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ISSN 2385-1988 [online] IBSN 007-111-19-55
CGIJ OAJI : 0,101

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Ita. J. Sports Reh. Po.

Italian Journal of
Sports Rehabilitation and Posturology

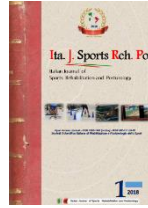
Alteration in scapular position with high intensity training- A study in competitive swimmer.

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Abstract

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Background. *Swimming is a popular sport that encompasses individual of all ages that swim for fitness, recreation and competition. In swimmers, the great number of stroke repetitions and force Generated through the upper extremity leaves the shoulder uniquely vulnerable to Injury. As competitive swimmers usually train 11000-15000 yards/day, using freestyle arm stroke for most of the distance. And with incorrect faulty mechanics leads to repetitive micro trauma at the shoulder joint leads to shoulder pain, muscle weakness and dynamic muscle imbalance that alters the normal scapular positioning and biomechanics where scapula fails to perform its stabilizer role and shoulder function become insufficient. The manual methods such as lateral scapula slide test are highly reliable in measuring the scapular position in swimmer.*

Purpose. *The purpose of this study was to assess alteration scapular position in swimmers following high intensity swim training.*

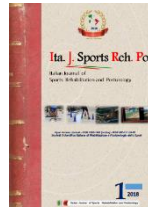
Methods. *43 swimmers were participated in study. A repeated measures design used and two position of the LSST (lateral scapula slide test) were used. All measurements in each position were taken bilaterally. The LSST was administrated in participated swimmers at different level of training. All subjects had no present or past history of with a recent shoulder, cervical or thoracic injury or shoulder pain that interfered with swim training.*

Results. *The data revealed statically highly significant difference for LSST position 2 on right side ($p=0.001$) and left side ($p=0.002$).and highly significant for LSST position 3 on left side ($p=0.001$) and significant on the right side ($p= 0.028$).*

Conclusion. *The present finding suggests that high intensity training programme was effective an alteration in scapular position at different level of swim training in swimmers. The LSST can be reliable in screening scapular position.*

(M.Padasala, J.Bhatt, R.D'Onofrio. Alteration in scapular position with high intensity training- A study in competitive swimmer. Ita J Sports Reh Po 2018; 5 ; 1 897 – 930 ISSN 2385-1988 [online] IBSN 007-111-19-55 CGIJ OAJI :0,101)

Keywords: *Swimmers, lateral scapula slide test, freestyle, shoulder pain.*



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Introduction

Swimming is a demanding sport, especially with respect to the shoulder joint. Shoulder injuries frequently occur in swimming athletes. 47% to 80% of all competitive swimmers reported shoulder injuries during their sport careers.¹² Competitive swimmers train approximately 11,000– 15,000 yd/d, 6 or 7 times per week, which correlates to 16,000 shoulder revolutions per week.^{4,5} Significant demand is placed on the shoulder, as the upper extremity supplies 90% of the propulsive force during swimming.⁶

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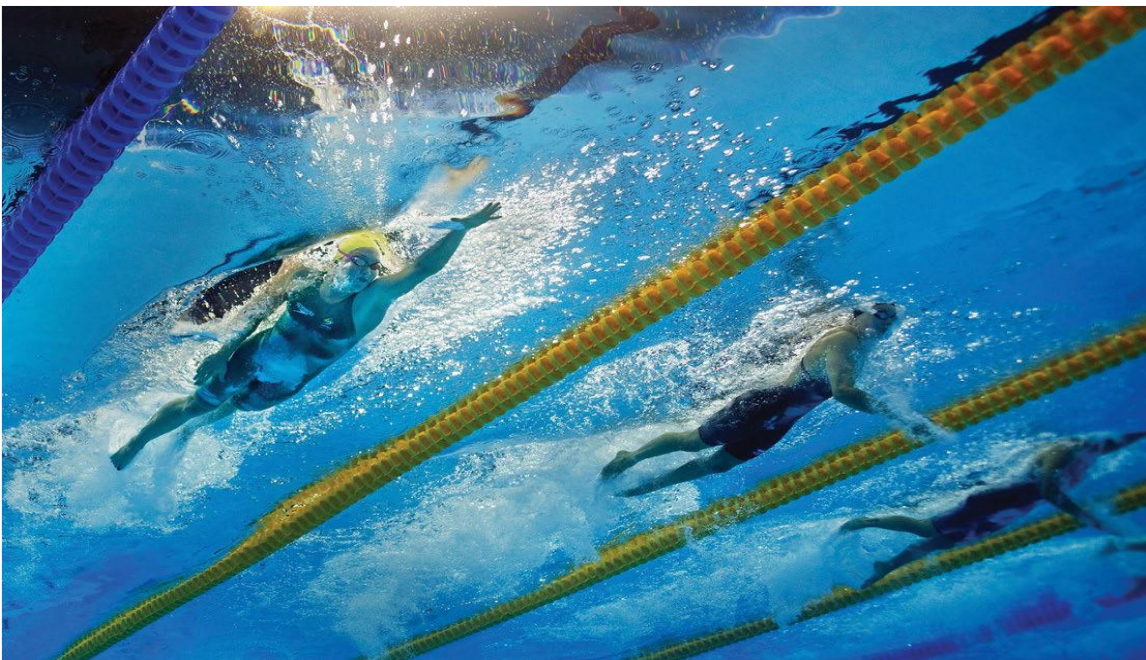
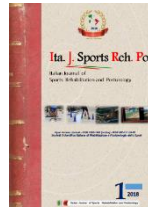


Photo 1. From Shoulder injury in swimming- meeting the challenge.

(From Elsbeth van Dorssen, Rod Whiteley, Andrea Mosler, Silvia Ortega- Cebrian and Paul Dijkstra, Qatar.)³²

The high frequency and intensity of training often leads to “swimmer’s shoulder,” which is the general term for shoulder overuse injuries in swimmers.⁷ (Photo.1). While the exact cause of swimmer’s shoulder is unknown, potential contributors include swimming technique, practice habits (including yardage, intensity, and training methods), and physical characteristics of the athlete. Of these potential contributors, the physical profile of the athlete is the most easily modifiable. Swimmers have been found to have altered range of motion, strength, and posture that may predispose them to shoulder injuries.^{8, 9, 10} On average, swimmers have an increase of 10° in external rotation and 40° in abduction and a decrease of 40° of internal rotation compared with non swimmers.⁸ Since decreased internal-rotation range of motion has been linked to a pattern of scapular kinematics that results in narrowing of the subacromial space, decreased internal-rotation range of



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motion is implicated in the development of subacromial impingement in overhead athletes.^{11, 12}

Finally, swimmers are notorious for having poor posture.^{6,9} they are characterized as having forward head, rounded shoulders, and increased thoracic kyphosis, which can affect scapular kinematics, muscle strength and range of motion.^{13, 14}

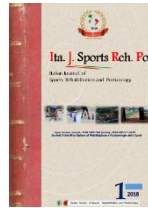
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Photo 2. Shoulder injury in swimming- meeting the challenge.

(From : Elsbeth van Dorssen, Rod Whiteley, Andrea Mosler, Silvia Ortega- Cebrian and Paul Dijkstra, Qatar.)³²

The high frequency and training of swimming (Photo.2) can often lead to shoulder overuse injuries, or what Kennedy and Hawkins's originally described in 1978 as swimmer's shoulder.¹⁵ Research has reported that swimmers believe moderate shoulder pain is a normal part of swimming and that seventy-three percent of adolescent swimmers use pain medication to manage their shoulder pain.¹⁶ Some authors note the contributing factors in swimmer's shoulder are a swimmer's stroke technique, fatigue, practice habits (yardage, intensity, training methods) and physical characteristics of the athlete.¹⁷ Those



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unique characteristics of each athlete can be a combination of muscular strength imbalance, impaired muscular flexibility, joint laxity, altered scapular kinematics and poor posture.¹⁸

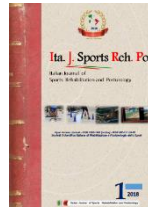
Biomechanics of shoulder stabilizer

The scapular muscles have an important function in swimming.^{4,19,20} Electromyographic stroke analysis shows that the serratus anterior muscle has the leading function,⁴ being continuously active throughout the stroke and positioning the scapula for hand entry, hand exit, and pulling the body over the arm. As a result, the serratus anterior may be susceptible to fatigue. An appropriate upward rotation of the scapula is necessary to avoid impingement during the swimming stroke. Considering the cooperation between the serratus anterior and lower trapezius muscles in scapular upward rotation,²¹ The lower trapezius is also of importance in swimming.^{19, 20}

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 / downward rotation of the scapula toward the vertebral column.²² If rhomboid weakness is present, the scapula will be unable to achieve full retraction. Full retraction is essential not only for overhead throwing motion but also for swimming strokes such as the crawl. The inability to achieve the fully retracted position during the throwing or overhead motion can lead to increased stress on the anterior structures of the shoulder.²¹ Activities that involve a pulling motion may be affected by lack of rhomboid strength. Electromyographic (EMG) analysis has demonstrated high level of rhomboid activity during the acceleration phase of pitching.²³ This EMG data suggests that the rhomboids are contracting eccentrically during the follow-through phase of throwing as the muscle continues to contract eccentrically to “brake” the energy released during acceleration.²¹ Therefore, rhomboid strength is vital in throwing and overhead arm movement.

