulder joint and If the subject is unable to understand instruction or to provide informed consent. Instrumentation for data collection includes Strain gauge, Goniometer, Wrist cuff, Stationary frame, Hooks and Inch-tape.

Procedure

Randomly selection of either boys and girls (n=30) of mean age 22.7±1.74, mean height 162.36cm ±7.67cms and mean weight 55.46±5.72 kgs were included.

There are two groups, Group A- Right side Dominant shoulder of the same 30 individuals assessed with LSST, MVIC and were given exercise in D2 flexion pattern i.e. shoulder flexion, adduction and external rotation till fatigueness. Group B- left side non-dominant shoulder of the same 30 individuals assessed with LSST, MVIC and given exercise inD2 flexion pattern i.e. shoulder flexion, adduction and external rotation till fatigueness.

All the participants were given verbal instructions for the testing and a signed consent form was obtained from each of them prior to the participation in the study. Each subject's descriptive data and information regarding arm dominance, injury status and game history were recorded to satisfy the subject selection criteria. An objective examination was done to evaluate and observe the scapula both statically and dynamically in relation to its role in the entire kinetic chain for both the limb from behind the patient and looked for any asymmetry, deformity, atrophy etc. A physical examination was done which consisted of thorough evaluation of both shoulder range of motion. The LSST begins with the establishment of a measurement reference point on the nearest spinous process to the inferior angles of the scapula. With the subject's arm at the sides in the anatomical resting position, the distance from the inferior angle of the involved (first the dominant side) scapula in measured from the reference point. The second position of measurement is with the patients hands on the hips, with the finger anterior and the thumb posterior. This position places the humerus in approximately 45° of abduction (Fig. 4*)*. The third measurement position of 90° of arm elevation with maximal internal rotation (thumb to floor) at the glenohumeral joint. This final position was chosen because it presents a challenge to the scapula stabilizing muscles in a much more functional position. Range of motion was assured by goniometer measurement of shoulder abduction while the subject was in standing position (Fig. 2 & 3).

For measuring isometric strength, a strain gauge was used. Arm dominance was determined first then the MVIC was obtained in the position of D2 flexion pattern i.e. shoulder flexion, adduction and external rotation (Fig. 1). Three isometric muscle contractions of three seconds duration were performed and the maximum force elicited was used as a criterion score. After these examinations, exercise was given. The exercise using the surgical tubing was performed by the subject to the point of fatigue or until the subject, loses the ability to maintain the shoulder in a 90° abducted position Rest was given for 1 min after the exercise and again MVIC was checked same as before in the same position repeated for three times each of three seconds duration and within 2 min the LSST were again investigated in the three positions. The same procedures described above were repeated for the non-dominant side limb and the same readings were taken and compared between them.

Data Analysis

There are two groups, Group A- Right Group B- left.

Fig. 1: D2 Pattern Exercise

Fig. 2: LSST at 180

Fig. 3: LSST at 90

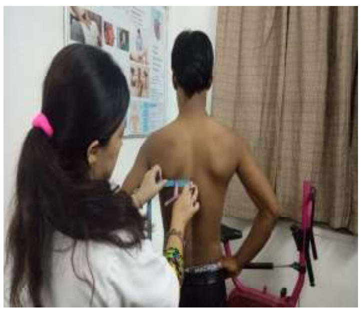

Fig. 4: LSST at 45

In this study lesser than 0.05 has been considered statically significant and greater than 0.05 as not significant. Mean (standard deviation) was computed for each groups in each particular degrees and compared within same groups using paired t test and between the different groups using independent t test.

Results

30 subjects including of boys and girls, who were randomly selected, in age group of 20-25 years (mean 22.7±1.74) with mean height (162.3±7.67cm) and mean weight (55.46±5.72) were included and within the same subject they were divided into group A for right side and group B for left side and were co-related for changes in scapular displacement at 0°, 45° and 90° between pre and post exercises and also the isometric strength was compared pre and post exercise.

