FLEXIBILITY, STABILITY AND MUSCULAR PERFORMANCE IN PAIN-FREE AND SYMPTOMATIC SHOULDER IN SWIMMERS

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FLEXIBILITY, STABILITY AND MUSCULAR PERFORMANCE IN PAIN-FREE AND SYMPTOMATIC SHOULDER IN SWIMMERS

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ABSTRACT

The purpose of this study was to compare shoulder flexibility, stability and muscle strength of swimmers between pain-free and symptomatic groups. The subjects were 30 female and 20 male athletes in swimming clubs, age 15-21 years. According to the symptoms, half of the subjects were allocated into the pain-free group and the other half into the symptomatic group. All subjects filled in two questionnaires and shoulder flexibility tests and stability tests were conducted. Shoulder rotator muscle strength was measured using Con-Trex human isokinetic at 60° and 240°/sec both conventional and functional modes.

The results showed the tendency of compromised shoulder flexibility and stability in pain-free group compared to symptomatic group. More subjects in the symptomatic group had posterior capsule tightness. The anterior translation of humeral head were found more frequently than other directions. The symptomatic group had higher shoulder rotator peak torque ratios both concentric external rotation/concentric internal rotation, and eccentric external rotation/concentric internal rotation than pain-free group. These trends were found in both female and male athletes.

The results of this study indicated that the symptomatic group tended to have less shoulder flexibility, stability and muscle strength, in particular shoulder internal rotator muscles. Therefore, rehabilitation in swimmers with shoulder pain should consider stretching the posterior capsule and strength training of the external and internal rotators, emphasizing internal rotator muscles.

KEY WORDS : FLEXIBILITY / STABILITY / PEAK TORQUE RATIO / ISOKINETIC / SHOULDER / SWIMMERS

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ความยืดหยุ่นของข้อไหล่ ความมั่นคงของข้อไหล่ และสมรรถภาพของกล้ามเนื้อข้อไหล่ในนักว่ายน้ำที่มีและไม่มีอาการปวดข้อไหล่ (FLEXIBILITY, STABILITY AND MUSCULAR PERFORMANCE IN PAIN-FREE AND SYMPTOMATIC SHOULDER IN SWIMMERS)

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บทคัดย่อ

การศึกษาครั้งนี้มีวัตถุประสงค์เพื่อเปรียบเทียบความยืดหยุ่นของข้อไหล่ ความมั่นคงของข้อไหล่ และความแข็งแรงของกล้ามเนื้อข้อไหล่ในนักกีฬาว่ายน้ำระหว่างกลุ่มที่มีและไม่มีอาการปวดข้อไหล่ ผู้เข้าร่วมการศึกษาเป็นนักกีฬาในสโมสรว่ายน้ำเพศหญิง 30 คน และเพศชาย 20 คน ช่วงอายุตั้งแต่ 15-21 ปี แบ่งเป็นกลุ่มที่ไม่มีอาการปวดและกลุ่มที่มีอาการปวดอย่างละครึ่ง โดยทุกคนตอบแบบสอบถาม 2 ชุดและรับการตรวจความยืดหยุ่นของข้อไหล่ ความมั่นคงของข้อไหล่ และ วัดความแข็งแรงของกล้ามเนื้อหมุนข้อไหล่ โดยใช้เครื่องคอนเทรกซ์ฮิวแมนไอโซไคเนติกส์ วัดที่ความเร็ว 60 และ 240 องศาต่อวินาที ทั้งแบบคอนเวนชั่นและแบบฟังก์ชั่น

ผลการศึกษาพบ แนวโน้มการลดลงของความยืดหยุ่นของข้อไหล่ และความมั่นคงของข้อไหล่ในกลุ่มนักกีฬาว่ายน้ำที่มีอาการปวดข้อไหล่เมื่อเทียบกับกลุ่มนักกีฬาว่ายน้ำที่ไม่มีอาการปวดข้อไหล่ โดยมีจำนวนนักกีฬาในกลุ่มที่มีอาการปวดข้อไหล่ที่มีการหดรั้งของเยื่อหุ้มข้อทางด้านหลังข้อไหล่มากกว่าและพบการเลื่อนของหัวกระดูกฮิวเมอรัสมาทางด้านหน้ามากที่สุดเมื่อเทียบกับการเลื่อนไปในทิศทางอื่นๆ ค่าอัตราส่วนแรงสูงสุดของกล้ามเนื้อหมุนข้อไหล่ออกต่อกล้ามเนื้อหมุนข้อไหล่เข้าทั้งแบบคอนเซนตริคกับคอนเซนตริคและอีเซนตริคกับคอนเซนตริค ในกลุ่มที่มีอาการปวดข้อไหล่มีค่าสูงกว่าในกลุ่มที่ไม่มีอาการปวดข้อไหล่ ผลการศึกษาข้างต้นพบทั้งในนักกีฬาหญิงและชาย

ผลการศึกษาครั้งนี้บ่งชี้ว่านักกีฬาว่ายน้ำที่มีอาการปวดข้อไหล่มีแนวโน้มของความยืดหยุ่นของข้อไหล่ ความมั่นคงของข้อไหล่ และความแข็งแรงของกล้ามเนื้อข้อไหล่น้อยกว่ากลุ่มที่ไม่ปวด โดยเฉพาะกล้ามเนื้อหมุนข้อไหล่เข้า ดังนั้นในการฟื้นฟูข้อไหล่ในนักกีฬาว่ายน้ำที่มีอาการปวดจึงควรคำนึงถึงการยืดเยื่อหุ้มข้อไหล่ทางด้านหลัง และการฝึกความแข็งแรงของกล้ามเนื้อหมุนออกและหมุนเข้าของข้อไหล่ โดยเน้นกล้ามเนื้อหมุนข้อไหล่เข้า

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LIST OF ABBREVIATIONS

PT	=	peak torque
Nm	=	Newton meter
Con	=	concentric
Ecc	=	eccentric
°/sec	=	degrees/second
ER	=	external rotation
IR	=	internal rotation
cm	=	centimeter (s)
kg	=	kilogram (s)
yrs	=	years

CHAPTER I
INTRODUCTION

Swimming is a popular recreational activity as well as sport, especially among young people (1-3). Performance level of athletes is known to be dependent on many physical and mental factors such as muscle strength and flexibility, stress level and environment status. A competitive swimmer usually has a long training duration, averaging 10,000 meters daily. It is estimated that a swimmer has to perform 10 freestyle cycles for every 25 m., therefore the swimmer strokes approximately 4,000 cycles per shoulder on a daily basis (2,4). Only minimal recovery time is available for muscles to recover from one stroke to the next during swimming (3).

Overhead movements during swimming can cause shoulder pain from repetitive micro-trauma and overuse in athletes (5-7). Shoulder problem prevalence was reported to be 66% in swimmers, 57% in professional pitchers, 44% in collegiate volleyball players, and 29% in collegiate javelin throwers (8). A number of studies showed that shoulder pain was the most common musculoskeletal complaint in swimmers with reported incidence ranged from 47-87% (2,5,9). Mcmaster and Troup found shoulder complaints to be 47% in young swimmers (13-14 years old), 66% in older group (15-16 years old) and 73% in elite swimmers (5). Beach et al reported that 87% of swimmers had experienced shoulder pain and 69% had pain at the time of the study (9).

Several studies found that the most common cause of shoulder pain in swimmers is impingement syndrome under the coracoacromial arch and glenohumeral instability (2,3,5,6,9,10). There are 50% incidence of subacromial impingement and anterior/posterior glenohumeral subluxation in swimmers (11). Warner et al stated that glenohumeral instability and impingement syndrome originated from an imbalance of internal and external rotator muscles of the shoulder, accompanied with degrees of capsular laxity and loss of capsular flexibility (10).

Subacromial impingement is classified as primary and secondary (12,13). Primary impingement refers to a mechanical encroachment into the subacromial space of the humeral (12) which leads to repetitive impingement of the rotator cuff under the coracoacromial arch (14). Secondary impingement syndrome is considered to be a result of shoulder structural dysfunctions such as instability, scapulothoracic weakness, and posterior capsule tightness. These factors may contribute to the subtle anterior instability (10,12,15). Glenohumeral instability can develop from a disruption of static stabilizers (ligament, labrum, and capsule) or fatigue as well as weakness of the dynamic stabilizers (13).

Anterior glenohumeral laxity was reported to be highly prevalent in backstrokers (2). The trouble points in the backstroke is when the arm touch the wall (immediately after hand entry) while shoulder externally rotates, flexes and horizontally abducts maximally. The force produced during this phase may clinically result in anterior capsular laxity to the extent that the anterior inferior glenohumeral ligament and a head of humerus may be pried anteriorly (2,17,22).

The pathomechanics of symptomatic shoulders in swimmers is suggested to be the position of horizontal adduction and internal rotation during mid pull-through of freestyle, backstroke and butterfly while the hand is crossed passing the midline of the body. This position has a greater chance of impingement and has been reported to have the highest incidence of pain (16). During recovery phase, the shoulder may be at risk for primary impingement due to the malpositioning from the decrement in the amount of external rotation resulted from fatiguing muscles or secondary impingement due to anterior laxity and rotator cuff fatigue (3).

Shoulder motions during swimming need the fine tuned motions of scapulothoracic joint. The scapulothoracic muscle weakness has been recognized as a cause of secondary subacromial impingement syndrome (17). During the recovery phase of swimming, the scapula should upwardly rotate and then be stabilized by the scapulothoracic muscles in order for the hand to be placed in the water. In early pull-through phase, scapula downwardly rotates, so sufficient strength of the scapula muscles is needed to prevent the abnormal mechanics (4).

Several authors conferred that an increased shoulder mobility is the etiology for shoulder dysfunction in swimmers (2,9), while some authors discussed that lack of mobility is the mean of dysfunction (18). Also, strength of the rotator cuff musculature has been recognized to contribute to the pathomechanics of both impingement and instability (14). However, reports on isokinetic strength of internal and external rotators are still controversial (9,18-20). Three studies reported increased internal rotation strength and decreased external rotation strength in swimmers (9,19,20). Another study reported decreased internal rotation strength in swimmers with shoulder pain and no difference in external rotation strength between the painful and pain-free shoulder swimmers (18). However, the results from isokinetic strength testing of the shoulder have significant limitations in interpretation due to the varied testing positions and protocols (9,18-20).

Endurance ratios were suggested to be a better indicator of symptomatic shoulder because it can identify greater deficits of the strength testing (3). However, there were only few researches on shoulder endurance. Beach et al found an increased pain scale in subjects with decreased endurance ratios of external rotation and abduction (9).

To our knowledge, there was no study investigated shoulder flexibility, strength and endurance in Thai swimmers with shoulder pain and normal shoulder. Injuries in athletes can affect the ability to play sport and can cause the athlete to stop playing prematurely if no proper treatment is provided. Therefore, this study aims to evaluate shoulder flexibility, stability and muscular performance in swimmers with shoulder pain and normal shoulder. The information from this study can be used as a guideline for preventing further injury and planning proper rehabilitation program in swimmers with shoulder pain.

Purposes of the Study

General Objective

To evaluate the patterns of shoulder flexibility, stability and muscular performance of pain free shoulder and symptomatic shoulder in swimmers.

Specific Objective

1. To compare flexibility between pain-free and symptomatic shoulders.
2. To compare stability profile between pain-free and symptomatic shoulders.
3. To compare muscle strength between pain-free and symptomatic shoulders.

Parameters

1. **Shoulder flexibility tests including:**
   - range of motions
   - anterior and posterior capsule flexibility
   - end feel of motions
2. **Shoulder instability profile tests including:**
   - grade of glenohumeral translation in anterior-posterior direction
   - grade of glenohumeral translation in inferior direction
3. **Shoulder muscle performance including:**
   - peak torque for ER and IR
   - peak torque ratios for ER/IR

Scope of the Study

This study focused on an evaluation of the patterns of shoulder flexibility, shoulder stability and shoulder muscular performance in competitive swimmers with shoulder pain comparing with pain-free shoulder.

Hypotheses of the Study

1. The shoulder flexibility will be significantly greater in the pain-free shoulder group compared to the symptomatic shoulder group.
2. The shoulder stability will be significantly greater in the pain-free shoulder group compared to the symptomatic shoulder group.
3. The shoulder ER/IR strength ratios will be significantly greater in the pain-free shoulder group compared to the symptomatic shoulder group.

Advantages of the Study

1. This study provided patterns of shoulder flexibility, stability profile and muscular performance in competitive swimmers.
2. The findings of this study can be used as a guideline for planning of shoulder rehabilitation programs in competitive swimmers with shoulder pain.
3. The findings of this study can be used as a guideline for preventing shoulder injuries in competitive swimmers.

CHAPTER II
LITERATURE REVIEW

2.1 The Characteristics of Different Swimming Strokes

Competitive swimming has four different strokes including freestyle (front crawl), backstroke, breaststroke and butterfly (11,21). The freestyle is often used as a training stroke substituting for others. The freestyle and backstroke use alternating arm patterns requiring body roll, whereas the butterfly and breaststroke use a simultaneous bilateral stroke.

The single arm stroke patterns rely on body roll for positioning. The use of body roll is essential for maintaining the shoulder in an efficient position of relative neutral. This allows muscular recruitments of both the pectorals which is placed anteriorly and works as the adductor/internal rotator and the latissimus dorsi which is placed posteriorly and works as the adductor/internal rotator resulting in a more powerful stroke (11).

The hand movement through water is relatively consistent and generally described as the S pattern. Observation of this movement demonstrates phases where the hand moves transversely through the water. Although at first glance this appears to be an impediment to forward movement, this pattern also creates a lifting component that helps propeling the body. If the arm and hand pull straight back through the water, the body would be pulled laterally, decreasing the efficiency of forward movement. Therefore, hand position is very crucial. It is dependent on the skill of the swimmer and the efficiency of the forearm musculature (11).

All strokes are divided roughly into two phases : the in-water phase called pull-through, and the out-of-water phase called recovery. This excepts the breastroke which does not have this pattern (11).