The function of the scapular muscles in swimming has already been examined by several authors.^{19,20} In 2004, Su et al⁶ compared isometric strength values of the scapular muscles in swimmers before and after a single swim session. Serratus anterior and upper trapezius strength decreased by 14% and 13%, respectively. Fatigue of the scapular muscles may influence other factors, such as muscle activity and kinematics. A few researchers^{24,25} examined the effect of serratus anterior fatigue on muscle-activation timing and scapular kinematics. After a fatigue protocol for the serratus anterior, muscle activation was greater in the upper trapezius, which can compensate for serratus anterior fatigue. The scapular kinematics after serratus anterior fatigue was characterized by decreased



posterior tilting and increased internal rotation. Alterations in both muscle activation and scapular kinematics may contribute to shoulder injuries, including subacromial impingement syndrome and glenohumeral joint instability.^{26,27} In patients with subacromial impingement, decreased serratus anterior activity and increased anterior tipping and internal rotation were found.²⁶

Muscle work for swimming

Shoulder adduction and elbow extension are the primary movements required to propel the body forward during swimming. These movements are produced predominantly by the pectoralis major, latissimus dorsi, and triceps brachii.⁸ Because of the contribution of the pectoralis major and latissimus dorsi muscles in the stroke, swimmers tend to have increased shoulder internal-rotation and adduction strength.^{8,2,28}(photo 3).The high volume of practice yardage paired with the significant contribution from the pectoralis major and latissimus dorsi causes overdevelopment of the anterior shoulder musculature, leading to a strength imbalance with the posterior shoulder musculature. Strength imbalances of the shoulder musculature and shoulder pain are significantly correlated in swimming athletes.²⁹ The overdevelopment of the anterior musculature promotes shoulder instability by creating an anterior displacement force on the humeral head and preventing the humeral head from being centered within the glenoid fossa.³⁰ Shoulder instability can lead to pain, impingement, and decreased functioning in overhead athletes.^{30, 31} Establishing a balanced strength profile in swimming athletes may decrease shoulder instability and pain.

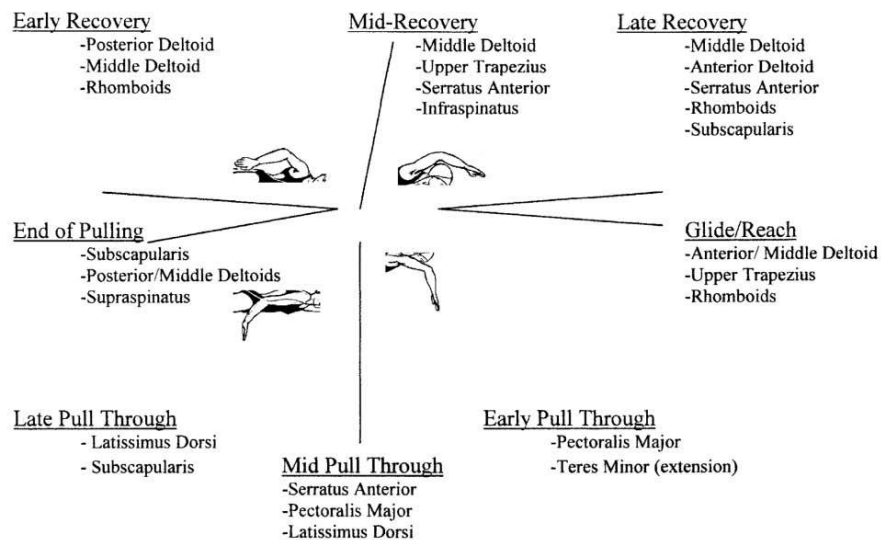
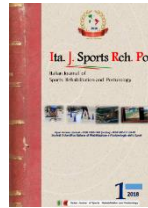


Photo 3. Muscle activity of the freestyle stroke based on electromyographic and cinematographic analysis. (From : Colwin CM. *Breakthrough Swimming*. Champaign, IL: Human Kinetics; 2002:50-70.)⁴⁷



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Biomechanics of free style swimmer

The key aims of maximizing freestyle performance are to generate a high propulsive force while simultaneously minimizing drag through the water. As with most motor patterns, there is variation in technique between individual swimmers.³²

Biomechanists divide the freestyle stroke into five phases (Photo 4, 5, 6, 7)

1. The hand entry.
2. The reach/glide.
3. The early pull-through.
4. The late pull-through.
5. The recovery phase.

The hand entry is right in front of or slightly medial to the shoulder, close to 75% of the total arm length. The elbow is at a Small flexion angle, allowing the fingers to make the first contact with the water. When the wrist and elbow touch the Water, the hand is reaching forward and gliding until full elbow extension – the reach. After this, the hand 'catches' the water in about 40° of wrist flexion. The shoulder is now in full flexion, abduction and internal rotation. Following the catch phase is the early pull-through phase, up to the moment the arm reaches a position at the same level of the shoulder with the elbow in 90° flexion. The hand seems to either take an S-shaped path (at slower speeds) or a straighter path at higher speeds, but should not cross the midline of the body. The late pull-through follows with a forceful extension and the stroke should finish with the hand past the hip. There is an accelerated thrust at the end of the pull through phase with palmar flexion and internal arm rotation to the surface for the Exit. The shoulder lifts out of the water for the recovery phase. Shoulder abduction and internal rotation is followed by external rotation. The elbow will be high (if possible) and the wrist in front of the elbow as soon as possible. With a relaxed forearm, the arm then moves forwards over the water to begin a new stroke with hand entry.³²

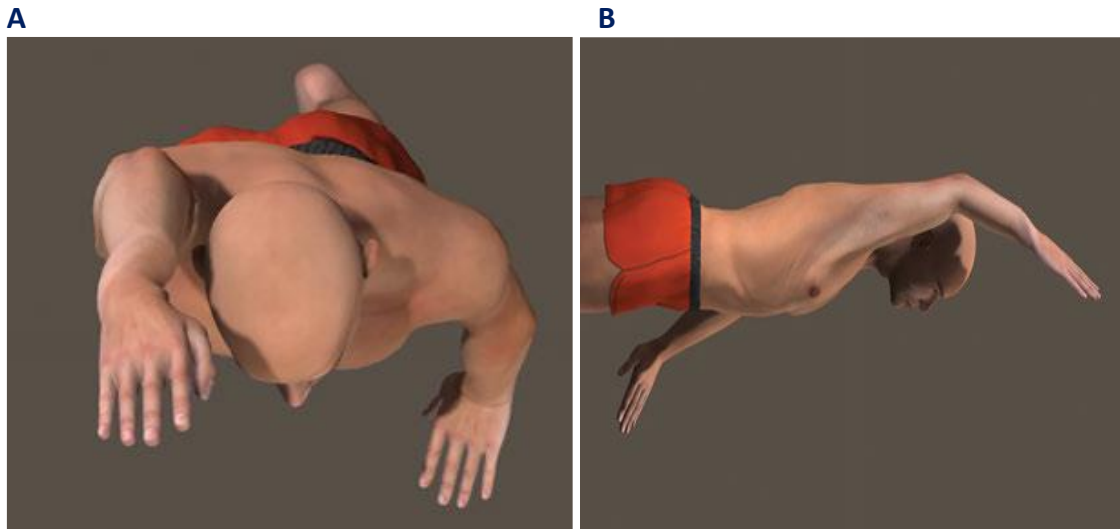
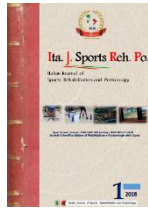


Photo 4 . Hand entry phase. From Shoulder injury in swimming- meeting the challenge.
(From : *Elsbeth van Dorssen, Rod Whiteley, Andrea Mosler, Silvia Ortega- Cebrian and Paul Dijkstra, Qatar.*)³²