Range of Motion

Paired ‘t’ test has been performed to compare between pre and post exercises at different degrees(0°, 45° and 90°) within group A and B and the results were significant ($p<0.05$) for each group at each particular degrees. Unpaired ‘t’ test has been performed to compare between group A and B for mean difference at various degrees. The result shows significant ($p<0.05$) difference at only 45°, there mean difference and SD were 0.97±0.83 for group A and 0.47±0.72 for group B and non significant (p>0.0° 5) difference at 0and 90°. Student ‘t’ test has been performed for comparing the mean of AROM of scapular abduction, pre exercise between 0° vs. 45°, 0° vs. 90° and 45° vs. 90° within the same group and result shows that significant differences are there. Same t-test was performed for comparing the mean for post exercise in same pattern and significant differences are present. ($p<0.05$) Student paired t-test performed to compare pre and post exercise for changes in isometric strength within same group and result are significant. Un-paired t-test was performed to compare the group A and group B for isometric strength for mean differences and the result show non significant ($p>0.05$). Their mean diff. and SD were 0.74±0.72 for group A and 70±0.71for Group B Student un-paired t test was performed to compare pre exercise between the group and result shows significant differences.

Discussion

This study was designed to obtain more thorough understanding of the effect of exercise induces fatigue in the D2 pattern flexion- extension on the amount of scapular lateral displacement and in the isometric strength. The study was also done to compare the scapular position after exercise in both dominant and non dominant hand.

Before implementing the experiment, the pre values of various ranges of the two group were compared between them using independent t-test and the result shown to be non significant which forms the baseline of my study.

The result of this study shows the pre test measurement of the two groups at various degrees show significant difference with the post test measurement, (Table 1). This significant difference has been resulted from the fatigue induced by the exercise. This result is supported by the study done by Thomson and Mitchell [24] and also Carpenter et al and Voight et al. [25] who suggested that a fatigue induced strength deficit of the shoulder musculature can have an adverse effect on scapular positioning and also on the shoulder proprioception, where joint kinesthesia is decreased.

In my study I have taken healthy subjects which show decreased asymmetry as they progress from the first (0°) to third (90°) position LSS. After the exercise cessation due to development of fatigue there was difference in the range of 0-1.5cm in each particular range in both the group. Kibler recognized a 1cm difference as clinically significant [23]. Recently, he has increased their threshold of abnormality to 1.5cm [19]. When pathology is present, it is not unusual to have

Table 1: t test to compare Pre and Post at different degrees (0^0, 45^0, 90^0) within Group A (Right) and Group B (Left) for lateral scapular slide

Degrees	Group A P value	Group B P value
0	S	S
45	S	S
90	S	S

asymmetry of as much as 3cm. This shows changes in asymmetry at various degrees pre and post exercises showing significant differences (Table 3,4).

Several studies have been performed to determine and validity of the LSST in which it is compared with radiographic examination [19,29,30]. and the result were found to have a correlation co-efficient of more than 0.90 [19].

A significant difference was detected between pre and post fatigue scores. No significant difference was detected between dominant (Group A) and non dominant (Group B) extremities when the arm is in the first and third position i.e. in the anatomical resting position and 90° of arm elevation with maximal internal rotation respectively. But significant difference was detected in the second position which is a transitional, gradual progression of difficulty to the scapular stabilizing musculature [1] (Table 2).

A significant difference was also detected between the pre and post fatigue scores in terms of isometric strength (Table 5). In my study since I used D2 flexion-extension pattern as the means of exercise and this involve the concentric, isometric and eccentric movement of shoulder musculature. So the muscle force may decline after concentric or isometric exercise because of fatigue and this is accompanied by perturbations of force perception. In eccentric exercise, where the active muscle is forcibly lengthened, components of force drop are thought to result from the disruption of sarcomeres and damage to some muscle fibers which may eventually develop localized contracture and lose their ability to generate active tension [45].