The pull-through phase consists of sculling, movements of pulling or pushing water to get the most efficient and forceful propulsion. The arm starts at maximum elevation and ends in extension. During the recovery phase, the arm returns to the position to start another pull. Front crawl, butterfly and backstroke mainly rely on the arms for the forward propulsion (75%), whereas in the breaststroke the legs and arms contribute equally (21).

2.1.1 Freestyle

The fastest stroke and the one most frequently used in practice session is the freestyle. Freestyle stroke depends mainly on the contribution of the upper extremity for forward propulsion, while the legs perform flutter kicks (11,21).

The pull phase of freestyle stroke is initiated with a sculling motion. The torso is rolled about its longitudinal axis so the arm can be positioned deeper in the water. An S-shaped curving pull is produced under the torso, with the hand ending at the hip. During the end of the pull-through phase the shoulder is in the impingement position of maximal adduction and internal rotation (11,21)

The recovery of one arm occurs during the pull phase of the other arm. Efficient recovery is based on the participation of the external rotators and body roll. The supraspinatus and infraspinatus are active during recovery until hand entry. A premature fatigue or an improper arm position leads to abnormal migration of the humeral head with possible impingement.

2.1.2 Butterfly

The butterfly is the second fastest stroke. The underwater arm action is similar to the freestyle. The arms do not alternate but move in unison through the pull phase and the recovery. To relieve stress on the shoulders and to move faster through the water, a dolphin motion is produced with the whole body (21).

The significant differences between the butterfly compared to the freestyle are the lack of body roll, the lack of hand rotation for breathing, and the simultaneous movement of the arms. The butterfly stroke is accomplished by keeping the arms apart in the mid pull-through phase. This maintains the shoulder in a position of neutral in rotation to horizontal adduction and horizontal abduction. Recovery of the butterfly stroke relies on the coordination of the stroke with kicking. The legs perform a dolphin kick, similar to the flutter kick except the legs move together (11).

2.1.3 Backstroke

In the backstroke, the arm pull is very similar to the freestyle. Yet, there are significant differences in potential to strain the shoulder. In freestyle, the external rotators/extensors of the shoulder and the adductors of the scapular work against gravity, whereas the backstroke needs the forward flexors/internal rotators of the shoulder and the abductors (protractor) of the scapula to work against gravity. At the beginning of the pull-through phase, the arm is abducted and externally rotated resulting in excessive stretch of the anterior soft tissue structures of the shoulder (11, 21). The arm is straight while entering the water, but the body roll enables the arm to produce a similar S-shaped pulling pattern. A flutter kick is also used (21).

2.1.4 Breaststroke

The breaststroke is different from other strokes in many manners. The arms move together in the pull and recovery phases. The legs play a minor role in propulsion for other strokes, whereas in the breaststroke the legs play an equal or more important role as the arms do. Initially, the pull-through phase is similar to other strokes, which involving shoulder adduction and internal rotation. However, as the pull progresses, the arms are pulled outward, downward, backward and never cross the midline. Toward the end of the pull-through, there is a rapid external rotation of the shoulder with elbow flexion rather than elbow extension as seen in other strokes (11, 21).

Recovery of breaststroke involves a pushing motion of the arms and elbows causing forward flexion rather than abduction to achieve full elevation. This crucial difference of moving to elevation with flexion rather than abduction spares the rotator cuff muscles from working to overcome the upward pull of the deltiod on the humeral head as happening in other strokes. The absence of rotator cuff work for balancing the deltiod pull is probably the reason why shoulder impingement is less common with the breaststroke (11).

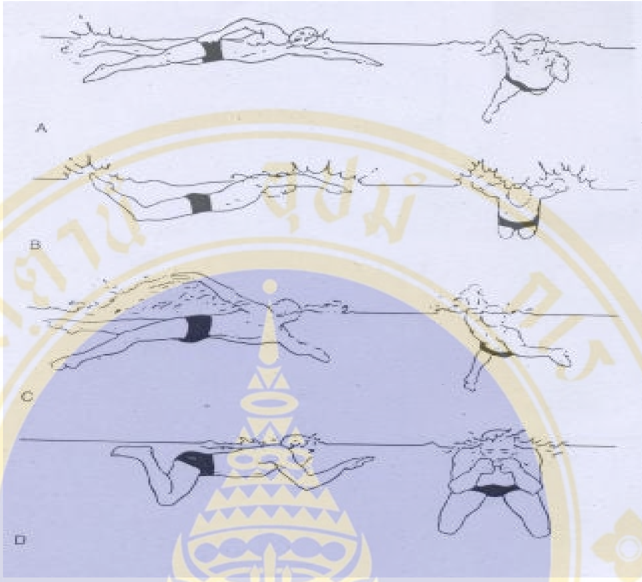

Figure 2.1 Patterns of movements in different strokes (21).
(A)Freestyle (B)Butterfly (C)Backstroke (D)Breaststroke

Table 2.1 A summary of swimming strokes (11)

Stroke	Phase	Subphase	Arm Position	Primary Muscles
Freestyle and butterfly	Pull-through	Hand-entry	Abduction, external rotation, elbow extension	Serratus anterior, rotator cuff, triceps
		Mid pull-through	Adduction, internal rotation, elbow flexion	Latissimus dorsi, pectorals, teres major
		End pull-through	Adduction, internal rotation, elbow extension	Latissimus dorsi, pectorals, teres major
	Recovery	Elbow lift	Abduction, external rotation, elbow flexion	Middle Deltiod, trapezius, rhomboids, rotator cuff, serratus anterior

Table 2.1 A summary of swimming strokes (cont.)

Stroke	Phase	Subphase	Arm Position	Primary Muscles
		Midrecovery	Abduction, external rotation, elbow flexion	Infraspinatus, teres minor, serratus anterior, deltiod
		Hand-entry	Abduction, nerutral rotation, elbow extension	Deltoid, serratus anterior, rotator cuff
Back-stroke	Pull-through	Hand-entry	Forward flexion, abduction, external rotation, elbow extension	Anterior deltoid, biceps, infraspinatus, teres minor
		Mid pull-through	Adduction, internal rotation, elbow flexion	Pectoralis major, teres major, latissimus dorsi
	Recovery	Elbow lift	Forward flexion, external rotation	Anterior deltoid, biceps, infraspinatus, teres minor
		Midrecovery	Forward flexion, external rotation, abduction, elbow flexion	Anterior deltoid, biceps, infraspinatus, teres minor, serratus anterior
		Hand-entry	Forward flexion, external rotation, abduction, elbow extension	Anterior deltoid, triceps, rotator cuff, serratus anterior
Breast-stroke	Pull-through	Hand separation	Adduction, internal rotation	Latissimus, pectorals
		Mid pull-through	Adduction, internal rotation	Latissimus, pectorals

Table 2.1 A summary of swimming strokes (cont.)

Stroke	Phase	Subphase	Arm Position	Primary Muscles
		Rapid pull-up	External rotation, elbow and shoulder flexion	Infraspinatus, teres minor, biceps
	Recovery	Elbow extension Shoulder flexion	Elbow extension Shoulder flexion	Triceps, anterior deltoid, coracobrachialis

2.2 Pathomechanics of Shoulder in Swimmers

Two major pathomechanics of shoulder, subacromion impingement and glenohumeral instability, are often observed in swimmers.

2.2.1 Subacromial impingement

Overwork, subacromial loading, and hypovascularity are three main factors possibly contributing to impingement tendinitis in the competitive swimmer (15, 21).

- Overwork

Swimming demands continuous repetitive loads on the shoulder. The rotator cuff muscles which work excessively to contain and stabilize the humeral head may become progressively fatigue, increasing the subacromial loading (21).

Fatigue of the shoulder muscles during swimming leads to deterioration of normal mechanics, particularly during recovery. External rotation during recovery is either incompleted or delayed while arm is abducting, with attendant subacromial impingement by the greater tuberosity (22).

- Subacromial Loading

The supraspinatus and the biceps tendons are anatomically susceptible to impingement. Their tendons insert on the humerus directly underneath the coracoacromial arch. During the first half of the pull phase of freestyle stroke, the shoulder is in forward flexion, abduction, and internal rotation. This forces the head of the humerus under the anterior acromion and coracoacromial ligament which may impinge on the supraspinatus and biceps tendon, particulary in the fatigue situation. Lateral impingement may be associated with the recovery phase of freestyle and butterfly strokes. To return to the entry position, the arm must abduct. Accompanying with internal rotation or horizontal abduction, the head of the humerus comes up against the lateral border of the acromion (21,22).

- Wringing-Out / Hypovascularity

During the end of the pull phase of freestyle stroke, the shoulder is in adduction and internal rotation, a position corresponding to the wringing-out mechanism. In adduction and neutral rotation, the tendons are strecthed tightly over the head of humerus and their blood supply is compromised. This wringing out mechanism, or repeated hypovascularity, may contribute to early degenerative changes in the tendon. It occurs in the area of the tendon most vulnerable to impingement, amplifying the potential for damage by repetitive stress (22).

Ciullo and Stevens in 1989 (18) reported that the position of horizontal adduction and internal rotation during mid-pull-through has a greater chance of impingement. This phase was also reported to have the highest incidence of pain. Pink and Tibone in 2000 (23) reported that in the freestyle stroke, the first half of pull-through was most frequently identified as the painful phase of the stroke, approximately 70 % of symptoms were noted at this phase.

In addition to these three factors, the capsular length insufficiency frequently causes impingement-like symptoms (24). Capsular structures play the role in controlling normal articulation between the humeral head and the glenoid (25-27). Excessive translation of the humeral head caused by anterior-inferior capsule and anterior-inferior glenohumeral ligament length insufficiency. This capsular tightness lead to suprahumeral space compression and shoulder problems including bursitis, impingement, rotator cuff tears and shoulder pain (24).

2.2.2 Glenohumeral instability

Increased laxity is believed to be a contributing factor of resistant tendinitis in the athlete. A loose or lax shoulder in the competitive swimmer may cause the rotator cuff muscles to work harder just to contain the humeral head (7, 21,28).

A study by Fowler and Webster in 1982 (29) examined swimmers and recreational athletes to determine the incidence of shoulder laxity. The results suggested that swimming did not predispose an athlete to increased posterior laxity. However, 25 % of the swimmers had a history of tendinitis accompanying with increase posterior laxity. Thus, tendinitis was always present in the lax shoulder, suggesting a relationship between tendinitis and posterior laxity.

The motions of adduction and internal rotation during pull-through were suggested to stress the posterior structures causing shoulder pain during this phase (30). Likewise, abduction and external rotation during the recovery phase of freestyle swimming might stress the anterior structures. The repetitive stresses on the capsule during swimming might lead to laxity and possible instability and dysfunction (3).

The study of Ronald et al in 1988 (15) demonstrated imbalance of the shoulder muscles in throwing athletes with anterior instability of shoulder. The mildly increased activity level of the biceps and supraspinatus suggested that these muscles may work to compensate for anterior laxity. The reduction in activity of pectoralis major, subscapularis, latissimus dorsi and surratus anterior reenforcing the anterior instability by decreasing the normal internal rotation force.

The study of Harryman et al in 1990 (25) showed anterior translation of the humeral head on the glenoid when the arm flexed and internally rotated. This translation was increased with an artificial tightening of the posterior capsule. The authors suggested that secondary impingement is potentially caused by anterior laxity and posterior capsular tightening.

The anterior glenohumeral laxity was reported to be much more prevalent in backstrokers (2,17,22). The troublesome point in the backstroke was when the arm touch the wall (immediately after hand entry), which shoulder externally rotated, flexed and horizonally abducted maximally. The force produced in this position may result clinically in anterior capsular laxity to the extent that the anterior inferior glenohumeral ligament may become incompetent.

2.3 Factors Influencing Swimmer's Injury

2.3.1 Shoulder flexibility

Griepp in 1985 found a correlation between pain and restricted range of motion. However, he used only a test of anterior shoulder flexibility i.e., of supraspinatus and the biceps. The test position was supine on a bench with both forearms fully pronated and both shoulders maximally abducted horizontally, measured the distance between the two palms as the arms dropped down (31).

Warner et al in 1990 performed a study in patients with instability and patients with impingement. They found that patients with impingement had greater limitation of active and passive internal rotation compared to patients with instability. There were nearly normal range of shoulder external rotation in the impingement group while significantly increased external rotation in the instability group (10).

Beach et al in 1992 found that competitive swimmers had excessive range of motions of shoulder flexion, abduction and external rotation but reduced internal rotation. There were no correlation between pain presentation and changes in range of motion . The limited internal rotation was the result of reactive fibrosis of the capsular tissues because of repetitive microtrauma in impinged shoulder (9).

Klaus Bak and Magnusson in 1997 compared the internal and external rotation range of motions between painful and pain-free shoulders in swimmers. The results showed no difference in internal and external range of motions. Internal rotation tended to reduced in painful shoulders, although without statistical significance (18).

2.3.2 Shoulder stability

Impingement as a secondary phenomenon to either glenohumeral or scapular instability has been reported to be common in throwing athletes (10, 12, 13). Warner et al in 1990 evaluated three groups of subjects including 15 asymptomatic volunteers, 28 patients with glenohumeral instability and 10 patients with impingement syndrome. The instability group showed a significantly greater humeral head translation during the drawer test than the asymptomatic volunteers. Sixty-eigth percents of these subjects also had positive impingement signs (10).

McMaster and Troup in 1993 conducted a survey in swimmers and found that the subjective experience of "shoulder looseness" was reported with varying incidences from 6% in 13 - 14 year old female swimmers and increase to 15% in elite female swimmers. The authors stated that excessive shoulder laxity could be an important basis for the syndrome "swimmer's shoulder" (tendinitis of the rotator cuff) (5).

Klaus and Faunø in 1997 evaluated competitive swimmers who had shoulder pain. The results showed that the majority of subjects had increased humeral head translation in the anteroinferior direction together with a positive apprehension sign (6). However, whether the laxity was inherent or acquired from swimming was still controversial.