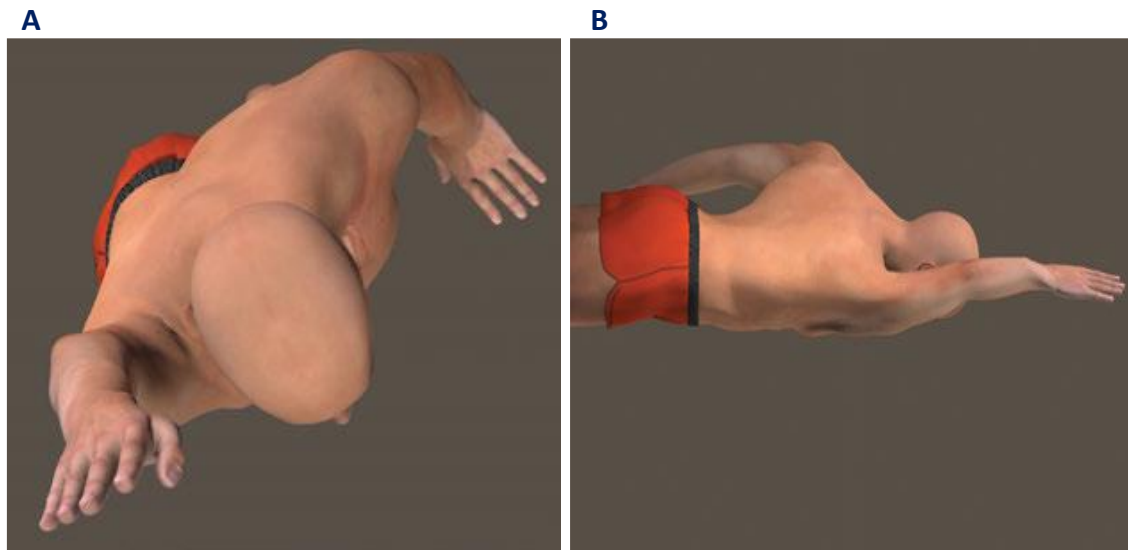
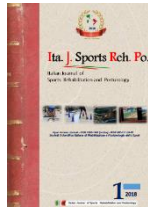


Photo 5 . The reach phase. From Shoulder injury in swimming- meeting the challenge.
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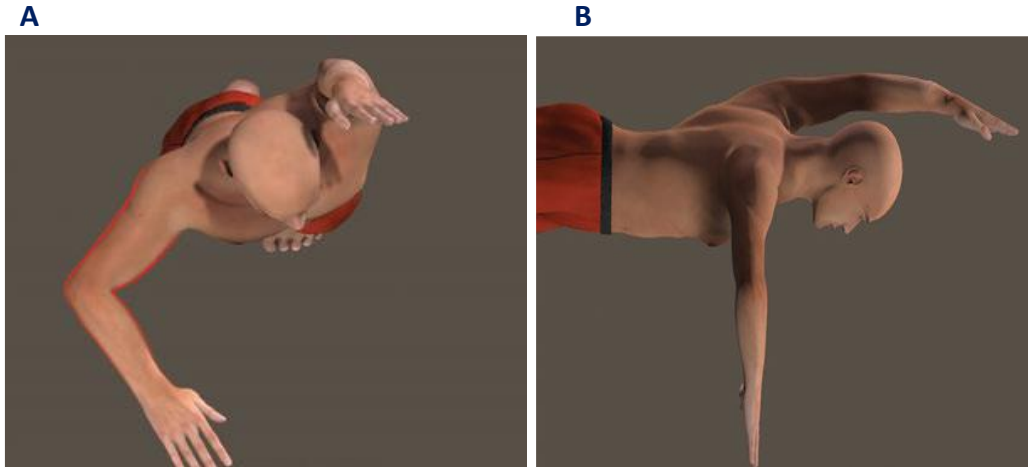


Photo 6. The pull-through phase. From Shoulder injury in swimming- meeting the challenge.
(From : Elsbeth van Dorssen, Rod Whiteley, Andrea Mosler, Silvia Ortega- Cebrian and Paul Dijkstra, Qatar).³²

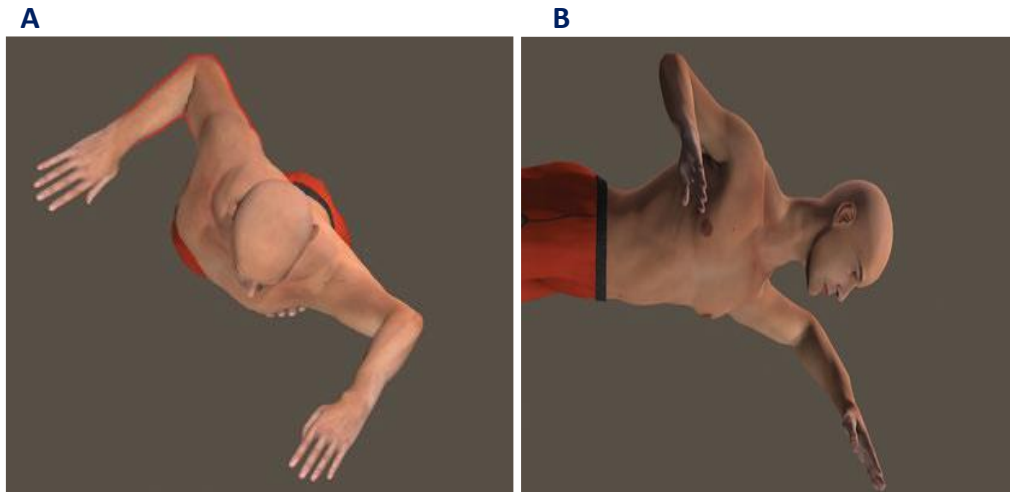
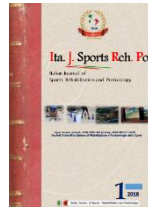


Photo 7. The recovery phase. From Shoulder injury in swimming- meeting the challenge.
(From : Elsbeth van Dorssen, Rod Whiteley, Andrea Mosler, Silvia Ortega- Cebrian and Paul Dijkstra, Qatar).³²



Physical profile of swimmer

One unique aspect of swimming mechanics is that the power comes from the muscles of the shoulder girdle. In most sports, there is a ground reaction force and power is transmitted from the legs through the trunk and scapula and out the arms. In swimming, however, the body is being pulled over the arms. Thus the arms are the propulsive mechanism, and the shoulders are quite vulnerable, especially if the scapula cannot act as a stable base for the glenohumeral control muscles.³³

Painful phases of freestyle stroke

During the freestyle stroke, 70% of the “most pain” occurred during the first half of pull-through⁴, Another vulnerable point of the stroke appeared during the first half of recovery (18% of the symptoms were elicited during this phase) (Photo 8). During the first half of the pull through, the arm is unilaterally pulling the body over the arm as the arm generates the propulsive force. The humerus has a common tendency to be hyper extended relative to the trunk rotation toward the submerged side (Photo 9, A). In this position, the humeral head is pushing anteriorly. Any anterior impingement, labral damage, or inflammation would be aggravated in this position.³³

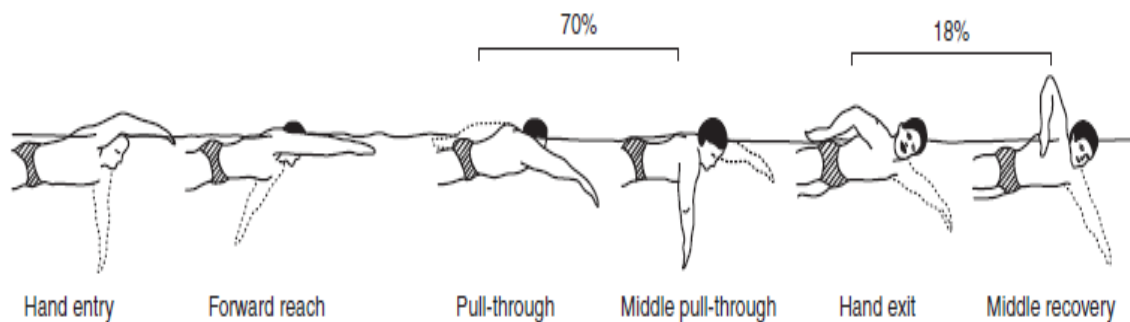
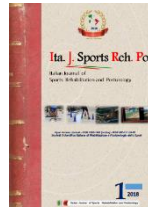