Table 2: t test to compare Group A and Group B for mean differences at various degrees For lateral scapular slide

Degrees	Group A Mean differenc ± S.D	Group B Mean difference ± S.D.	P value
0	0.57± 0.53	0.64± 0.62	N S
45	0.97± 0.83	0.47± 0.72	S
90	1.04± 0.76	1.05± 0.79	N S

p < 0.05 → Significant(S)
p > 0.05 → not significant(NS)

Table 3: t test between Pre exercise at various degrees (00, 450, 900) within Group A (Right) and Group B (Left) for LSST.

Variables	Group A P value	Group B P value
Post 0 vs Post 45	S	S
Post 0 vs Post 90	S	S
Post 45 vs Post 90	S	S

p < 0.05 → Significant(S)
p> 0.05 → not significant(NS)

Table 4: t test between Post exercise at various degrees (00, 450, 900) within Group A (Right) and Group B (Left) for LSST.

Variables	Group A P value	Group B P value
Pre 0 vs Pre45	S	S
Pre 0 vs Pre 90	S	S
Pre 45 vs Pre 90	S	S

p < 0.05 → Significant(S)
p> 0.05 → not significant(NS)

Table 5: t test to compare Pre and Post within Group A (Right) and Group B (Left) for Isometric strength

	Group A P value	Group B P value
Pre vs Post	S	S

Table 6: t test to compare Group A and Group B for mean differences for Isometric strength.

Group A Mean diff ±S.D.	Group B Mean diff. ± S.D.	P value
-0.74 ±1.15	-0.70 ±0.71	NS

p < 0.05 → Significant(S)
p > 0.05 → not significant(NS)

There was no significant difference in the muscle's isometric strength between the group A and group B (Table 6). This result is supported by J. Magalhaer et al. [28] who also didn't show significant difference in leg bilateral deficit between soccer and volleyball players, with the exception for hamstrings muscle group evaluated at 90°/s. In their opinion there was no consistent reason that could justify their difference unless they could speculate about probable unilateral demands of hamstrings recruitment in stabilizing muscle actions in some specific soccer skill.

The primary mechanical factor that may related to fatigue is cross bridge cycling and ATP is needed for both the activation of the cross bridge to cause movement and the dissociation of the cross bride from action. Exercise can cause a physical disruption of the sarcomere and reduce the capacity of the muscle to produce tension. A high H+ concentration due to high rate of lactate ways like reduce the force per cross bridge, inhibit SR Ca++ release.

Limitations

1. The study comprises of a small sample size.
2. The study could not be able to do over the overhead throwing athlete.
3. In my study I checked the lateral scapular slide immediately 1min. after the exercise but could not recheck it again after few min or hours in the same day.
4. I neither compare nor correlate the results with the actual muscle activity and power of the muscular, which are responsible for abnormal scapular position.

Scope of Future Study

1. Further studies can be done in a well set up laboratory with the usage of Biodex dynamometer for accurate estimation of isometric strength at various degree
2. Future study can be done on population having proprioceptive loss due to some injury or degeneration.
3. The effect of exercise on scapular stability can be seen for longer period of time i.e., 30 min-1hr or any particular time of the day.
4. Further studies can be done to correlate among larger group of subjects.

Conclusion

The shoulder must be considered a kinetic chain made up of several joints. The normal function of the scapula and surrounding musculature is vital to the overall normal function of the scapula. The study concluded that a fatigue induced strength deficit of the shoulder musculature can have an adverse affect on scapular positioning by allowing the scapula to glide more laterally during functional activities. It also come to the conclusion that increase displacement of scapula as a result of fatigue of the shoulder girdle could interfere with normal coordination and joint stability thus can impair function around the shoulder girdle. Thus rotator cuff strengthening has been an obvious treatment for various pathologies. Since the origins of the rotator cuff muscles arise from the scapula, an effective exercise regime for rehabilitation should include improving the strength and functions of the muscles that control the position of the scapula. Weakness of these anchoring muscles may lead to altered biomechanics of the glenohumeral joint, with resultant excessive stress impaired to the rotator cuff and anterior capsule.

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