2.3.3 Muscle imbalance

- **Muscle strength of shoulder**

Fakel et al in 1987 studied muscle performance of university team swimmers using the Cybex II isokinetic dynamometer in prone and supine positions at speed of 120, 180 and 240 degrees/sec. The results showed that with the exception of 120°/sec for the external rotators, the prone position produced significantly greater torque values of external and internal rotation than the supine did. The results confirmed the specificity of exercise theory in that when swimmers were tested in a position that most closely approximate their position during swimming, they were able to produce higher torque values for both internal and external rotation of the shoulder (20).

Beach et al in 1992 studied shoulder pain in competitive swimmers and tested muscle strength using Cybex II isokinetic dynamometer in prone position at speed of 60°/sec. The results showed that internal rotation strength was greater than external rotation strength by approximately a 3:2 ratio and adduction strength was found to be greater than abduction strength by approximately a 2:1 ratio. There was no significant correlation between external/internal rotation and abduction/adduction strength ratios and shoulder pain in comptitive swimmers (9).

McMaster et al in 1992 evaluated muscle performance in a control group of college-aged men and women and a study group of competitive men and women swimmers, and subjects were tested with the Cybex II isokinetic dynamometer at speed of 30° and 180°/sec. They were reportedly higher adduction/abduction and internal/external strength ratios due to increased internal rotation and adduction strength in competitive swimmers. Testing at different speeds revealed more significant differences of muscle strength i.e., at slow speed of contraction, muscles was capable of generating larger force (19).

Klaus and Magnusson in 1992 (18) compared shoulder strength between painful and pain-free shoulders using a KinCom dynamometer at 30^0/sec. The results showed no significant difference of external rotation strength. Symptomatic shoulders displayed decreased internal rotation strength compared with non-symptomatic shoulders. Moreover, this study found an increase in the ER/IR strength ratio which contradicted the results of previous studies (9,19).

The previous evaluations of shoulder strength have focused on the concentric strength of the rotator cuff (9,19,20). They omitted eccentric contractions involved in the overhead motion. Wilk et al in 1993 called for the use of a “functional ratio” that included eccentric testing of the shoulder external rotator muscles and concentric testing of the internal rotator muscles (32).

Scoville et al in 1997 evaluated this functional ratio in overhead athletes using the KinCom isokinetic dynamometer at 90^{0}/sec and reported ratios of 1.05 and 1.08 to 1 for the nondominant and dominant shoulder respectively. The results supported that eccentric external rotation torques should be greater than concentric internal torques (33).

Noffal GJ in 2003 calculated the functional ratio at 300/sec using Biodex isokinetic dynamometer. The results revealed that the dominant arm of throwers had a significantly lower ratio than that of nonthrowers and significantly higher concentric internal rotation peak torques for throwers. They concluded that the functional ratio was important for clinicians in interpreting isokinetic strength tests for both nonthrowers and elite throwers (34).

- **Muscle endurance of shoulder**

Beach et al in 1992 evaluated muscle endurance of competitive swimmers with shoulder pain using Cybex II isokinetic dynamometer in prone position at speed of 240°/sec. They found moderately high negative correlation between isokinetic endurance ratio of external rotation and abduction and shoulder pain (9).

2.4 Shoulder Examination

2.4.1 Range of motion

The measurement of active ROM is performed to clarify the causative structures of the symptoms. It is important to use either an arthrodial protraction or an inclinometer to measure the ranges of motion bilaterally for comparison between sides (11,35,36). This study includes measuring all glenohumeral movements througout their ranges.

- Flexion: Normal flexion range is 160 to 180 degrees. The subject may complain of pain when flexing the shoulder. This motion is most commonly affected by impingement syndrome and condition affecting the biceps tendon (35).

- Extension: Normal extension range is 45 to 60 degrees. During the measurement the shoulder should be stabilize anteriorly so the subject cannot lean forward as the arm extending (35).

- Internal Rotation with arm at side: Normal internal rotation range is 60 to 90 degrees. Internal rotation is primarily affected by diseases that affect the integrity of the shoulder joint, leaving it vulnerable to dislocate. However, movement limitation is expected in case of chronic dislocation (35).

- External Rotation with arm at side: Normal range of external rotation is 80 to 90 degrees. In the case of subcoracoid bursitis, the external rotators will be limited and painful (35).

- Abduction: Normal abduction is 170 to 180 degrees. In case of the purest test for abduction, the supination of the palm at 90 degrees allows the greater tuberosity to move out and away from the coracoid process (35).

Various clues can be uncovered when observing active ROM including (11,36):

1) Painful initation of movement (often indicating an unstable shoulder or tendon tear).

2) Attempts at modifying movement by :

a. Recruitment of muscles not normally needed for a particular movement for example, upper trapezius contraction for forward flexion or abduction.

b. Use of trunk or body substitution to simulate or compensate a particular movement for example, laterally bending the trunk to initiate abduction with a torn rotator cuff.

3) A specific mid-range arc of painful ROM. The painful arc indicates subacromial impingement.

4) End-range restrictions and their cause which could be weakness, tigthness, or pain.

5) Mild restriction is common in a number of conditions, such as stiffness following immobilization, trauma, surgery, cuff injury or arthritis.

6) Moderate or severe restriction, particularly in the absence of trauma, suggests adhesive capsulitis as a probable cause.

2.4.2 Capsule flexibility

1) Anterior capsular length

- This part of the capsule is tested by the subject performing active elevation progression with increasing amounts of abduction and external rotation. If insufficient capsular length exists, the involved shoulder will ride higher, the taut anterior-inferior glenohumeral ligament will prevent further glide in the joint and motion will come from the scapulothoracic joint (24).

2) Posterior capsular length

- Active motions of flexion with internal rotation and reaching behind the back place primary tension on the posterior capsule and the posterior band of the inferior glenohumeral ligament complex. The involved side will show a decrease in active range of motion and pain (24).

- The subject is in supine with 90° shoulder abduction with internal rotation. The evaluator provides over-pressure for end feel and symptom reproduction. The involved side will come off the table earlier with internal rotation and will be firmer and painful during overpressure (24).

2.4.3 Impingement testing

All of the following tests rely on reproducing the patient's symptoms by manipulating the shoulder in a way that is thought to mechanically irritate the rotator cuff (36).

1) Painful arc

The painful arc is an observation of pain on active abduction through a range of 70 to 110 degrees with less or no pain before and after this range.

2) Neer's test

In this test, the examiner attempts to jam the humerus under the arch. Pain reproduced is more end-range pain without the characteristic painful arc found in abduction (36).

3) Hawkins-Kennedy's test

This test takes advantage of the increase in subacromial compression with internal rotation of the humerus. This will produce more of an end-range pain felt anteriorly if impingement is present. Resisted active internal rotation in the Hawkins-Kennedy's position may functionally add the sensitivity to the test (36).

In addition, the rotator cuff tendinitis often occurs accompanying with shoulder impingement. The rotator cuff muscles are assessed individually.

4) The supraspinatus test

This test is assessed at 90 degrees of flexion in the scapular plane with the thumbs pointed to the floor. Downward pressure is applied resistance by the tester. This test is supposedly specific for evaluation of the supraspinatus function and reasonably accurate in assessment of rotator cuff strength and integrity (36).

5) Posterior cuff including infraspinatus and teres minor tests

The tests are examined by having the patient externally rotate against resistance with arm at the side and elbow 90° flexed (36).

6) The lift off test

This test is used to evaluate subscapularis strength and integrity by having the patient lifts the hand away from the low back (22).

Values of impingement tests

Hyung et al in 2005 studied the diagnostic values of eight clinical tests including the Neer impingement sign, Hawkins-Kennedy impingement sign, painful arc sign, supraspinatus muscle strength test, Speed test, cross-body adduction test, drop-arm sign and infraspinatus muscle strength tests in patients with rotator cuff tendinitis or bursitis, partial-thickness rotator cuff tears and full-thickness rotator cuff tears. The results of rotator cuff tendinitis or bursitis showed that the Neer impingement sign was the most sensitive (85.7%) test with highest positive predictive value (20.9%) and highest negative predictive value (95.7%). For the patients with partial- thickness rotator cuff tears, the researchers found that the Neer and the Hawkins-Kennedy impingement sign were highly sensitive (75.4%), the Neer impingement sign had the highest positive predictive value (18.1%) and the highest negative predictive value (92.6%). The authors suggested that the combination of examinations would provide greater accuracy (37).

Holtby and Razmjou in 2004 investigated the validity of the supraspinatus test in patients with decompression rotator cuff pathology (tendonitis and partial tears) and full-thickness tears (large or massive). The results showed that the sensitivity and specificity of the supraspinatus test for supraspinatus tendonitis and partial-thickness tears were 62% and 54%, respectively. The sensitivity and specificity of full-thickness tears were 41% and 70%, respectively (38).

MacDonald et al in 2000 evaluated the diagnostic accuracy of the Neer and Hawkins impingement signs for subacromial bursitis or rotator cuff tearing.

The Neer sign had a sensitivity of 75%, negative predictive value of 82.9% and specificity of 47.5% for subacromial bursitis. The Hawkins sign had a sensitivity of 92%, negative predictive value of 93.1% and specificity of 44.3% for subacromial bursitis. The sensitivity for rotator cuff tearing was 85% of the Neer sign and 88% of the Hawkins sign, a negative predictive value of 89.7% for the Hawkins sign and 88.6% for the Neer sign and the specificity was 42.6% for the Hawkins sign and 50.8% for the Neer sign (39).

Calis et al in 2000 investigated the diagnostic values of clinical diagnostic tests in patients with subacromial impingement syndrome. The clinical tests had the sensitivity of 92.1% for Hawkins test, 88.7% for Neer test and 82% for horizontal adduction test and the specificity of 97.2% for drop arm test, 86.1% for Yergason test and 80.5% for painful arc test. Three tests with the highest negative predictive values were 56.2%, 52.3% and 41.6% for Hawkins, Neer and Speed test respectively. Accuracy ratio values were the highest of 72.8% for Hawkins test, 72% for Neer test and 66.4% for horizontal adduction test (40).

Christian and Robert in 1991 studied in patient post-traumatic rupture of the tendon of the subscapularis muscle. The result found that the lift-off test can be interpreted accurately if active internal rotation is not limited by pain (41).

From studies showed the Neer and Hawkins sign are the most accurate test for making the diagnosis of subacromial bursitis and rotator cuff partial tearing, the painful arc and the drop-arm sign are the most accurate for making the diagnosis of full-thickness rotator cuff tear. However, sensitivity the painful arc is low. The supraspinatus test is helpful in diagnosing large or massive rotator cuff tears and the lift off test is reliable diagnosed relevant rupture of the subscapularis tendon.

2.4.4 Ligament laxity test

Examination for ligamentous laxity is helpful, particularly in the young athletic population, and in patients with suspected instability. Laxity can be assessed by observing if the patient has the following signs: the elbow hypertension, the metacarpophalangeal joint of the little finger for hyperextension, knee hyperextension and the thumb to-the-forearm sign. The presence of these signs suggests a generalized laxity pattern that may contribute or predispose to instability (36,42).

2.4.5 Shoulder instability test

Examination for instability of the shoulder is difficult to perform, especially to stabilize scapula while testing glenohumeral joint specifically (11). The following tests are commonly used for assessing shoulder stability.

1) Load and shift test

The examination is performed while the patient sits, the examiner places one hand over the patient's shoulder and scapula to steady the limb girdle and grasps the humeral head with the other hand (24). The examiner then attempts to translate the humeral head in three directions i.e., anterior, posterior and inferior. The amount of anterior translation should not exceed about 25% of the glenoid surface whereas posterior translation and inferior translation should not exceed 50% (43).

The following grading system is used (11):

a) Grade I: subluxation without dislocation. This grade indicates a greater than 50% translation of the humeral head. There is no clunking sensation although grinding is noted.

b) Grade II: dislocation and the humeral head returns to the initial position.

c) Grade III: locked dislocation. The examiner is able to lock the humeral head over the glenoid.

Inferior stability usually involved a distracting force at the elbow (11).

2) Shoulder apprehension test

The apprehension test is performed in the supine or seated position, although maximum muscle relaxation is best achieved with the patient supine. The role of pain needs to be interpreted because frequently a patient may not be apprehensive in this position but only painful. Pain alone is not a positive apprehension sign (22).

- Anterior apprehension test

To perform the apprehension test, The examiner places a hand over the shoulder with the index finger over the anterior part of humeral head, the middle finger over the coracoid, and the thumb on the posterior part of the humeral head (11).

The patient's arm in 90° abduction and external rotation, a posterior to anterior force is applied to the proximal humerus. A sense of apprehension or pain is produced if the test is positive (11, 22).

- Posterior apprehension test

The examiner places the pateint's arm into forward flexion with the forearm internally rotated. A posterior directed force is applied through the elbow in an attempt to elicit apprehension. Posterior apprehension is not commonly present and not a reliable sign. With posterior stress, patients who has pain may resist the motion and this is sometimes errorneously interpreted as apprehension (11, 22).

3) Shoulder drawer test

This is performed with the patient in supine position to make the measurement more reliable (22).

- Anterior drawer test

This test is used to detect and grade laxity. It can also be performed on painful shoulders where the apprehension test is difficult to interpret. It enables the evaluator to diagnose anterior subluxations unequivocally even in patients with a negative apprehension test. The affected shoulder is held in 80° to 120° of abduction, 0° to 20° of forward flexion, and 0° to 30° of external rotation. The examiner press the scapular spine forward with index and middle fingers, thumb exerts counter-pressure on the coracoid process. The other hand grasps the patient's relaxed upper arm in its resting position and draws the arm anteriorly (44).

- Posterior drawer test

The instable shoulder is usually presented with either anterior instability or inferior instability or the combination of both directions. The case of unidirectional posterior instability often has history of voluntarily subluxated shoulder in forward flexion and medial rotation. The examination is performed by abducting shoulder 80° to 120°, forward flexion 20° to 30° and flex the elbow. The examiner holds the scapula with index and middle fingers on the scapular spine, while the thumb lies immediately lateral to the coracoid process. The examiner then slightly rotates the upper arm medially and flexes it to approximately 60° or 80° while the thumb feels the subluxation of the humeral head posteriorly (44).