Photo 8. Painful phases of the freestyle stroke. Seventy percent of painful symptoms are identified during the first Half of pull-through. Eighteen percent of symptoms are identified during the first half of recovery. (From : Pink MM, Tibone JE: The painful shoulder in the swimming athlete, *Ortho Clin North Am* 31[2]:248, 2000.)⁴



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Toward mid recovery, the humerus is swinging the forearm forward. When the elbow is too high and close to the body, the humerus is in hyperextension, which is most likely causing the pain. It has been suggested that the humerus is moving into maximal external rotation, and this has been equated to the late cocking phase of the baseball pitch. Although it is true that at this point the humerus is as far into external rotation as it goes during the freestyle stroke, it is nowhere near the degree of maximal external rotation required during the baseball pitch. During the mid recovery phase of the freestyle stroke, the humerus is closer to neutral rotation than it is to “maximal” external rotation. This singular fact underscores the issue that the mechanics of injury in the swimmer are unique for that sport; indeed, they are unique for each stroke within swimming. A grouping of all overhead athletes does injustice to the understanding of specific injury mechanics.³³

Humeral hyperextension during different strokes

The shoulder is the primary area of interest to clinicians working with swimmers because of its vulnerability to injury. The visually apparent mechanics related to potential shoulder injury in the freestyle, backstroke, and butterfly strokes is that of humeral position relative to the axis of the body. (Photo 9) These three strokes and demonstrates the problem of humeral hyperextension relative to body axis, humeral hyperextension is defined as a combination of humeral abduction and extension (i.e., the humerus is behind the long-axis of the body while the arm is abducted). This position places stress on the anterior joint structures. Too much or too little body rotation changes the position of the humerus relative to the body axis, and thus is related to humeral hyperextension. Whether these faulty mechanics cause the pathological muscle firing patterns or whether weak or fatigued muscles cause these faulty mechanics is a bit like the issue of the chicken and the egg. The changes in muscle firing patterns are not as visually apparent as is the body rotation; however, knowledge of the faulty muscle firing patterns defines the underlying issues and allows the clinician to effectively and efficiently diagnose and treat the problem.³³

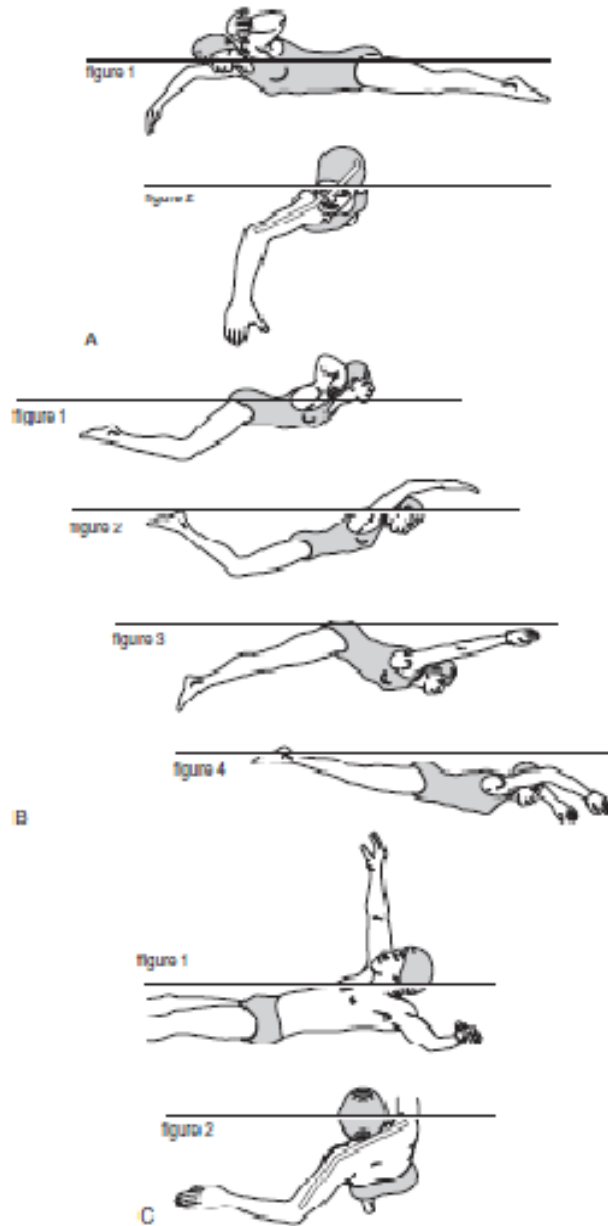
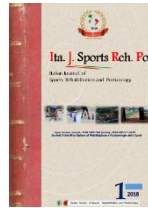


Photo 9. Humeral hyperextension. **A**, During the freestyle stroke. Hand exit (*left*) and hand entry (*right*). **B**, During the butterfly stroke. **C**, during the backstroke.
 (From : Pink MM, Tibone JE: The painful shoulder in the swimming athlete, *Ortho Clin North Am* 31[2]:248, 2000.)⁴



Phases of swimming stroke

The basic arm mechanics—with the arm position marking different phases of the freestyle stroke—are as follows (Photo 10) :

1. The arm enters the water and extends forward in front of the shoulder. The underwater pull-through starts with the early pull-through phase, which is marked by the initiation of the backward arm movement. The palm and forearm should face the backward direction with the fingertips pointing down for as long as possible.
2. The point at which the humerus is perpendicular to the body is called the mid pull-through.
3. Subsequent to mid pull-through is the late pull through. The hand continues back and passes next to the hip until it exits the water, leading with the elbow.
4. After the arm exits the water, the recovery phase begins, when the arm is swung above the water to bring the arm into position to pull once again.

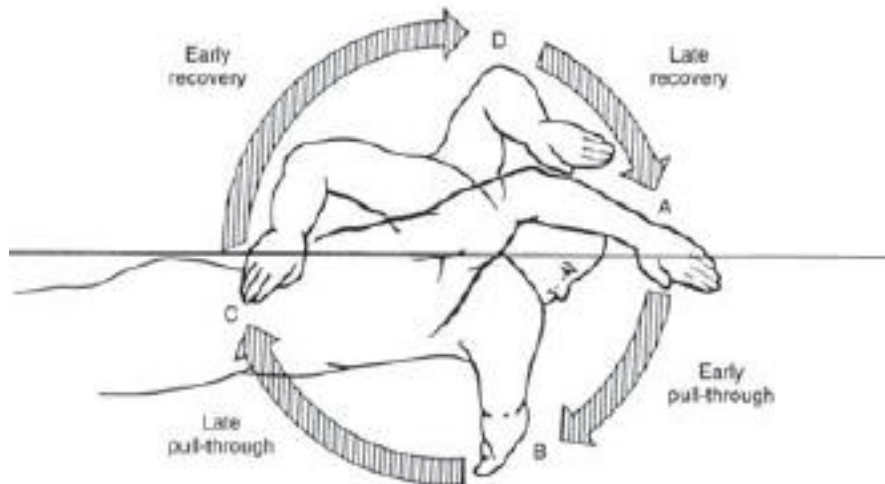
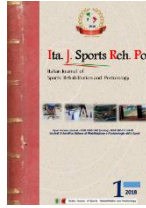


Photo 10. Phases of the swimming stroke.

(From : Pink M, Perry J, Browne A, et al: The normal shoulder during freestyle swimming, *Am J Sports Med* 19:569–576, 1991.)³

The arm motion is accompanied by axial rotation of the body. Many swimmers are taught to rotate, yet some degree of rotation will naturally occur toward the side of arm entry. As the arm is entering and the elbow is extending, the shoulder and side of the body rotate below the surface of the water. During the recovery, that same shoulder and side of the



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body begin to counter-rotate above the surface of the water (while the opposite shoulder is rotated down). As previously mentioned, it has been noted that shoulder pain occurs most frequently in two phases of the stroke: (1) the early pull-through to mid pull-through and (2) hand exit to mid-recovery. There is potential in both of these phases for humeral hyperextension that could likely cause pain (photo, 9 A). When adjusting to mitigate the pain, the swimmer will most likely seek a path of least resistance and decrease efficiency of the arm stroke while shortening the pull-through phase. One of the easiest ways to see this is during an increase in stroke count.³³ (Photo 9 A, B, C).

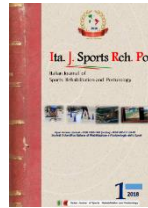
Muscle Activity

Clinically, the key to potential pathological conditions in the shoulder during the freestyle stroke may be related to the serratus anterior. In swimmers with normal shoulders, the serratus anterior continually fires above 20% of its maximum.³ This muscle appears to be stabilizing the scapula in a protracted position as the arm pulls the body over itself. When a muscle continually fires above 20%, it is susceptible to fatigue.³⁴ With the distances required during swim training, the serratus anterior is certainly vulnerable to fatigue. Indeed, in swimmers with painful shoulders, the serratus anterior demonstrates significantly less muscle action during a large portion of pull-through.

Although the serratus anterior diminishes its action during pull-through, the rhomboids increase their activity. It may be that, in an attempt to stabilize the scapula during the absence of the serratus anterior, the primary muscles available are the rhomboids. Yet the action of the rhomboids (retraction and downward rotation of the scapula) is the exact opposite of the serratus anterior (protraction and upward rotation). This may well be positioning the acromion to impinge on the rotator cuff.

Another muscle to consider when studying muscle activity during the freestyle stroke is the subscapularis. In swimmers with normal shoulders, this muscle also continually fires above 20% of its maximum.³ And, in swimmers with painful shoulders, there is significantly less activity during pull-through.³

Of interest, the primary “power” muscles of the shoulder during swimming (the latissimus dorsi and the pectoralis major) demonstrate no significant differences when comparing normal versus painful shoulders. So it appears that these muscles may not be integral in the prevention of injury.³ Also of note, neither the supraspinatus, teres minor, nor posterior deltoid exhibit any significant differences in muscle activity between painful and non painful or normal shoulders.³



Freestyle Pathomechanics

The cause of the painful shoulder in swimmers can be attributed to a myriad of stroke flaws. A hand entry that crosses the midline of the long axis causes mechanical impingement in the anterior shoulder, including the long head of the biceps and the supraspinatus (Figure 11 A). This is exacerbated by a thumb-first entry that further stresses the biceps attachment to the anterior labrum. A crossover pull-through usually results from a crossover entry (Figure 11.B) and increases the time in the impingement position. Proper body roll, however, can resolve most of the impingement risks, unless the athlete has glenohumeral instability or anterior capsular laxity and concomitant anterior subluxation.

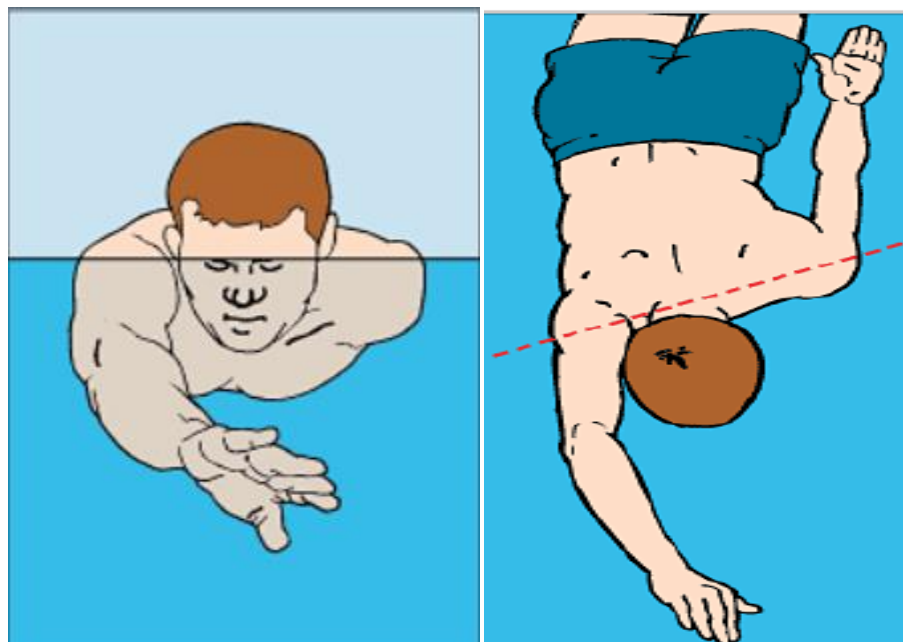
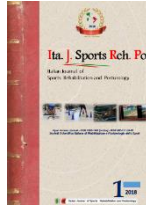


Photo 11 A. In improper freestyle techniques, the head is held too high with the eyebrows at the waterline and the arm crossing the centerline., **B.** View from above , illustrates poor shoulder alignment(dotted line), 'snaking' and lack of body rotation.

(From : James N. Johnson, MD Jason Gauvin, PT, ATC Michael Fredericson, MD Swimming Biomechanics and Injury Prevention The physician and sports medicine - VOL 31 - NO. 1 – January 2003.)⁴⁸

Asymmetric body roll or unilateral breathing may increase impingement by causing a compensatory crossover pull-through on the side with less roll or on the non breathing side. Improper head position, forward-sloping shoulders, and scapular instabilities are also implicated in arm, shoulder, upper-back, and neck pain that may or may not be associated



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with neurologic signs and symptoms.³⁵ EMG analysis by Pink³ in swimmers with painful shoulders revealed that the most prominent abnormality is a weakness of the serratus anterior and increased activity of the rhomboids during the pull. The resulting mechanical imbalance ("floating scapula") increases anterior impingement of the biceps and supraspinatus tendons.³⁶ EMG studies by Pink et al³ and resulting therapy recommendations for scapular stabilization are now widely accepted and used in the rehabilitation of shoulder injuries.³⁷

Kibler²¹ maintains that shoulder injury is prevented first by core stabilization and then by scapular stabilization. He describes the scapula as the link in the kinetic chain from the legs and trunk to the shoulder. Coaches and physical therapists are beginning to recognize the importance of strengthening the entire kinetic chain for the prevention and treatment of shoulder injuries.

Measurement of scapular positioning- lateral scapula slide test

The lateral scapular slide test (LSST) was designed by Kibler²¹ to assess scapular asymmetry under varying loads. In order to maintain a consistent posture during the various test positions, subjects are instructed to fix their eyes on an object in the examination area.³⁹ For the first test position of the LSST, the patient is instructed to keep the arms relaxed by their sides. The distance between the inferior-most aspect of the inferior angle of the scapula and the closest spinous process in the same horizontal plane are measured bilaterally with a tape measure. This procedure is repeated for test position 2 (the patient is instructed to actively place both hands on the ipsilateral hips, and consequently the humerus is positioned in medial rotation at $\pm 45^\circ$ of abduction in the coronal plane) and test position 3 (the patient is instructed to actively extend both elbows, elevate and maximally internally rotate – thumbs down – both arms at or below 90° in the coronal plane). Between test positions 2 and 3, the patient is instructed to reposition the upper extremities from the test position to neutral. For interpreting the LSST, a side-to-side difference of 1.5 cm was originally suggested for the diagnosis of shoulder dysfunction.²¹ (photo 12. A,B,C ; photo 13.A,B,C; photo 14. A,B,C)⁴⁶

The measurement of scapular position in swimmers recommended the use of Kibler^{2nd} and ^{3rd} methods. They speculated that there are only a few scapular stabilizer muscles active in the Kibler –1 position and greater activity of these muscles in the Kibler -2 and Kibler -3 positions. Therefore, Kibler – 2 and Kibler - 3 measurements may be more sensitive indicators of scapular fatigue as these assess the scapular position in dynamic state rather than the Kibler – 1 measurement that measures in static position.¹⁴



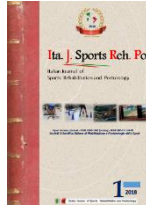
Photo 12. A, B, C. - First Positional measurements with arms at side. In the first of the three different positions, the first position (fig. 12A) is the related photographic projections of Kibler's test. Measurement of the distance between the lower corner of the scapula and the thorny correspondent is the fig 12B. This is measured in a comparison with the athlete arms outstretched at sides. On a landmark between the distance from the bottom of the scapula and the thorny parallel is in figure 12C. (D'Onofrio R.).⁴⁶



Photo 13. A, B, C - Second position and relative photographic projections of the Kibler's test: the second position, with hands on hips. - The second position in the proposed test of Kibler use language simplistic with the athlete's hands positioned on the iliac crest, fingers effectively forward and the thumb on the back. It puts the humerus at approximately 45 degree of abduction and always measured from the lower and the thorny, socket, initially as a landmark (Figure 13 A, B, C). (D'Onofrio R.)⁴⁶



Photo 14. A, B, C - Third position of the test of Kibler and related photographic projections - The third position, proposed as a progression, teaching, is an assessment of mobility, in a position much more functional. In this position, upper limb is abduction of 90 degree and involves glenohumeral internal rotation. The measurement is always the same having a landmark on thorny and inferior angle of the scapula. (Figure 14, A,B,C.) (D'Onofrio R.)⁴⁶