- Inferior drawer test

This test is done with the patient upright and the shoulder in the neutral position. The clinical diagnosis is made by gentle traction on the relaxed upper arm. Indication of laxity is the appearance of a sulcus between the acromion and the humeral head, thus this test is also known as the sulcus sign (36,44).

2.5 Isokinetic Test

The term “isokinetics” can be translated as “constant movement speed”. It describes a process in which a body segment moves through a certain range at a preselected fixed speed (27).

Dynamic isokinetic testing includes two basic types. The passive type has a rotary force-input lever that limits the speed of the subject's movement during maximum contraction to a preselected angular velocity. The active type has a servocontrolled input level programmed to move at a constant preset speed as the subject exerts effort against the lever (46).

Isokinetic exercise has major advantage over other exercise modalities because the dynamometer's resistance can accommodate maximal resistance throughout range of motion. Isokinetic exercise is also safer than isotonic owing to the dynamometer's resistance mechanism which essentially disengages when pain or discomfort is experienced by the patient (47). Isokinetic exercise is measured and recorded the quantification of torque, peak torque, work, power, average power and time rate to torque development (47,48).

The amount of force applied by the subject is measured in the axis of rotation as torque (Nm) which is displayed both numerically and graphically. Those torque curves are related to the amount of muscle force.

Torque is force times perpendicular distance from the axis of rotation when a muscle is stimulated to contract (11,47,48). Peak torque is the highest point on the graph regardless of where it occurs in the range of motion (49). Peak force or torque is likely to occur within the midrange of motion. Work is amount of tension produced by the force and distance of muscle contraction. Power is the quantity of time required to produce work of muscle (47).

Muscle strength can be defined as the ability to generate maximal force for very short durations or for a small number of repetitions. Muscular endurance is related to the sub-maximal muscle force. The number of repetitive, of sub-maximal dynamic contractions will define the level of muscular endurance (45).

The Con-Trex M® is one of the newest devices which allows testing and training of all major joints of the human body. The large velocity spectrum (0^0/sec-500^0/sec) enables subjects to exercise at their functional speeds (45).

Studies of many commercial dynamometer systems have shown that they are accurate in their measurements of torque and have good or excellent test and retest reliability, particularly after proper instruction and familiarization of the subjects with the testing procedures (50-56).

For muscle endurance regardless how it is measured, the test and retest reliability is usually low. There is also little or no correlation between muscle endurance and the functional status (56-59).

2.5.1 The isokinetic mode

A muscle can produce dynamic tension by either shortening or lengthening. If the joint motion is in the direction opposite to the gravitational force and the external resistance encountered, the tension produced by the muscle exceeds the joint motion is in the direction of the contraction is concentric. If the joint motion is in the direction of the gravitational force and the external resistance encountered exceeds the muscle's ability to generate tension, the contraction is eccentric (47).

In the isokinetic mode the maximal velocity is controlled. When the patient tries to go faster than the predetermined velocity, the dynamometer produces an equal counterforce to ensure that the set velocity is not exceeded (45).

- **Mode Con/Con**

In Con/Con mode, both movements are in the same direction as the torque/force produced by the patient. Two opposing groups of muscles are used in alternating mode, one group when moving in one direction followed by the opposing group when moving in the other direction. The active muscle group undergoes shortening while creates the movement. The torque limitation depends solely on the action of the patient (45).

- **Mode Ecc/Con**

In ECC/Con mode, the first movement runs against the direction of the resistant offered by the patient. Here the dynamometer is producing the work, while the patient absorbs the energy. The second movement is in the same direction as torque/force produced by the patient. The dynamometer absorbs the energy produced by the patient. Only one muscle group is used throughout the whole motion. In one direction, the active muscle group undergoes lengthening (eccentric), and in other direction, the same muscle group undergoes shortening (concentric). The torque limitation depends on the action of the patient (45).

- **Mode Con/Ecc**

In Con/Ecc mode, the first movement is in the same direction as torque/force produced by the patient. The dynamometer absorbs the energy produced by the patient. The second movement runs against the direction of the resistant offered by the patient. Only one muscle group is used throughout the whole motion. In the direction of the movement of the adapter, the active muscle group undergoes shortening (concentric), and in the direction against the movement of the adapter, muscle group undergoes lengthening (eccentric). The torque limitation depends on the action of the patient (45).

- **Mode Ecc/Ecc**

In Ecc/Ecc mode, both movements runs against the direction of the resistance offered by the patient. The dynamometer is producing the work, while the patient absorbs the energy. Two opposing groups of muscles are used in alternating manner, one group when moving in one direction followed by the opposing group when moving in the other direction. So the active muscle group undergoes lengthening. The torque limitation depends on the action of the patient (45).

2.5.2 Isokinetic angular velocity classification

According to the angular velocity classifications for isokinetic testing devices, there are four classes of velocities i.e., the slow velocity (15°-60°/sec), the intermediate velocity (60°-180°/sec), the fast velocity (180°-200°/sec) and 300°-500°/sec(11).

2.5.3 Body position and stabilization

Position and stabilization on a dynamometer are designed to isolate the target muscle group and to eliminate contribution from accessory muscle groups. Therefore, in measuring shoulder muscles, the subject should be straped at both waist and chest (47).

2.5.4 Gravity correction

Isokinetic assessment involves movement of a limb through a gravity dependent position. Gravity correction is a procedure aiming to account for the weight of the dynamometer's lever arm and the limb being tested. The importance of gravity correction in obtaining valid strength measures, failure to correct gravity also confounds determination of reciprocal muscle group ratios (47).

2.5.5 Test protocal

- Warm up

Each test protocol should be started with a warm up session. Good reliability of measurement was reported using a warm-up protocol in obtianing measures of peak torque, work and power during assessment of knee and shoulder flexion, extension, internal and external rotation (60).

- Rest

A period of rest for 30-60 seconds is sufficient for recovery after four maximal repetitions at any test velocity, depending on the nature of the test. The endurance test with over 30 repetitions requires at least 1 minute of rest (47).

- Test velocity

Testing at slow velocity is recommended to be undertaken first. It would facilitate motor learning at a slow velocity prior to testing at faster velocities (61).

- Number of test repetitions

Multiple contractions are necessary to obtain a true maximal value of force or torque (47). Maximum torque is typically evaluated from the first two to six contractions (62). Three or four repetitions were reccommended to achieve measurement of maximal torque (47).

- Verbal encouragement

Encouragement is likely to stimulate a maximum effort during any kind of strength assessment or performance (47).

2.5.6 Effect of position and speed on isokinetic testing

The phenomenon reported by several researchers that as velocity increases, torque increases during eccentric muscle contractions and decreases during concentric muscle contractions (61,62,64).

Walmsley and Szybbo in 1987 studied in healthy female university students by using Cybex II® Isokinetic Dynamometer in three positions (neutral, 90° of flexion, 90°of abduction) and at three speeds of contraction (60, 120 and 180°/sec). The results showed that the greatest torque for the internal rotator muscles were achieved in neutral position, while the maximum value for the external rotators was developed in 90° of shoulder flexion. The test speed of 60°/sec was shown to produce the highest torque values for the external rotator muscles (65).

Hageman et al in 1989 studied in dominant shoulder of healthy male and female by using KIN-COM® robotic dynamometer in sitting position at speed of 60° and 180°/sec. The results showed that peak torque was significantly greater in 45° glenohumeral abduction position compared to 45° glenohumeral flexion position during eccentric and concentric external rotation for both females and males, and for eccentric internal rotation in females. The peak torque of concentric internal rotation was decreased significantly at the higher speed in males and peak torque of eccentric external rotation increased significantly at the higher speed in females (66).

CHARTER III
MATERIALS AND METHODS

3.1 Subjects

Male and female subjects with the following characteristics were invited to participate in this study.

- competitive swimmers
- age ranged from 15 to 21 years
- participate one of swimming clubs

The subject was excluded from the study if he or she has :

- history of shoulder instability or shoulder injury
- shoulder pain which effect swimming training (pain scale IV to VI, adapted from Griepp (68) see appendix B)

The swimmer's shoulder pain scale at the time of examination was assessed according to the pain level adapted from Griepp

(0) : No pain

(1) : Occasional shoulder pain which lasts less than two hours. No problem.

(2) : Shoulder pain lasting longer than 2 hours following swim practice.

(3) : Shoulder pain experienced on forceful arm movements.

(4) : Shoulder pain which was annoying for perhaps eight hours a day. Could have affected the practice abilities.

(5) : Pain was very annoying. Almost certainly affected the ability to practice hard.

(6) : Severe shoulder pain, lasting at least 12 hours a day (unless I used ice, medication, etc). Almost impossible to practiced hard.

Subjects were allocated into one of two groups according to their presence of pain during examination.

All subjects were explained about the objective, process of testing and equipment. Each subject signed an informed consent (Appendix F) prior to participating in the study. The present study was approved by the Ethical Committee on research involving human subject, Faculty of Medicine Siriraj Hospital, Mahidol University.

Design of the study

This study was a cross-sectional study aiming to determine the patterns of shoulder flexibility, stability and muscular performance of pain-free shoulder and symptomatic shoulder in competitive swimmers.

3.2 Instrumentation

1. Universal goniometer
2. Isokinetic dynamometer

This study used the Con-Trex human isokinetic® (AG, Swizerland) (figure 3.1) for assessing muscular performance of shoulder joint. The data from isokinetic dynamometer included torque parameters, acceleration and deceleration characteristics and muscular performance parameters (10).

Figure 3.1 Con-trex human isokinetic.

3. The United States Swimming Sport Medicine Shoulder Pain Questionnaire (adapted from Troup (9) see appendix B) was used to obtain the following information:
   - swimming training profile
   - flexibility program
   - strengthening program
   - history of shoulder pain
4. Swimmer's Shoulder Pain Scale (adapted from Greipp (68) see appendix B)

3.3 Shoulder Examination

Shoulder examination included general appearance, palpation, impingement test, ligament laxity test, shoulder flexibility, shoulder stability and shoulder muscle performance. Range of motion and shoulder muscle performance were assessed by the researcher. The rest of the tests were evaluated by an orthopedist (Dr. Bavornrit Chuckpaiwong).

1. General appearance and palpation

   The examiner performs the following observation and palpation
   - general muscular contour of both shoulders
   - shoulder height
   - tender structures of shoulder

2. Impingement test (11)

   The following tests were performed to evaluate presentation of impingement lesions.

   2.1 Hawkin-Kennedy's test. This test was performed in sitting. The subject's arm was set in internal rotation with the shoulder forward flexed 90 degrees and elbow bent to 90 degrees. The examiner supports the arm at the elbow with one hand while the other imports more internal rotation by pressing on the dorsal wrist. This procedure would produce an end-range pain felt anteriorly if impingement was present.

   2.2 Neer's test. This test was performed in sitting by passively flexing to end range the supinated arm with the elbow extend, the examiner attempts to jam the humerus under the arch. The positive sign of this test was to produce an end- range pain.

2.3 Empty Can test for the supraspinatus. The test was performed in standing. The subject abducts the arm in the scapula plane which was approximately 30 to 40 degrees forward to the coronal plane and the arm maximally internally rotated so that the thumb points toward the ground.

2.4 Resisted external rotation with arm at side. The test was performed with the arm at the side for the infraspinatus in sitting position. The subject was resisted external rotation with the elbow bent 90 degrees.

2.5 Resisted external rotation with arm 90° abduction. The test was performed with the arm abduct 90 degrees for the teres minor in sitting. The subject was resisted external rotation with the arm abducted to 90 degrees and the elbow bent 90 degrees.

2.6 Lift-off test for the subscapularis. The test was performed in standing. The subject lifted the hand which was placed back away from the small of the back.

Figure 3.2 Hawkin-Kennedy’s test.

Figure 3.3 Neer's test.

3. Ligament laxity test. The generalized ligamentous laxity was assessed according to criteria described by Carter and Willkinson(42). These criteria were 1) hyperextension of the fingers metacarpophalangeal joint beyond 90°, 2) elbow hypertension beyond 10°, 3) knee hypertension beyond 10°, 4) apposition of the thumb to the flexor aspect of the forearm. A person was classified as having generally hypermobility if three or more than three of these criteria were met.

4. Shoulder flexibility (69):

4.1 Range of motion was tested using the universal goniometer as following:

a. Active flexion. The range was measured in sitting with the palm of the hand in neutral position and the elbow extended with the arm to be lifted to side of the head.

b. Active extension. The range was measured in prone with palm of the hand in neutral position and the elbow extended with the arm over the table.

c. Active horizontal abduction and adduction. The ranges are measured in sitting position with shoulder flexion to 90°, the forearm was in the neutral position and the elbow flexed.

d. Active internal and external rotation with arm at side. The ranges were measured with arm at side and elbow flexion 90° in sitting.

e. Active external rotation at 90° of shoulder abduction. The range was measured with shoulder abduction 90°and elbow flexion 90° in supine.

f. Active internal rotation at 90° of shoulder abduction. The range was measured with shoulder abduction 90° and elbow flexion 90° in prone.

g. Active abduction. The range was measured in sitting position with the plam of the hand facing upward and the elbow extension.

4.2 Anterior and posterior capsule flexibility

a. Anterior capsule flexibility (24) was tested as follows:

- flexion
- elevation in scapular plan (hands in front of trochanter)
- abduction with thumbs up (hands begin even with trochanter)
- hyperabduction with thumbs up (hands begin behind trochanter)

b. Posterior capsule flexibility (24) was tested as follows:

- reach behind the back
- flexion with maximal internal rotation
- The subject was in supine with arm abducting to 90°, the examiner then the subject arm internally rotates until anterior shoulder begins to come off the table and provide over-pressure for end feel and symptom reproduction.