The manual methods such as Kibler and Diveta scapular measurement techniques are reliable in measuring the scapular position in swimmers. (Intraclass correlation coefficients (ICCs) for intratester reliability range from 0.92–0.95 - DiVeta technique and 0.81–0.94 -Kibler technique).¹⁴

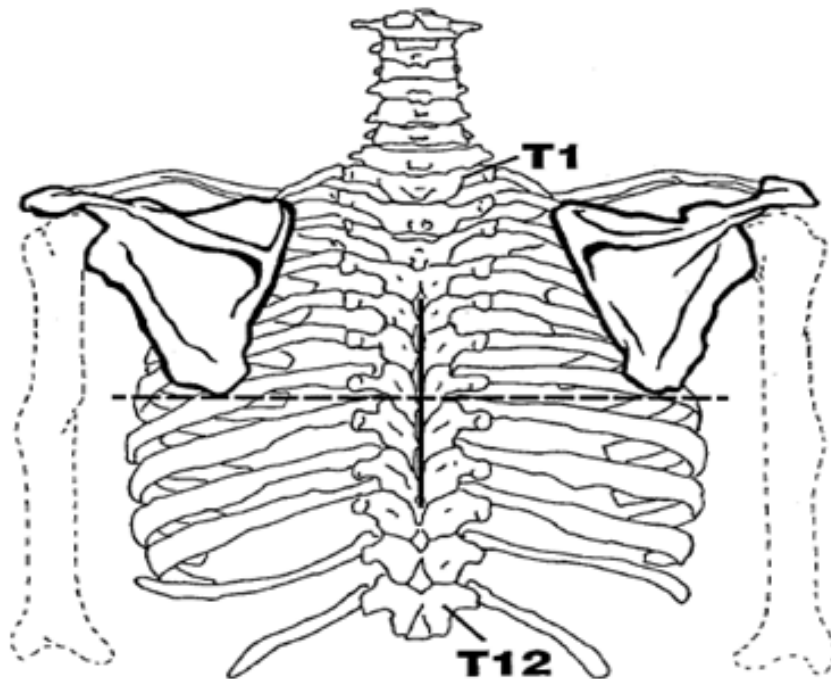
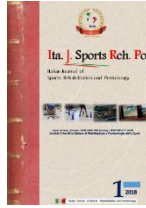


Photo 15. Bony landmark for the lateral scapula slide test .from Measurement of scapular asymmetry and assessment of shoulder dysfunction using the lateral scapular slide test.
(from : Corrie J Odom, Andrea B Taylor, Christine E Hurd, Craig R Denegar, *physical therapy*. 2001; 81:799-809.)⁴⁹

Kibler ²¹ reported that the test-retest (intratester) ratio of LSST ranges from 0.84 to 0.88 and that the intertester reliability ranges from 0.77 to 0.85, depending on the position, and he suggested that LSST is reliable in terms of reproducibility. Although they reported high intraclass correlation coefficients (ICCs) for intratester reliability (ICC = 0.81–0.95) using Kibler's protocol, Gibson et al ³⁸ reported that differences between examiners might account in part for their low ICCs for interrater reliability (ICC = 0.18–0.69). However, their use of a modified version of Kibler's protocol also might have accounted for their low interrater reliability. Gibson et al ³⁸ standardized the landmarks and measured the scapular distance from the inferior angle of the scapula to the spinous process of T8.



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Methods

Study Design

Repeated measures design was used in this study.

Participants

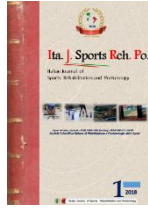
Forty-three male swimmers between 20 -25 years of age were recruited, on a volunteer basis, for participation in the study. They were recruited from a different swimming academy at Ahmedabad. and included in the study if they participated in swim practice at least 4 d/wk, and completed at least 15 of the 18 training sessions and had approximately 2 years of regular training experience, and considered freestyle their preferred stroke.. Subjects were excluded from the study if they were diagnosed with a recent shoulder, cervical or thoracic injury or shoulder pain that interfered with swim training. None of the swimmers experienced any shoulder pain during the 12-week test period. And previous interventions with steroid injections. The swimmers signed informed consent documents. Testing was conducted poolside during normal practice hours.

Procedures

The two positions of the lateral scapular slide test devised by W. Ben Kibler²¹ are the semi dynamic method of evaluating the position of scapula on both the sides of spine. In the second position (LSST 2) the subject stands with his or her hands on the hips. In the third position (LSST 3) the subject's shoulders are abducted to 90 degrees with the upper limbs internally rotated Kibler quoted a side to side difference of 1.0 – 1.5 cm as being significant and the same is considered in the present study.¹⁹ (Photo.16,17,18,19)

Prior to the warm up, measurement of scapular position using the LSST 2nd and 3rd method was taken. The subjects were then asked to proceed for the warm up. The warm up consisted of 200 meters swimming using freestyle stroke. Immediately after the warm up, they were asked to step up aside the pool for the scapular position measurements using LSST 2nd and LSST 3rd position. Once the measurements were completed, they were asked to begin with their training session. It consisted of 3000 meters of swimming using the freestyle stroke again. Immediately after the training, the swimmers were again asked to step up aside the pool and the scapular position measurement using the LSST 2nd and 3rd position was taken. The subjects were then instructed to continue with their cool down which consisted of 100 meters swimming using freestyle strokes. After the cool down was completed, the scapular position measurements again taken.

All the sessions of warm up, exercise and cool down were of equal distance for all the participant .so that the time periods of all the sessions was similar for all the subjects. A



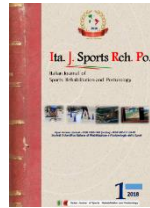
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side to side difference of greater than or equal to 1.5 cm was taken as clinically significant.¹⁹

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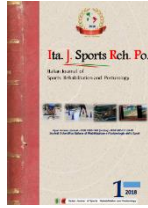
Photo 16. LSST 2nd position: Participant was instructed to place hands on the hips, which resulted in 10 degrees of extension, some internal rotation, and about 45 degrees of glenohumeral abduction.



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Photo 17. Position 2 for the lateral scapular slide test (hands on the hips).



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Photo 18 In the LSST 3rd position, the shoulders were abducted to 90 degrees with full internal Rotation.

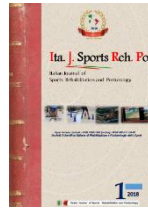


Photo 19. Position 3 for the lateral scapular slide test (arms at or below 90° abduction, with Glenohumeral internal rotation).

Statistical Analysis

All data were analyzed using SPSS (Version 16) with the friedmen test, wilcoxin signed rank test for proportion to the detect differences in scapular position across multiple levels namely - baseline, after warm up, after exercise and after cool down. All of the results are presented with their mean and standard deviation (SD).

P value of less than or equal to 0.05 was considered statistically significant.



Result

Table 1. Demographic Data of Swimmers (N=43)

Variable	Mean ± SD			
Age	22.41± 1.78			
Years of Swimming	3.50 ± 1.05			
Days /Week	5.02 ± 0.76			
Weight	42.25± 5.26			

The mean age of the swimmer was 22.41±1.78 with mean weight 42.25± 5.26 and a minimal of participation at the state level. The swimmer was swimming for an average of 5.02 ±0.76 days per week and swimmers have swimming experience of mean years of 3.50 ±1.05. (Table 1).

All the swimmers included were of right hand dominance.

Table 2. Mean (Standard deviations, ±), median of LSST2 (right), regarding high intensity training. (N=43)

Variable	Mean ± SD	Median	Friedmen test value	P value
Baseline	10.83± 4.39	10.26		
After Warm- up	10.59± 3.77	9.94	24.66	0.001**
After exercise	11.41± 3.84	10.2		
After cool down	11.57± 4.13	10.03		

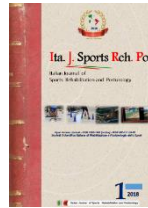
Level of significance $p \leq 0.05$

** - highly significant

The linear distance between the inferior angle of scapula and adjacent vertebrae in LSST 2nd position on right side at baseline was 10.83 ± 4.39, after warm up 10.59 ± 3.77, after exercise 11.41 ± 3.84, after cool down 11.57± 4.13.

The LSST 2nd position shows highly significant result ($p=0.001$) when assessed at various intervals for lateral scapular displacement with friedmen test. (Table 2).

Table 3. Mean (Standard deviations, ±), median of LSST2 (left), regarding high intensity



training. (N=43)

Variable	Mean ± SD	Median	Friedmen test value	P value
Baseline	10.73± 3.54	9.88		
After Warm- up	10.37± 3.11	10.1	15.4	0.002**
After exercise	10.92± 3.10	10.26		
After cool down	11.04± 3.67	10.26		

Level of significance $p \leq 0.05$

** - highly significant

The linear distance between the inferior angle of scapula and adjacent vertebrae in LSST 2nd position on left side at baseline was 10.73± 3.54, after warm up 10.37± 3.11, after exercise 10.92± 3.10, after cool down 11.04± 3.67.

The LSST 2nd position on left side shows highly significant result ($p=0.002$) when assessed at various intervals for lateral scapular displacement with friedmen test. (Table 3).

Table 4. Mean (Standard deviations, ±), median of LSST3 (right), regarding high intensity training. (N=43)

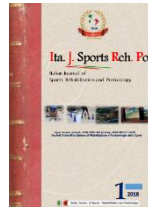
Variable	Mean ± SD	Median	Friedmen test value	P value
Baseline	11.72± 2.84	11.07		
After Warm- up	12.33± 3.22	11.98	9.11	0.028*
After exercise	12.76± 3.12	12.39		
After cool down	12.23± 3.33	11.37		

Level of significance $p \leq 0.05$

* - significant

The linear distance between the inferior angle of the scapula and adjacent vertebrae in LSST 3rd position on right side at baseline was 11.72± 2.84, after warm up 12.33± 3.22, after exercise 12.76± 3.12 and after cool down 12.23± 3.33.

The LSST 3rd position shows significant result ($p=0.028$) when assessed at various



intervals for lateral scapular displacement with friedmen test. (Table 4).

Table 5. Mean (Standard deviations, ±), median of LSST3 (Left), regarding high intensity training. (N=43)

Variable	Mean ± SD	Median	Friedmen test value	P value
Baseline	10.91± 2.42	10.41		
After Warm- up	12.0 ± 3.45	11.22	37.2	0.001**
After exercise	11.88± 2.62	11.6		
After cool down	12.28± 2.90	11.53		

Level of significance $p \leq 0.05$

** - highly significant

The linear distance between the inferior angle of the scapula and adjacent vertebrae in LSST 3rd position on left side at baseline was 10.91 ± 2.42 , after warm up 12.0 ± 3.45 , after exercise 11.88 ± 2.62 and after cool down 12.28 ± 2.90 .

The LSST 3rd position on left side shows highly significant result ($p=0.001$) when assessed at various intervals for lateral scapular displacement with friedmen test. (Table 5).

Table 6. Scapula position alteration before, during and after high intensity training in LSST2 (right) (N=43)

Variable		Median difference	Mean difference	P value(wilcoxin)
Baseline	After Warm- up	0.32	0.2335	0.334
	After exercise	- 0.6	- 0.5804	0.016*
	After cool down	0.23	- 0.7397	0.001**
After Warm- up	After exercise	- 0.26	- 0.9732	0.001**
	After cool down	- 0.09	- 0.8139	0.001**
After exercise	After cool down	0.17	- 0.1593	0.361

Level of significance $p \leq 0.05$

** - highly significant



* - Significant

Pair wise comparison by wilcoxon signed ranks test shows that on right side in LSST 2nd position there is highly significant increase ($p=0.016^* < 0.001^{**}$) and increase is found from baseline to after exercise and from baseline to after cool down.

Highly Significant increase is also found from after warm up to after exercise and after warm up to after cool down.

When compared from baseline to after warm up and after the exercise to after cool down there is no significant increase found. (Table 6).

Table 7. Scapula position alteration before, during and after high intensity training in LSST2 (left) (N=43)

Variable		Median difference	Mean difference	P value(wilcoxin)		
Baseline	After Warm- up	-0.22	- 0.3667	0.066		
	After exercise	-0.38	- 0.1821	0.289		
	After cool down	-0.38	- 0.3105	0.098		
After Warm- up	After exercise	-0.16	- 0.5488	0.001**		
	After cool down	- 0.16	- 0.6772	0.01*		
After exercise	After cool down	-0.36	- 0.1284	0.828		

Level of significance $p \leq 0.05$

** - highly significant

* - Significant

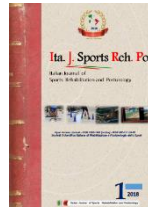
Pair wise comparison by wilcoxon signed ranks test shows that on left side in LSST 2nd position there is highly significant increase ($p=0.01^* < 0.001^{**}$) and increase is found from after warm up to after cool down and from after warm up to after exercise.

When compared from baseline to after warm up and baseline to after exercise and baseline to after cool down there is no significant increase found.

When compared from after the exercise to after cool down there is no significant increase found. (Table 7).

Table 8. Scapula position alteration before, during and after high intensity training in LSST3 (right) (N=43)

Variable		Median difference	Mean difference	P value(wilcoxin)		
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Baseline	After Warm- up	-0.91	- 0.6051	0.17		
	After exercise	-1.32	- 1.0363	0.005**		
	After cool down	-0.30	- 0.5076	0.313		
After Warm- up	After exercise	-0.41	- 0.4312	0.051*		
	After cool down	0.61	0.0975	0.666		
After exercise	After cool down	1.02	-0.5287	0.031*		

Level of significance $p \leq 0.05$

** - highly significant

* - Significant

Pair wise comparison by wilcoxon signed ranks test shows that on right side in LSST 3rd position there is highly significant increase ($p=0.005^{**}$) and increase is found from baseline to after exercise.

Significant increase is also found from after warm up to after exercise and after exercise to after cool down.

When compared from baseline to after warm up and baseline to after cool down there is no significant increase found.

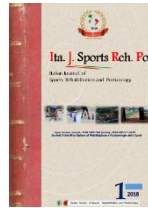
When compared from after warm up to after cool down there is no significant increase Found. (Table 8).

Table 9. Scapula position alteration before, during and after high intensity training in LSST3 (left) (N=43)

Variable		Median difference	Mean difference	P value(wilcoxin)		
Baseline	After Warm- up	-0.81	- 1.09	0.001**		
	After exercise	-1.19	- 0.973	0.001**		
	After cool down	-1.12	- 1.3686	0.001**		
After Warm- up	After exercise	-0.38	0.117	0.807		
	After cool down	-0.31	- 0.2786	0.018*		
After exercise	After cool down	0.07	- 0.3956	0.035*		

Level of significance $p \leq 0.05$

** - highly significant



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*- Significant

Pair wise comparison by wilcoxon signed ranks test shows that on left side in LSST 3rd position there is highly significant increase ($p=0.001^{**}$) and increase is found from baseline to after warm up and baseline to after exercise and baseline to after cool down.

Significant increase is also found from after warm up to after cool down and after exercise to after cool down.

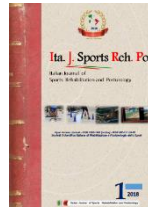
When compared from after warm up to after exercise there is no significant increase Found. (Table 9).

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Discussion

Kibler^{21, 51, 52} described the first manual test as the trial evaluation of the scapular muscle strength. The athlete is asked to perform an isometric contraction of the shoulder blade and hold for 15- 20 seconds. A possible weakness of the scapular muscle gives rise to a "burning pain" in less than 15 seconds. However, this first test can be used to validate or properly objectify muscle weakness in scapulars as a specific evaluation of the functional behaviour of the scapula.⁵² This test involves measuring the distance from the inferior angle of the scapula to the nearest vertebral spinous process using a tape measure or goniometer in three positions: shoulder in neutral, shoulder at 40-45 degrees of coronal plane abduction with hands resting on hips, and the shoulder at 90 degrees abduction with the arms in full internal rotation. Kibler^{21, 51, 52} contends that injured or deficient side would exhibit a greater scapular distance than the uninjured or normal side and asserted that a bilateral difference of 1.5 cm (15 mm) should be the threshold for deciding whether scapular asymmetry is present⁵⁰ also suggested that LSST may be used to monitor the scapular stabilizer muscles in any rehabilitative program that involves shoulder strengthening exercises.⁵²

The purpose of this to determine the effects of high intensity swim training program on scapula position in swimmers. In this study, LSST values significantly increased after the high intensity training programme. This contrasts with the results of Crotty and Smith¹⁹, who found no significant changes at the post training period. In their study, only male swimmers were tested, and only the first position of the LSST was included Crotty & Smith¹⁹. Electromyographic evaluation has shown that very few muscles are working during the first position Kibler,²¹ Only in the third position do scapular stabilizing muscles work at 40% of their maximum contraction.²¹ Consequently, the first position is less



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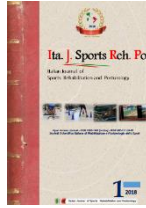
appropriate to detect fatigue in scapular muscles (Crotty & Smith¹⁹). That is the reason we did not take measurement of LSST 1st position in our study.