4.3 Muscle length test (6)

a. Pectoralis major muscle

: Shoulder abduction to 90° with elbow flexed. Subject was in supine with the shoulder was moved to maximal horizontal abduction. Length and end-feel of the motion were observed.

b. External rotator muscles (supraspinatus, infraspinatus and teres minor muscle)

: The shoulder was abducted to 90° with elbow flexed and moved to maximal internal rotation. Length and end-feel of the motion were observed.

c. Subscapularis muscle

: The shoulder was abducted to 90° with elbow flexed and moved to maximal external rotation. Length and end-feel of the motion were observed.

5. Shoulder laxity:

5.1 anterior, posterior and inferior drawer tests (10,44).

a. The anterior drawer test

: This test was performed with the subject supine. The subject's shoulder was abducted with external rotation. Pressure was exerted anteriorly while the scapula is fixed.

b. The posterior drawer test

: This test was performed with the elbow flexed and the shoulder abducted and forward flexed. The examiner holded the scapula with thumb was placed lateral to the coracoid process while posterior pressure was applied.

c. The inferior drawer test (sulcus sign)

: This test was done with subject sitting uprigth and the shoulder in the neutral position. The stress was applied to the upper arm.

The test results were determined by grading the degree of humeral translation in each direction as follows :

Anterior and Posterior drawer test		Inferior drawer test (sulcus sign)	
0	No perceived movement of the humeral head.	0	No inferior translation of humeral head.
1+	Humeral head moves to glenoid rim, but not over it.	1+	< 5 mm. inferior translation of humeral head.
2+	Humeral head subluxates over glenoid rim, and spontaneously reduces.	2+	5-10 mm. inferior translation of humeral head.
3+	Frank dislocation of humeral head over glenoid rim with locking.	3+	> 10 mm. inferior translation of humeral head.

Figure 3.4 Anterior drawer test.

Figure 3.5 Inferior drawer test.

6. Shouder muscle performance:

6.1 Strength of all shoulder muscle groups were tested with a Con-Trex human isokinetic and the Con-Trex data reduction computer (45). The parameter of strength was peak torque (the maximum torque produced by the shoulder at any point in the range of motion) (10) . Strength (peak torque) ratios was obtained for internal/external rotation at 60°/sec and 240°/sec during the external/internal rotation test, the subject was in supine position with flexed elbow 90°and abducted shoulder 90°. The position of the dynamometer was aligned with the joint axis of rotation. Velcro straps were used to stabilize the waist and chest. The testing procedure would be explained to the subjects before testing. Each subject would perform a warm up session prior to the testing. The warm up session consisted of stretching and completing five submaximal repetitions at the specified speed prior to testing. Subject performed a stretching protocol by sustaining each stretch for 30 seconds, repeating for 5 times (70). The muscles stretched were supraspinatus, infraspinatus, subscapularis, teres minor and pectoralis major. Following stretching, the subject warms up by performing 5 submaximal each session. A 30-second rest took place between warm-up and the initiation of the test. The test included three repetitions of maximum effort at 60 °/sec and 240°/sec with external concentric and eccentric contracting and internal concentric contraction with 30 seconds rest between each period. The testing protocol was demonstrated in figure 3.13. During the test, the subject was verbally encouraged to move the shoulder as hard and as fast as possible against the lever. The subject looked at the computer screen for visual feedback on his/her performance during the tests. Following testing session, the subject performed a 5- minute stretching of shoulder muscles for cooling down. The Con-Trex human isokinetic was calibrated according to the manufacturer's specifications before the testing begin.

Figure 3.6 Isokinetic testing position.

3.4 Procedure

The procedure of this study was as follows :

1. The researcher explained the purpose and procedure of the study to the subject prior to participation.
2. All subjects were interviewed for personal profile data includind age, sex, entry into swimming, weight, height, and asked to fill in two questionnaires, The United States Swimming Sport Medicine Shoulder Pain Questionnaire and Swimmer's Shoulder Pain Scale.
3. Subjects who met all inclusion criteria signed the consent form.
4. The subjects were tested the shoulder flexibility including range of motion, anterior and posterior capsule flexibility and end feel range of motion.
5. The shoulder laxity including anterior, posterior and inferior (sulcus sign) drawer tests were evaluated.

6. Subjects were tested muscle strength ratios using a Con-Trex human isokinetic in supine position for internal/external rotation with the arm at 90° abduction.

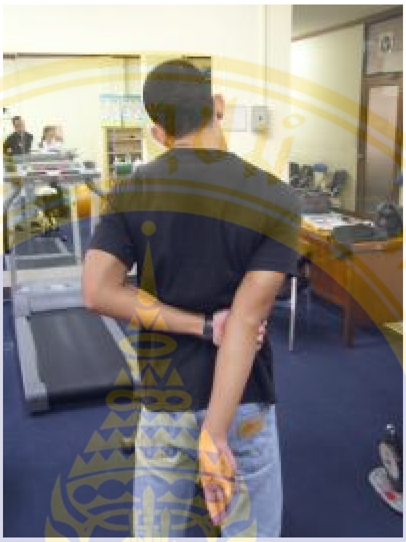

Figure 3.7 Supraspinatus stretching.

Figure 3.8 Inpraspinatus stretching.

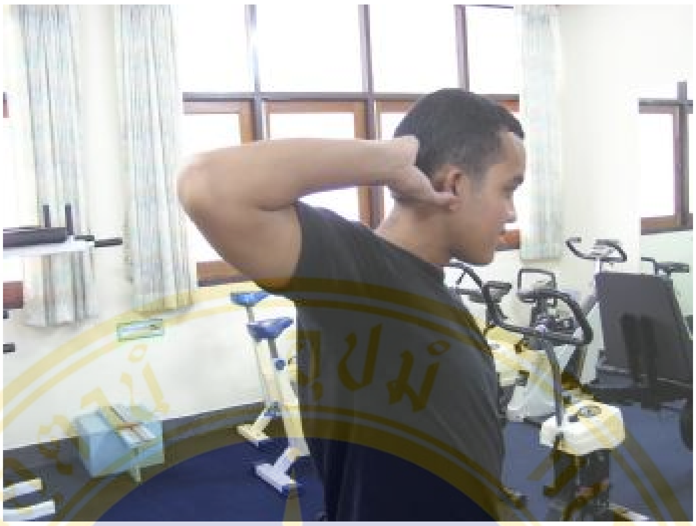

Figure 3.9 Subscapularis and pectoralis major stretching.

Figure 3.10 Teres minor stretching.

Warm-up

Stretching and concentric isokinetic testing 5 submaximal repetitions at 60^0 /sec

⇓ 30 seconds rest

ER_{con}/IR_{con} 3 maximal reps at 60^0 /sec

⇓ 30 seconds rest

ER_{con}/IR_{con} 5 submaximal, rest 30s. and 3 maximal reps at 240^0 /sec

⇓ 30 seconds rest

ER_{ecc}/IR_{con} 5 submaximal, rest 30s. and 3 maximal reps at 60^0 /sec

⇓ 30 seconds rest

ER_{ecc}/IR_{con} 5 submaximal, rest 30s. and 3 maximal reps at 240^0 /sec

⇓

Cool-down (strecthing)

Figure 3.11 Isokinetic testing protocol.

3.5 Data analysis

The statistic analysis was performed with value set at 0.05.

1. The Kolmogorov Smirnov Goodness of Fit test was used to test the distribution of the data.
2. Descriptive statistics were used to describe the age, sex, weight and height of pain-free shoulder group and symtomatic shoulder group.
3. Unpaired t-test was used for between-group differences to compare the shoulder flexibility, stability and muscular performance between pain-free shoulders and symptomatic shoulder if the data were normally distributed. Mann-Whitney U test was used if the data were not normal distributed.

3.6 Sample Size Calculation

The sample size was calculated by the following formula:

$$n = \frac{S^2 p \left(Z_{\alpha} + Z_{\beta} \right)^2}{D^2}$$

n = sample size for each group

$$S^2 p = \frac{(n_1 - 1)\, S^2{}_1 + (n_2 - 1)\, S^2{}_2}{n_1 + n_2 - 2}$$

if $n_1 = n_2$

n_1 = subjects of sympyomatic group in the pilot study

n_2 = subjects of pain-free group in the pilot study

$S^2{}_1$ = variance of sympyomatic group in the pilot study

$S^2{}_2$ = variance of pain-free group in the pilot study

Z_{α} = Z-value when set the confident level equal to 95% or significance level at 0.05 (α = 0.05) = 1.645

Z_{β} = Z-value when set the confident level equal to 90% (β = 0.1) = 1.282

D = the difference of means of parameter between symptomatic and pain- free groups in the pilot study

For the sample size calculation from conventional peak torque ratio at 240^0 /sec, the appropriate sample size for each group in the present study was 23 subjects.

CHAPTER IV
RESULTS

4.1 Characteristics of Subjects

The participants of this study were thirty female and twenty male athletes with age ranging from 15 to 21 years. Half of female and male subjects were symptomatic and the other half were pain-free. The characteristics of subjects in each group are presented in tables 4.1 and 4.2. Both groups were similar in age, weight, height and body mass index (BMI) with no significant differences between groups ($p>0.05$).

In term of training profile, the average swimming experience of the athletes in this study were seven years in pain-free group and eight years in symptomatic group. The pain-free group usually trained 6 days/week, with an average swimming distance of 6,600 meters/day while the symptomatic group trained 6 days/week, with an average of 6,800 meters/day. All swimmers practiced 11 months per year (± 1 month). Ninety-six percents of pain-free group and 60% of symptomatic group stretched everytime prior to workout. Forty-four percents of the pain-free group and 28% of symptomatic group were on dumbell or weight training program. Forty-four percents of the pain-free group and sixty percents of the symptomatic group used elastic band for training. Seventy-six percents of the pain-free group had ever used hand paddles and 20% presently used. Thirty-two percents of the symptomatic group had ever used hand paddles and 68% presently used. Thirty-six percents of the pain-free group and 20% of the symptomatic group used kickboard for training.

In term of symptom profile, 86% of swimmers had experienced shoulder pain with reported VAS ranging from 1 to 6 out of 10. Among the female athletes in symptomatic group, 33% had shoulder pain less than two hours, 30% had shoulder pain longer than 2 hours and 47% had shoulder pain on forceful arm movements. Among the male athletes in symptomatic group, 70% had shoulder pain less than two hours, 10% had shoulder pain longer than 2 hours and 20% had shoulder pain on forceful arm movements.

Table 4.1 Characteristics of female subjects

Subject's characteristics	Pain-free group (n=15)	Symptomatic group (n=15)	*p*-value[a]
Age (years)	16.07 ± 1.28	15.80± 1.57	0.614
Weight (kg)	53.50 ± 6.53	53.53 ± 4.60	0.987
Height (cm)	163.20 ± 5.39	163.67 ± 4.22	0.794
BMI ($kg.m^{-2}$)	20.03 ± 1.57	19.98 ± 1.31	0.930

a; *p*-value from unpaired t-test.

Table 4.2 Characteristics of male subjects

Subject's characteristics	Pain-free group (n=10)	Symptomatic group (n=10)	*p*-value[a]
Age (years)	17.00 ± 1.89	16.40 ± 1.35	0.425
Weight (kg)	68.60 ± 5.65	66.14 ± 7.70	0.427
Height (cm)	175.40 ± 2.88	177.60 ± 6.28	0.332
BMI ($kg.m^{-2}$)	22.31± 1.90	20.90 ± 1.35	0.074

a; *p*-value from unpaired t-test.

4.2 Pattern of Shoulder Flexibility

4.2.1 Shoulder flexibility of female athletes

The examinations of shoulder muscle length in female athletes in both groups showed no tigthness of muscles. However, posterior capsule tightness was found in three female athletes in pain-free group and eleven female athletes in symptomatic group.

The data of shoulder range of motion of both groups are presented in table 4.3. The results showed no significant differences of all shoulder range of motions in pain-free group and symptomatic group (p>0.05). The range of motions of symptomatic group were slightly less than pain-free group in all directions.

Table 4.3 Shoulder range of motion of female athletes

ROM of shoulder (degrees)	Pain-free group (n=15)		Symptomatic group (n=15)		*p*-value[a]	
	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.
Flexion	183.27±1.28	183.13±1.30	182.80±1.01	183.27±1.39	0.278	0.788
Extension	63.73±3.15	64.20±3.21	62.27±2.31	62.33±2.47	0.158	0.086
Horizontal abduction	48.00±2.54	47.80±2.76	47.00±2.54	46.33±2.97	0.289	0.172
Horizontal adduction	125.47±0.99	125.53±1.46	124.00±2.80	124.00±2.80	0.073	0.074
Abduction	183.07±1.28	183.80±1.01	182.80±0.68	183.47±1.13	0.483	0.401
Int. rot. with 90° abduction	72.13±3.34	72.60±3.07	70.73±1.44	71.13±2.07	0.152	0.137
Ext. rot. with 90°abduction	91.87±1.92	92.27±1.94	90.53±1.92	91.40±1.30	0.068	0.164
Int. rot. with arm at side	74.73±2.47	75.87±2.90	73.13±2.53	74.00±3.32	0.092	0.112
Ext. rot. with arm at side	82.67±3.06	84.33±3.60	80.33±2.09	82.27±2.22	0.176	0.071

a; *p*-value from unpaired t-test.

4.2.2 Shoulder flexibility of male athletes

The shoulder muscle length assessments in male athletes in both groups also showed no tigthness of muscles. The posterior capsule tightness was found in six male athletes in pain-free group and seven male athletes in symptomatic group.

The comparisons between groups on shoulder range of motions in table 4.4 showed significant differences of left shoulder flexion, shoulder extension, shoulder internal and external rotations with 90° abduction of both sides and left internal rotation with arm at side (p<0.05). In addition, almost all of shoulder range of motions of the symptomatic group were less than those of pain-free group.

Table 4.4 Shoulder range of motions of male athletes

ROM of shoulder (degrees)	Pain-free group (n=10)		Symptomatic group (n=10)		*p*-value	
	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.
Flexion	183.50±1.18	183.20±1.32	182.30±1.34	183.27±1.39	0.048*	0.080
Extension	66.00±2.11	66.30±2.31	61.50±4.47	62.70±3.43	0.017*	0.015*
Horizontal abduction	46.50±2.42	48.00±3.50	47.00±2.58	47.00±2.58	0.660	0.477
Horozontal adduction	124.80±1.93	125.50±1.58	124.00±2.11	123.50±3.38	0.388	0.114
Abduction	183.50±0.85	183.50±1.08	183.20±1.14	182.90±1.52	0515	0325
Int. rot. with 90°abduction	73.00±2.58	73.60±3.03	70.90±1.66	70.70±2.87	0.047*	0.041*
Ext. rot. with 90°abduction	92.60±2.12	93.40±2.17	90.60±1.08	91.20±1.40	0.019*	0.016*
Int. rot. with arm at side	76.30±2.63	76.30±3.53	73.50±2.12	74.50±2.59	0.018*	0.212
Ext. rot. with arm at side	82.60±2.37	83.50±2.42	81.60±2.17	82.40±2.41	0.338	0.322

*statistically significant by unpaired t-test (p<0.05)

4.3 Pattern of Shoulder Instability

The joint laxity tests in this study composed of four standard tests (42). A subject would be determined to have overall joint laxity when three or more than three of these tests were positive. The numbers of athletes with positive joint laxity test are presented in tables 4.5 and 4.7

In this study, shoulder laxity tests consisted of anterior drawer test, posterior drawer test and sulcus sign. The test results were catgorized into three levels.

Glenohumeral instability was defined as more than grade 2+ translation in any direction (6). Number of athletes presenting shoulder instability are presented in tables 4.6 and 4.8

In female athletes, the results showed a higher tendency of joint laxity in the symptomatic group compared to pain-free group. The number of athletes with shoulder stability in symptomatic group were less than the number of pain-free group.

For the male athletes, the results showed the same trend of joint laxity in both groups. However, the number of athletes with shoulder instability in symptomatic group were more than the number of in pain-free group.

Table 4.5 The results of joint laxity test in female athletes

Joint laxity test	Number of pain-free group		Number of symptomatic group	
	Lt.	Rt.	Lt.	Rt.
Positive	5	5	8	8
Negative	10	10	7	7
Total	15	15	15	15

Table 4.6 The results of shoulder laxity tests in female athletes

Shoulder laxity	Number of pain-free group (n=15)		Number of symptomatic group (n=15)	
	Lt.	Rt.	Lt.	Rt.
Anterior Drawer Test				
- 0	1	1	1	1
- 1+	13	13	10	9
- 2+	1	1	4	5
- 3+	-	-	-	-
Posterior Drawer Test				
- 0	9	9	7	7
- 1+	6	6	7	7
- 2+	-	-	1	1
- 3+	-	-	-	-
Sulcus Sign				
- 0	2	2	1	1
- 1+	13	13	13	13
- 2+	-	-	1	1
- 3+	-	-	-	-

Table 4.7 The results of joint laxity test in male athletes

Joint laxity test	Number of pain-free group		Number of symptomatic group	
	Lt.	Rt.	Lt.	Rt.
Positive	4	4	4	4
Negative	6	6	6	6
Total	10	10	10	10

Table 4.8 The results of shoulder laxity tests in male athletes

Shoulder laxity	Number of pain-free group (n=10)		Number of symptomatic group (n=10)	
	Lt.	Rt.	Lt.	Rt.
Anterior Drawer Test				
- 0	2	2	-	-
- 1+	5	5	6	6
- 2+	3	3	4	4
- 3+	-	-	-	-
Posterior Drawer Test				
- 0	8	8	5	5
- 1+	2	2	4	4
- 2+	-	-	1	1
- 3+	-	-	-	-
Sulcus Sign				
- 0	2	2	-	-
- 1+	6	6	8	8
- 2+	2	2	2	2
- 3+	-	-	-	-

4.4 Pattern of Shoulder Muscle Strength

In this study, shoulder muscle strengths were measured in term of peak torque (Nm) and ratio of peak torque (%) at 60°/sec and 240°/sec in supine position. The measurements of peak torque ratio were performed as consisted of conventional ratio (ER_{con} : IR_{con}) and functional ratio (ER_{ecc} : IR_{con}).

4.4.1 Shoulder muscle strength of female athletes

The peak torques of conventional test are presented in table 4.9. The results showed significant differences of peak torques between two groups ($p<0.05$) in internal rotation and external rotations at 60°/sec of both sides and internal rotation at 240°/sec of both sides. All of the conventional muscle peak torques of symptomatic group were less than those of pain-free group.

The peak torques of functional tests are presented in table 4.10. There were significant differences between two groups ($p<0.05$) in internal rotation and external rotation at 60°/sec and 240°/sec in both shoulders. Functional muscle torques of symptomatic group were less than those of pain-free group.

The data of shoulder rotator peak torque ratios are presented in table 4.11. There were significant differences between both groups at 60°/sec and 240°/sec, when tested in conventional ratio. The significant differences were found in the conventional ratio at 60°/sec of both shoulders and right shoulder conventional ratio at 240°/sec ($p<0.05$). In addition, all of muscle strength ratios of symptomatic group were higher than those in pain-free group.

Table 4.9 Shoulder conventional muscle peak torque (Nm) of female athletes

Conventional muscle strength (Nm)	**Pain-free group (n=15)**		**Symptomatic group (n=15)**		***p*-value**	
	Lt.	**Rt.**	**Lt.**	**Rt.**	**Lt.**	**Rt.**
Int. Rot. (60°/sec)	32.56±3.96	38.87±6.67	26.13±4.71	24.84±6.29	0.0001*	0.0001*
Ext. Rot. (60°/sec)	19.42±2.26	23.55±3.75	16.55±3.14	17.62±3.53	0.008*	0.0001*
Int. Rot. (240°/sec)	30.73±5.10	34.10±6.65	26.47±3.20	26.14±2.64	0.012*	0.0001*
Ext. Rot. (240°/sec)	19.29±2.36	22.11±4.06	17.81±2.85	19.52±2.79	0.131	0.075

*statistical significance by unpaired t-test ($p<0.05$)

Table 4.10 Shoulder functional muscle peak torque (Nm) of female athletes

Functional muscle strength (Nm)	Pain-free group (n=15)		Symptomatic group (n=15)		*p*-value	
	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.
Int. Rot. (60°/sec)	29.60±4.21	35.26±6.09	25.15±4.47	26.81±6.00	0.009*	0.001*
Ext. Rot. (60°/sec)	36.88±3.90	40.66±7.01	31.60±5.89	32.39±7.30	0.008*	0.004*
Int. Rot. (240°/sec)	39.92±5.71	34.28±5.83	24.45±4.70	27.03±3.77	0.008*	0.0001*
Ext. Rot. (240°/sec)	38.06±5.40	41.64±6.87	32.51±5.63	35.24±6.13	0.010*	0.012*

*statistical significance by unpaired t-test (p<0.05)

Table 4.11 Shoulder muscle strength ratio (%) of female athletes

Muscle strength ratio (%)	Pain-free group (n=15)		Symptomatic group (n=15)		*p*-value	
	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.
ER_{con} : IR_{con} (60°/sec)	59.95±6.21	61.27±8.32	65.43±6.57	72.45±15.80	0.026*	0.024*
ER_{con} : IR_{con} (240°/sec)	63.33±5.71	64.99±6.43	67.84±8.41	73.14±10.74	0.098	0.019*
ER_{ecc} : IR_{con} (60°/sec)	125.69±11.44	116.63±15.30	125.59±15.71	121.18±10.99	0.984	0.359
ER_{ecc} : IR_{con} (240°/sec)	128.79±13.95	120.57±14.64	134.35±16.26	130.33±13.71	0.324	0.070

*statistical significance by unpair t-test (p<0.05)

4.4.2 Shoulder muscle strength of male athletes

The peak torques of conventional muscles tests are presented in table 4.12. The results showed significant differences between groups when tested in concentric mode. There were significant differences in internal rotation and external rotation at 60°/sec and 240°/sec ($p<0.05$) of both sides. All conventional and functional muscle peak torques of symptomatic group were less than those of pain-free group.

The peak torques of functional muscles are presented in table 4.13. There were significant differences between two groups ($p<0.05$) in internal rotation and external rotation at 60°/sec and 240°/sec in both shoulders. All of the functional muscles torques of symptomatic group were less than those in pain-free group.

The data of peak torque ratios in table 4.14 show significant differences in conventional ratio at 240°/sec of left shoulder and functional ratios at 60°/sec and 240°/sec ($p<0.05$) of both shoulders. The ratios of symptomatic group were higher than those of pain-free group.

Table 4.12 Shoulder conventional muscle peak torque (Nm) of male athletes

Conventional muscle strength (Nm)	**Pain-free group (n=10)**		**Symptomatic group (n=10)**		***p*-value**	
	Lt.	**Rt.**	**Lt.**	**Rt.**	**Lt.**	**Rt.**
Int. Rot. (60°/sec)	55.96±7.13	55.05±7.99	35.36±4.00	38.74±3.01	0.0001*	0.0001*
Ext. Rot. (60°/sec)	34.19±6.80	36.23±6.58	23.26±4.17	29.66±3.66	0.001*	0.015*
Int. Rot. (240°/sec)	51.07±5.69	48.16±4.78	34.51±4.77	36.23±3.58	0.0001*	0.0001*
Ext. Rot. (240°/sec)	33.18±4.41	33.97±4.64	24.10±3.58	28.84±2.91	0.0001*	0.01*

*statistical significance by unpaired t-test ($p<0.05$)

Table 4.13 Shoulder functional muscle peak torque (Nm) of male athletes

Functional muscle strength (Nm)	Pain-free group (n=10)		Symptomatic group (n=10)		*p*-value	
	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.
Int. Rot. (60°/sec)	50.36±6.31	53.40±7.16	33.56±3.80	36.59±3.36	0.0001*	0.0001*
Ext. Rot. (60°/sec)	57.19±6.19	60.80±7.54	43.14±5.32	48.14±4.45	0.0001*	0.0001*
Int. Rot. (240°/sec)	46.58±5.52	48.73±8.80	31.72±3.75	34.63±4.05	0.0001*	0.001*
Ext. Rot. (240°/sec)	57.34±4.37	59.74±5.04	43.29±5.20	49.06±6.54	0.0001*	0.001*

*statistical significance by unpaired t-test ($p<0.05$)

Table 4.14 Shoulder muscle strength ratio (%) of male athletes

Muscle strength ratio (%)	Pain-free group (n=10)		Symptomatic group (n=10)		*p*-value	
	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.
ER_{con} : IR_{con} (60°/sec)	60.96±8.61	65.99±9.32	66.60±9.05	73.99±8.29	0.171	0.058
ER_{con} : IR_{con} (240°/sec)	65.12±7.28	68.64±8.32	70.12±7.24	79.85±7.09	0.141	0.005*
ER_{ecc} : IR_{con} (60°/sec)	113.85±5.67	112.76±6.69	128.69±8.45	132.56±8.20	0.0001*	0.0001*
ER_{ecc} : IR_{con} (240°/sec)	124.07±11.68	126.94±15.28	137.38±15.35	142.21±16.64	0.043*	0.047*

*statistical significance by unpaired t-test ($p<0.05$)

CHAPTER V
DISCUSSION

5.1 Characteristics of Subjects

The subjects of both groups in this study were not significantly different in terms of age, weight, height and body mass index (BMI). The age range from 15 to 21 years was chosen in this study because the majority of athletes in swimming club are lower than 21 years old. This age group also presents high muscle strength and mass (71,72). Lindle et al investigated the relationship between age and strength in both isometric and dynamic strengths reported that the peak strength was demonstrated between age 20 and 30 years (71). Wilmore and Costill in 1999 (72) stated that peak strength attained by age 20 in women and between age 20 and 30 in men.

The training profile of the athletes in this study concurs with the study by Beach et al (9), which reported the amount and yardage of workouts. Characteristics of the competitive swimmer were previously described in the literature (9,16,73,74).

The training equipments and profile have impact on the athletes. Regular stretching prior to workout is believed to decrease shoulder injury in athlete. However, Mcmaster et al in 1993 (5) stated that the buddy stretching technique aggravated shoulder pain in both genders. Buddy stretching by a partner may produce damage by forcefully manipulating a joint beyond its safe limit. This study found that most of the participants stretched by themself. Thus, stretching should not contribute to shoulder injury in the participants. The use of dumbell or weight training in this study should not influence the tendency of increase shoulder pain in swimmers. On the contrary, Greipp in 1985 (31) suggested that weight training aggravated pain in the athletes, particularly the beginning of training program in a number of prepubescent individuals (5). The athletes with shoulder pain used dumbbell, resisted training with elastic band and hand paddle more than the athletes without shoulder pain. Elastic band and hand paddles might be the factor aggravating the painful shoulder in athletes, because they were resistance training which increased the torques at the shoulder. The hand paddles increased hand surface area and resistance during pulling activities and might aggravate shoulder pain (5). Also, the use of hand paddles might not directly cause shoulder pain but it might contribute to shoulder girdle fatigue and led to various overuse pathologies (22). Increasing resistance on the pull-through phase might predispose the swimmer to impingement (11). Kickboard used in this study should not have tendency to aggravate shoulder pain in swimmers, although Mcmaster et al (5) identified that the use of kickboard aggravated shoulder pain during forward flexion and adduction which approximate to the impingement position. The numbers of athletes with symptom in this study might not be appropriate to show the effect of kickboard using in swimmers with shoulder pain.

Most of the swimmers in this study had experienced shoulder pain. The majority of female athletes in symptomatic group had shoulder pain on forceful arm movements. The majority of male athletes with shoulder pain had shoulder pain less than two hours. The shoulder pain performance scale in female athletes was more than male athletes, owing to less muscle strength and more number of strokes of female athletes. These factors made higher risk of shoulder injury in female athletes.