According to Kibler,²¹ higher LSST values could be a result of the fatigue of the scapular stabilizers and therefore considered as disadvantageous. The relevance of the LSST is generally still under debate. Currently, no validity studies regarding scapular muscle fatigue and changes in LSST are available in literature. Our results suggested the presence of an altered scapular position after a swim training session. We must remark that an increased distance between the inferior angle and the spinal process could be a result of increased upward rotation. Especially in the second and third test position, sufficient upward rotation during elevation is necessary to avoid impingement, Kibler,²¹ according to Su et al.²⁰ as lateral displacement of the scapula contributes in upward rotation, an increased LSST could be considered as beneficial. Only one previous study had examined the influence of short term fatigue on scapular upward rotation in swimmers. In a group of healthy swimmers no changes occurred after a swim training session, where as in swimmers with some shoulder impingement syndrome, a decrease in scapular upward rotation was found by Su et al.²⁰

Kibler²¹ proposed that assessment of scapular symmetry is based on biomechanics and believed that muscle deficiencies are associated with and unstable scapula. Although a thorough understanding of shoulder girdle mechanics is important, the reliability of the LSST remains in question. Results of previous reliability studies of scapular positioning, as well as those presented in this article, have demonstrated that measurements of linear distance related to the scapula can be reliable. The LSST has been used to assess scapular asymmetry, which may be indicative of shoulder dysfunction. Moreover, the LSST is a relatively simple procedure that is neither time intensive nor expensive. However, while some researchers have found the LSST to be reliable, many researchers concluded the LSST may be too variable and, thus, unreliable.⁴⁰

Ka Pik Eva Su et al.⁴¹ conducted a study on scapular rotation in 20 swimmers with impingement and 20 swimmers without impingement syndrome to examine the effects of a normal swim practice on the scapular kinematics pre swim to post swim. Results showed that both the groups experienced muscle fatigue and decreases in scapular upward rotation in subjects with shoulder impingement when measured at 45, 90 and 135° of humeral elevation with inclinometer. They concluded that abnormal scapular kinematics in swimmers may be immediately examined after swimming and provide more information regarding impingement syndrome than a typical clinical exam.

Crotty and Smith¹⁹ studied the effects of intense swimming exercise on the scapular position in twenty male high school swimmers using the commonly accepted Kibler and Diveta²¹ scapular position measurement techniques and concluded that the



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non-dominant side scapulae moved more laterally post exercise and recommended further studies using the Kibler 2nd and 3rd scapular measurement methods.

Su et al ²⁰ used digital inclinometer in their study and showed that in swimmers with subacromial impingement syndrome, the arm with pathology, showed a decreased upward rotation at 45, 90 and 135 degrees of humeral elevation in the scapular plane after a one to two hour swimming session, whereas before the session no differences were noted between the painful shoulder and the pain free shoulder. This would suggest altered motor patterns occur as a result of the swimming training. For the current study the reported values for scapular rotation were measured at 90 degrees of abduction. Whereas Su et al ²⁰ performed humeral elevation in the scapular plane when assessing the upward rotation of the scapula making the values difficult to compare. Even when considering the differences in the plane of motion of humeral abduction, both the current study and Su et al ²⁰ show that bilateral changes in upward rotation do occur as a result of a single swimming session.

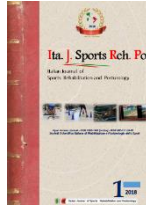
These results are in contrast to a study by Van de Velde⁴² who reported that the dominant side showed an increased upward rotation of the scapula as a result of a two hour long swim training session when compared to the non-dominant side. Possible explanations for the differences in the results could be that different methodologies were used in the measurement of scapular upward rotation. In previous study described by Johnson, ⁴³ scapular upward rotation was measured using digital inclinometer . While Van de Velde ⁴² used the lateral scapular slide test (LSST) which measures the distance of the inferior angle from the seventh thoracic spinous process as a marker of upward rotation in centimeters during varying angles of humeral elevation.⁴⁴

Scapular displacement measurement by LSST 2nd position

The results of the friedman test performed to assess the linear change in scapular position over the warm up, exercise and cool down period showed highly significant result for LSST 2nd position on right side (p=0.001) and left side (p=0.002).

When pair wise comparisons by wilcoxin signed rank tests were performed for right side in LSST 2nd position at baseline, after warm up, after exercise and after cool down levels, highly significant changes were found in the scapular position from baseline to cool down (p=0.001) and from after warm up to after exercise (p=0.001) and from after warm up to after cool down (p=0.001).

Pair wise comparisons by wilcoxin signed rank tests for LSST 2nd position on left side, results showed highly significant result from after warm up to after exercise (p=0.001) and significant from after warm up to after cool down (p=0.01).



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The deviation of the scapula from thoracic midline in LSST 2nd position is thought to be due to fatigue of serratus anterior and lower trapezius, which are the only two muscles working to stabilize the scapula in LSST 2nd position.¹⁷ The electro-myographic findings have shown that that serratus anterior and trapezius muscles are more prone to undergo fatigue than other muscles about the shoulder during the repetitive overhead motions such as swimming and throwing.⁴⁵

This might be the reason for the muscles to displace the scapula laterally as a result of muscle fatigue.

Scapular displacement measurement by LSST 3rd position

The results of the friedmen test for LSST 3rd position on the left side showed highly significant results ($p=0.001$) and significant results ($p= 0.028$) were found for LSST3 position on the right side.

On performing the post hoc analysis using the wilcoxin signed rank pair wise comparisons test on right side to isolate the changes in scapular displacement over various levels, highly significant results were found in LSST 3rd position on right side from baseline to after exercise ($p= 0.005$) and significant results from after warm up to after exercise ($p= 0.051$) and after exercise to after cool down. ($p=0.031$).

On left side highly significant result seen from baseline to after warm up ($p=0.001$), from baseline to after exercise ($p=0.001$), from baseline to after cool down ($p=0.001$). And significant results were found from after warm up to after cool down ($p=0.018$) and from after exercise to after cool down. ($p=0.035$).

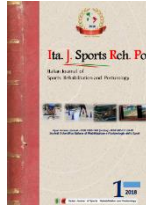
Conclusions

The results of the present study clearly indicated that LSST 2nd method of scapular position measurement is good and sensitive enough in detecting the lateral scapular displacement on both right and left side.

Further LSST 2nd position can be effectively used to detect the occurrence of fatigue i.e., clinically significant lateral scapular displacement immediately after warm up to after exercise and after warm up to after cool down on right side and left side. LSST 3 position is good in assessing the lateral scapular displacement only on the right and left side.

Further LSST 3 position can be effectively used to detect the occurrence of fatigue i.e., clinically significant lateral scapular displacement from baseline to after exercise right side and baseline to after warm up, after exercise and after cool down on left side.

Poor scapular posture and movement have been suggested as mechanisms in the pathogenesis of a number of shoulder pathologies. Although this is yet to be proven, many clinicians believe that the clinical assessment of scapular position is an essential part



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of the clinical examination of the shoulder. The findings of the current study provide clinicians with clinically accessible measurements to determine the static and angular position of the scapula (when the arm is by the side) in subjects with and without symptoms.

The results of our investigation were that measurements obtained with the lateral scapular slide test (LSST) is reliable in assessing scapular positioning or symmetry. The authors believe the LSST provides.

More objective measures than pure observation and can be enhanced by using a scoliometer or caliper rather than a tape measure.

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Acknowledgments

We would like to thank the swimmers and coaches of the swimming clubs for their participation in our study. We appreciate the suggestions offered by anonymous reviewers.

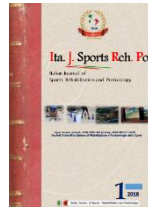


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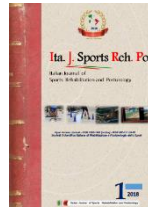
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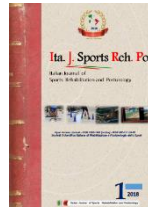
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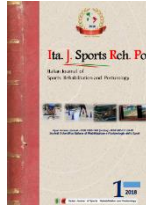
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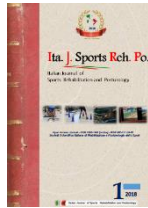
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