5.2 Pattern of Shoulder Flexibility

From the evaluation, all subjects in the present study showed no tightness of shoulder muscles. However, posterior capsule tightness was found in 20% and 73% in pain-free and symptomatic group of female athletes and 60% and 70% in pain-free group and symptomatic group of male athletes. Jobe and Pink in 1993 (75) described that the weakness or fatigue of the anterior wall muscles (subscapularis, pectoralis major, latissimus dorsi and teres major) and the posterior capsule tightness in younger overhead athletes caused the humeral head to translate anteriorly leading to impingement. Several studies demonstrated that the capsule tightness contributed the humeral head translation and shoulder impingement (12,25). Harryman et al in 1990 (25) stated that glenohumeral translations were not the result of ligament length insufficiency or laxity but translation usually appeared when the capsules were asymmetrically tight. Asymmetrical capsule tightness caused anterior and superior migration of the humeral head during forward elevation of the shoulder, contributing to impingement. Tyler et al in 2000 (12) undertook a study in patients with shoulder impingement and controlled subjects without shoulder abnormality. They found posterior capsule tightness and loss of internal rotation range of motion in impingement patients. The authors suggested that restriction of internal rotation corresponding with posterior capsule tightness, and then the tightness would force the humeral head to move forward, causing mechanical impingement. The loss of range of motion could be the mechanism to avoid painful movements. Three of the most prevalent contributing factors of secondary shoulder impingement were posterior capsule tightness, external rotation weakness in a position of 90° of shoulder abduction and 90° of elbow flexion and abnormal scapulohumeral rhythm.

The average range of motion in female and male athletes demonstrated mild increase for shoulder flexion, extension, abduction and external rotation with 90° shoulder abduction when compared with normative data (69). This trend was consistent with the study in competitive swimmers reported by Beach et al which found hypermobility in shoulder flexion, abduction and external rotation with 90° shoulder abduction (9). Another study by Warner et al found nearly normal external rotation range of motion in overhead athletes with impingement and significantly increased external rotation range of motion in subjects with instability. However, the active and passive internal rotation ranges of motions were reduced in both groups (10). Changes in shoulder range of motion might be explained by a physiologic adaptation to repetitive stress of the anterior labrum and capsular structures during swimming strokes (5,6,81). Previous studies on overhead athletes exhibited increased external rotation range of motion together with decreased internal rotation range of motion when compared with normative data (9,10,76-78). Several authors (31,79,80) had attributed these findings to posterior capsular tightness. Pappas et al hypothesized that limited internal rotation due to reactive fibrosis of the capsular tissues might be the result of repetitive microtrauma in shoulder impingement. However, this study did not find reduced shoulder internal rotation of athletes in both groups. However, the shoulder motion of internal rotation in symptomatic group was less than the pain-free group both male and female athletes owing to increasing posterior capsule tightness in symptomatic group.

In addition, the comparison between pain-free and symptomatic groups in female athletes showed no significant differences of all shoulder range of motion. However, male athletes showed significant differences between groups in left shoulder flexion, shoulder extension, shoulder internal and external rotations with 90° shoulder abduction of both sides. In this study, the shoulder range of motion of all directions in symptomatic group were less than the pain-free group. Previous studies discussed the relationship of shoulder mobility and shoulder pain (9,10,31). Two studies indicated no correlation between shoulder flexibility and shoulder pain in overhead athletes (9,10). In contrast, Griepp in 1985 (31) found a correlation between pain and restricted range of motion and the test position for anterior shoulder flexibility was supine with both forearms pronated and both shoulder maximally abducted horizontally, then measuring the distance between the two palms as the arms dropped down. Therefore, the correlation between shoulder flexibility and shoulder pain is needed to be further clearified in the further study.

5.3 Pattern of Shoulder Instability

The results of general joint laxity and shoulder instability test in female athletes showed a greater tendency of positive results in the symptomatic group compared to pain-free group. The general joint laxity test in male athletes showed the same trend in both groups. However, the numbers of male subjects with instability were greater in symptomatic group than in pain-free group. Two studies suggested that a generalized laxity pattern may contribute or predispose to instability (36,42). Carter and Wilkinson found that generalized joint laxity was an important predisposing factor to congenital dislocation of the hip in boys (42). This study found 36% of subjects in pain-free group and 48% of subjects in symptomatic group presenting joint laxity. In addition, 56% in pain-free group had shoulder instability with laxity and 67% in symptomatic group had instability with laxity. Only 19% of swimmers in this study had and multidirectional instability with laxity.

In female symptomatic group, there were four subjects with anterior instability and one with multidirectional instability. In pain-free group, there was one subject with anterior instability. In symptomatic group, two male athletes had anterior instability and two had multidirectional instability. In pain-free group, two male athletes had anterior instability, one had inferior instability and one had anterior-inferior multidirectional instability. The common lesion that contributes to shoulder instability is an enlarged joint capsule due to repetitive forceful stretching from the wide range of shoulder circumduction during swimming (2). The present study found nine swimmers with anterior instability (18%), one swimmer with inferior instability (2%) and four swimmers with multidirectional instability (8%). Isolated posterior shoulder instability was rare in swimmers in this study which was in agreement with previous study (6). Four studies suggested that the anterior glenohumeral instability was primarily seen in backstroke swimmers (2,17,22,83). The laxity of anterior capsule caused by repetitive stretching of the capsule during flip turn initiation which shoulder forcefully moved in the directions of internal rotation and forward flexion with arm in extreme abduction and external rotation. These positions stressed anterior shoulder joint ligaments. This study also found high incidence of anterior instability (6 out of 9 subjects).

In previous investigations, there was a correlation between clinical presentation of impingement syndrome and shoulder instability (6,12,44,79,80,84). In this study, nine painful swimmers (36%) with positive impingement sign also exhibited excessive anterior and multidirectional translation. Impingement as a secondary phenomenon to glenohumeral instability has been reported to be common in throwing athletes (10,12,13,85). Klaus and Peter in 1997 (6) suggested that the pathologies found in swimmers' shoulder included anteroinferior laxity of the capsuloligamentous structures with atraumatic instability due to repetitive overhead and impingement with rotator cuff tendonitis. The previous studies investigated that secondary impingement syndrome was a result of shoulder instability, scapulothoracic weakness and posterior capsule tightness, which may contribute to subtle anterior instability (10,17,85-87).

5.4 Pattern of Shoulder Muscle Strength

Three previous studies demonstrated that internal rotation strength was greater than external rotation strength by approximately a 3:2 ratio for both the fast and slow arm speeds in asymptomatic shoulders (88-90). The 2:3 ratio (67%) of external rotation to internal rotation strength and the value obtained from the data of pain-free group in this study (59-65% left and 61-68% right) are quite similar. However, results from isokinetic strength testing of the shoulder have limitations to directly interpret due to the varied testing position and protocols used in the research.

Testing of the shoulder's external and internal rotators can be performed in several testing positions. These positions consist of the 90 degrees shoulder abduction position, modified neutral position, scapular plane position and neutral position (11). Three studies have demonstrated significance of variation torque value by altering the test positions (91-93). Greenfield et al in 1990 (91) tested shoulder external and internal rotation in 45° abduction both scapular and frontal planes, and reported no significant difference between the two positions for internal rotation strength values but increased external rotation strength values in the scapular plane. Hageman et al in 1989 (92) assessed external and internal rotation peak torque values at 45° glenohumeral abduction and 45° glenohumeral flexion. They found increased eccentric and concentric external rotation for both females and males, and eccentric internal rotation in females for the 45° glenohumeral abduction position compared to flexion. Walmsley and Szybbo studied external and internal rotation strengths in three test positions i.e., neutral, 90° flexion and 90° abduction. They found increased internal rotation torque values in the neutral position and the highest external rotation values in the 90 degrees flexion position (93).

However, some positions for isokinetic testing may be potentially injurious to the rotator cuff or capsulolabral structures (10). The 90° abducted position places the shoulder at risk for anterior instability, and the neutral position (shoulder at the side and elbow flex 90°) is an awkward position and harmful for the supraspinatus tendon since its insertion could be hypovascularised. The 90° forward flexed position (shoulder flexed forward 90° and the elbow flexed 90°) reproduced the impingement test of Hawkins and Kennedy and pain could make the subject's effort submaximal. However, 90° shoulder abduction in the coronal plane with the subject supine is the most common testing position (90,94,95). Since the isokinetic testing in overhead athletes is necessary to test the shoulder in a position that closely resembles its position of function during activity, Thomas in 1995 recommended the position of 90° abducted with 90° elbow flexed for testing shoulder internal and external rotations (11).

Beach et al calculated the stroke speed resembling the pull-through phase to be 240°/sec (9). Richardson reported that the average number of arm strokes per 25 yards of the pool was 20 (81). Walmsley and Szybbo studied shoulder internal and external rotator muscle strength at 60°, 120° and 180°/sec. The test speed of 60°/sec produced the highest torque values for the external rotator muscles and no difference of internal rotator peak torque values between different test speeds (93). Hageman et al investigated the effects of two different speeds (60° and 180°/sec) on peak torque values of the shoulder internal and external rotators during concentric and eccentric muscle contraction. Torque values of concentric internal rotation decreased at the higher speed in males and eccentric external rotation increased at the higher speed in females (12). In this study, the muscle strengths were tested at 60 deg/sec (slow speed) and 240 deg/sec (fast speed). The strengths tested in concentric mode of both external and internal rotators were not found to be different between two speeds in female athletes. For eccentric mode, the external rotator tended to increase strength at higher speed in female athletes. The peak torque values of shoulder internal and external rotator concentric contractions tended to decrease at higher speed in male athletes. The results of this study were similar to the results published by Hageman et al (92). However, these results agreement to the report by Mcmaster et al which showed decreased in torque production by the shoulder internal and external rotator concentric contractions at higher speed (19), which the author discussed that skeletal muscles were capable of generating large force at slow speed and generated less tension in high speed (19). However, the conflicting results may also be caused by the testing of different speeds. The speed tested in the study of Mcmaster et al were 30 and 180 degrees/sec(9).

Several studies have demonstrated that at higher speeds the external:internal rotator ratios in the throwing arm were shifted to favor the internal rotators (94,96,97). such as baseball pitchers, water polo players. Mcmaster et al in 1992 (19) assessed the shoulder of swimmers by comparing the ratio of torque external:internal rotation to control group. They reported decreased external and internal rotation strength ratios in swimmers i.e., internal rotation strength increased. They explained that sculling pattern of stroke in swimming would emphasize internal rotation and adduction movements of the shoulder. Nuber et al in 1986 (74) studied muscle action with fine-wire electromyography during swimming. They demonstrated minimal activity of the supraspinatus and infraspinatus during the propulsive phase of freestyle stroking, while the pectoralis major and latissimus dorsi, the internal rotators and adductors of the shoulder are most active during the propulsive phase. It supported the biomechanical analyses that demonstrated a dependence on adduction and internal rotation during the propulsive phase of swimming.

The results of this study showed that conventional and fuctional torque values of external rotation and internal rotation in pain-free group were significantly greater than those in swimmers with shoulder pain. The conventional ratios of external:internal rotation in female swimmers with shoulder pain was found to be significantly higher than the ratio of the pain-free group with greater differences at slow contraction speed. The male swimmers with shoulder pain demonstrated significantly higher conventional ratios than the pain-free group only in left shoulder at 240° /sec. However, the conventional ratios of male athletes were similar to those of female athletes for both arms and speeds. The greater conventional external:internal rotator strength ratios in symptomatic shoulders displayed the greater decrease of internal rotational strength compared with pain-free shoulders. Consistently, Bak and Magnusson in 1997 (18) evaluated differences in shoulder strength between painful and pain-free shoulders in swimmers. They demonstrated that symptomatic shoulders had decreased internal rotational strength and increased external:internal rotation strength ratio compared with non-symptomatic shoulders. In contrary, previous studies showed the increase internal rotation strength and the decrease in the external:internal rotator strength ratio in the overhead athletes and the authors suggested the therapeutic exercise program specifically addressing the external rotators (9,19,20,94,97,98). However, a direct comparison was not possible because in these studies overhead athletes were matched with nonactive controls. This study found the decreased internal rotation strength, therefore exercise program suggested ought to consider the internal rotator strength, not only external rotator strength.

Pappas et al described that eccentric contraction of a maximally lengthened subscapularis muscle at the end of cocking phase and suddenly contract concentrically to propel the arm forward, might place an intrinsic overload on the muscle insertion. The tensile strength of muscle exceeded causing tendon injury, fatigue and weakness (79). Warner et al found increased in external:internal rotation strength ratios in a group of athletes with glenohumeral instability and suggested that the result could be ascribed to a decreased in internal rotational strength (10). However, the symptomatic group in their study had signs of concomitant coracoacromial impingement and nontraumatic glenohumeral instability (secondary impingement), thus the populations are not directly comparable. Glousman et al and Gowan et al found evidence of inconsistent posterior cuff activity and increased subscapularis activity in the late cocking phase and acceleration phase of throwing (15,99). Glousman et al demonstrated a decrease activity of the internal rotator muscles during throwing motion in althletes with glenohumeral instability (99). Moreover, this study found the decrease external rotational strength in the symptomatic group compared with the pain-free group. The repetitive eccentric loads imposed on the external rotators during the follow-through phase of throwing or swimming strokes. The repetitive eccentric loading might lead to a cycle of inflammation, fatigue and weakness in the external rotators (10,96).

Many researchers reported a ratio of external to internal rotation for concentric strength in an attempt to identify imbalance that may lead to injury (9,10,19,20,89,94,96,100,101). Although these measures indicated the strength of muscles, they omitted eccentric contractions involved in the throwing of overhead athletes. The internal rotator muscles act concentrically during the acceleration phase whereas the external rotator muscles act eccentrically during the deceleration phase. The role of the external rotator muscles is not only to decelerate the arm but also to maintain dynamic stabilization of the glenohumeral joint (34). Scoville et al investigated this functional ratio in asymptomatic college-level males and reported ratio of 1.05 and 1.08 for the nondominant and dominant shoulders at 90°/sec, respectively (33). Noffal tested functional ratio in throwers and nonthrowers and reported functional ratios ranged from 1.17 to 1.60 at 300°/sec (34). Bak and Magnusson reported functional ratios of 1.08, 0.89 and 0.86 for swimmers in injured, normal and control group at 30°/sec respectively (18). Present study showed functional ratios range from 1.12 to 1.25 and 1.21 to 1.32 for pain-free and symptomatic group at 60°/sec as well as functional ratios range from 1.24 to 1.28 and 1.30 to 1.42 for pain-free and symptomatic groups at 240°/sec. These functional ratios indicated that the eccentric strength of the external rotator muscles was greater than the concentric strength of the internal rotator muscles. The higher functional ratio in symptomatic group was resulted by a greater decrease in the concentric strength of internal rotator compared to the eccentric strength of the external rotator muscles.

The speed of testing also influences the functional ratio because when the speed increases, the concentric internal torques generated decreases and eccentric external torques remain the same or increase (91,96). Thus, as speed of testing increases, the ratio will also increase. The functional ratios in the present study were greater than functional ratios reported by Bak and Magnusson which measured at the speed of 30° /sec.

5.5 Clinical Implication

The investigation of shoulder flexibility, stability and rotator muscle strength by using isokinetic dynamometer provided the range of motion, capsule flexibility, shoulder muscles length, grade of glenohumeral translation, the quantitative data of peak torque in both conventional and functional modes as well as the strength ratios. The measurements of these parameters were determined to indicate difference of shoulder characteristics in symptomatic group compared to pain-free group.

The results showed greater number of subjects presenting posterior capsule tightness and decrease of all shoulder ranges of motions in symptomatic group. This implies that swimmers should stretch the posterior capsule to prevent anterior translate of the humeral head which could lead to impingement.

The shoulder stability assessments showed that pain-free group presented better shoulder stability than symptomatic group especially anterior stability. The results also showed correlation of backstroke dominance in swimmers with anterior shoulder instability. Therefore, swimmers might have to avoid stretching of anterior capsule shoulder particularly in the backstroke swimmers.

The shoulder rotator cuff strength demonstrated the decrease in external rotation strength and internal rotation strength in symptomatic group, particularly, internal rotator strength which were obviously reduced in symptomatic group. Therefore, the exercise program in swimmers should emphasize strengthening of internal rotators and external rotators and concentrate on the balanced strength of the shoulder rotator muscles.

For further study, it is interesting to investigate the strength of the scapular stabilizers, pectoralis major, latissimus dorsi and deltoid muscles. These muscles also contribute to prevent shoulder injury in swimmers since abnormal scapulohumeral rhythm could cause secondary shoulder impingement. It is also interesting to study relationship of shoulder flexibility, shoulder stability and shoulder pain in swimmers .

CHAPTER VI
CONCLUSION

The present study compared the shoulder flexibility, stability and muscle strength between competitive swimmers with pain-free shoulder and competitive swimmers with shoulder pain.

Subjects in this study were thirty female and twenty male athletes with age ranging from 15 to 21 years. Half of female and male subjects were symptomatic and the other half were pain-free. All subjects were evaluated shoulder flexibility, stability and muscle strength. The parameters determined were range of motion, anterior and posterior capsule flexibility, end feel range of motion, grade of drawer tests, peak torque and peak torque ratios. The peak torque and peak torque ratios were measured both conventional and functional modes at 60° and 240°/sec. All subjects were tested three maximal contractions by Con-Trex human isokinetic dynamometer.

The results could be concluded as followings:

1. The symptomatic group had less shoulder ranges of motion of all directions and greater posterior capsule tightness than the pain-free group did. These results indicated less shoulder flexibility of symptomatic group than flexibility of pain-free group.

2. There was a greater tendency of shoulder instability in symptomatic group than pain-free group and most of instability presenting in swimmers were anterior instability of glenohumeral joint.

3. The peak torque values of external and internal rotators both conventional and functional modes in swimmers were decreased in symptomatic group compared

with pain-free group. The results indicated that symptomatic group had weakness of rotator muscles.

4. The ER:IR ratios of conventional and functional modes in athletes were increased in painful shoulders compared with pain-free shoulders. The results indicated that painful shoulders had lower internal rotation torque production than pain-free shoulders.

5. The rehabilitation program of the swimmers' shoulder must emphasize balanced strength training of the shoulder girdle. The present study suggested the importance of improvement of internal rotation strength in swimmers with painful shoulders. In addition, posterior capsular stretching is an important part of treatment of the painful shoulders.

REFERENCES

1. Kulthanan T. Injuries in swimmers. J Sport Med Ass Thailand 1993; 6(1): 19-22.

2. Johnson JE, Sim FH, Scott SG. Musculoskeletal injuries in competitive swimmers. Mayo Clin Proc 1987; 62: 289-304.

3. Marnie A, Whitney SL, Irrgang JJ. Clinical implications of secondary impingement of the shoulder in freestyle swimmers. J Orthop Sports Phys Ther 1994; 20(6): 307-18.

4. Pink M, Perry J, Browne A, Scovazzo ML, Kerrigan J. The normal shoulder during freestyle swimming: an electromyographic and cinematographic analysis of twelve muscles. Am J Sports Med 1991; 19(6): 569-76.

5. Mcmaster WC, Troup J. A survey of interfering shoulder pain in United States competitive swimmers. Am J Sports Med 1993; 21: 67-70.

6. Klaus B, Peter F. Clinical findings in competitive swimmers with shoulder pain. Am J Sports Med 1997; 25(2): 254-60.

7. Hawkins RJ, Mohtadi NG. Controversy in anterior shoulder instability. Clin Orthop and Related Research 1991; 272: 152-66.

8. Johnson D. In swimming, shoulder the burden (abstract). Sport Care Fitness 1988; May-June: 24.

9. Beach ML, Whitney SL, Dickoff-Hoffman SA. Relationship of shoulder flexibility, strength and endurance to shoulder pain in competitive swimmers. J Ortho Sports Phys Ther 1992; 16(6): 262-8.

10. Warner JJ, Michell LJ, Arslanian LE, Kennedy J, Kennedy R. Patterns of flexibility, laxity, and strength in normal shoulders and shoulders with stability and impingement. Am J Sports Med 1990; 18(4): 366-75.

11. Thomas AS. Sports injuries of the shoulder. America: Churchill Livingstone Inc; 1995: 112-243.

12. Tyler TF, Nicholas SJ, Roy J, Glein GW. Quantification of posterior capsule tightness and motion loss in patients with shoulder impingment. Am J Sports Med 2000; 28: 668-73.

13. Fu FH, Harner CD, Klein AH. Shoulder impingement syndrome: a critical review. Clin Orthop 1991; 269: 162-73.

14. Neer CS II. Impingement lesions. Clin Orthop 1983; 173: 70-7.

15. Ronale G, Frank J, James T, Diane M, Daniel A and Jacquelin P. Dynamic electromyographic analysis of the throwing shoulder with glenohumeral instability. J Bone Joint Surg 1988; 70A(2): 220-6.

16. Ciullo JV, Steven GG. The prevention and treatment of injuries to the shoulder in swimming. Sports Med 1989; 7: 182-204.

17. Schmitt L, Synder-Mackler L. Role of scapular stabilizers in etiology and treatment of impingement syndrome. J Orthop Sports Phys Ther 1999; 29(1): 31-8.

18. Klaus B, Magnusson SP. Shoulder strength and range of motion in symptomatic and pain-free-elite swimmers. Am J Sports Med 1997; 25(4): 454-9.

19. Mcmaster WC, Long SC, Ciazzo VS. Shoulder torque changes in the swimming athlete. Am J Sports Med 1992; 20(3): 323-7.

20. Falkel J E, Murphy TC, Murray TF. Prone positioning for testing shoulder internal and external rotation on the Cybex II Isokinetic dynamometer. J Orthop Sports Phys Ther 1987;8(7): 368-70.

21. Bruce R. Sports medicine. The school-age athlete. America: W.B. Saunders; 1996: 471-489

22. James RA. The Athlete's shoulder. America: Churchill Livingstone Inc; 1994: 45-55.

23. Pink MM, Tibone JE. The painful shoulder in the swimming athlete. Orthop Clin North Am 2000; 31(2): 247-61.

24. Rick H, Chirs D, Sarah S. Anterior-inferior capsular length insufficiency in the painful shoulder. J Ortho Sports Phys Ther 1996; 25(3): 216-22.

25. Harryman D, Sidle J, Clark J, McQuade K, Gibe T, Matsen F. Translation of the humeral head on the glenoid with passive glenohumeral motion. J Bone Joint Surg 1990; 72A(9): 1334-43.

26. O'Brien S, Neves M, Arnoczky S, Rozbruck R, Dicarlo E, Warren R, Shovartz R, Wickiewicz T. The anatomy and histology of the inferior glenohumeral ligament complex of the shoulder. Am J Sports Med 1990; 5: 449-57.

27. Terry G, Hammon D, France P, Norwood L. The stabilizing function of passive shoulder restraints. Am J Sports Med 1991; 19(1): 26-34.

28. Freddie HF, David AS. Sports injuries mechanisms, prevention, treatment. America: Williams&Wilkins; 1994: 633-48.

29. Fowler PJ, Webster MS. Shoulder pain in highly competitive swimmers (abstract). Orthop Trans 1982; 7:170.

30. Warren RF. Subluxation of the shoulder in athletes (abstract). Clin Sports Med 1983; 2(2): 339.

31. Griepp JF. Swimmer's shoulder: the influence of flexibility and weight training (abstract). Phy Sports Med 1985; 13(8): 92.

32. Wilk KE, Andrews JR, Arrigo CA. The strength characteristics of internal and external rotator muscles in professional baseball pitchers. Am J Sports Med 1993; 21: 61-6.

33. Scoville CR, Arciero RA, Taylor DC, Stoneman PD. End range eccentric antagonistic/concentric agonist strength ratios: a new perspective in shoulder strength assessment. J Orthop Phys Ther 1997; 25: 203-7.

34. Guillerno JN. Isokinetic eccentric-to-concentric strength ratios of the shoulder rotator muscles in throwers and non throwers. Am J Sports Med 2003; 31: 537-41.

35. Janet A, Steven L. Orthopaedic testing. New York: Churchill Livingstone; 1994: 87-8.

36. Sam W, John N. Principles of orthopaedic medicine and surgery. Philadelphia: W.B. Saunders Company; 2003: 523-7.

37. Hyung BP, Atsushi Y, Harpreet SG, George ER, Edward GM. Diagnostic accuracy of clinical tests for the different degrees of subacromial impingement syndrome. J Bone Joint Surg 2005; 87(A): 1446-55.

38. Holtby R, Razmjou H. Validity of the supraspinatus test as a single clinical test in diagnosing patients with rotator cuff pathology. J Ortho Sports Phys Ther 2004; 34(4): 194-200.

39. MacDonald PB, Clark P, Sutherland K. An analysis of the diagnostic accuracy of the Hawkins and Neer subacromial impingement signs. J Shoulder Elbow Surg 2000; 9: 299-301.

40. Calis M, Akgun K, Birtance M, Karacan I, Calis H, Tuzun F. Diagnostic values of clinical diagnostic tests in subacromial impingement syndrome. Ann Rheum Dis 2000; 59: 44-7.

41. Christian G, Robert JK. Isolated rupture of the tendon of the subscapularis muscle. Clinical features in 16 cases. J Bone Joint Surg Br 1991; 73: 389-94.

42. Cedric C, John W. Persistent joint laxity and congenital dislocation of the hip. J Bone Joint Surg 1964; 46B(1): 40-5.

43. Hawkins RJ, Schuttle JP, Huckell GH. The assessment of glenohumeral translation using manual and fluoroscopic techniques (abstract). Orthop Trans 1988; 12: 722.

44. Gerber C, Ganz R. Clinical assessment of instability of the shoulder. With special reference to anterior and posterior drawer tests. J Bone Joint Surg 1984; 66B: 551-6.

45. CMV AG. Con-Trex MJ Multijoint System User's Guide. Version 1.5.1. Zürich: Switzerland; 2000: 1-6.

46. Alexander AS. Current concepts review muscle performance evaluation in orthopaedic practice. J Bone Joint Surg 1990; 72A(10): 1562-74.

47. Perrin D. Isokinetic exercise and assessment. Virginia: Human kinetics; 1993: 35-51.

48. Moffroid M, Whipple R, Holfkosh J, Lowman E, Thistle H. A study of isokinetic exercise. Phys Ther 1969; 47: 735-46.

49. Feiring D, Ellenbeeker T, Derscheid G. Test-retest reliability of the Biodex isokinetic dynamometer. J Orthop Phys Ther 1990; 11: 298-300.

50. Barbee J, Landis D. Reliability of Cybex Computer Measures (abstract). Phys Ther 1984; 64: 737.

51. Altken S, Lord J, Bernaure E, McCrory M. Analysis of the validity of the Lido digital isokinetic system (abstract). Phys Ther 1987; 67: 756.

52. Bemben MG, Grump KJ, Massey BH. Assessment of technical accuracy of the Cybex II isokinetic dynamometer and analog recording system. J Orthop and Sports Phys Ther 1988; 10: 12-7.

53. Harding B, Black T, Bruulsema A, Maxwell B, Stratford P. Reliability of a reciprocal test protocol performed on the kinetic communicator: an isokinetic test of knee extensor and flexor strength. J Orthop and Sports Phys Ther 1988; 10: 218-23.

54. Karnofel H, Wilkinson K, Lentell G. Reliability of isokinetic muscle testing at the ankle. J Orthop and Sports Phys Ther 1989; 11: 150-4.

55. Lord J, Altken S, McCrory M, Bernaure E. Reliability of the Lido digital isokinetic system for the measurement of muscular strength (abstract). Phys Ther 1987; 67: 757.

56. Reitz C, Rowinski M, Davies G. Comparison of Cybex II and Kin-Com reliability on the measures of peak torque, work and power at three speeds (abstract). Phys Ther 1988; 68: 782.

57. Armstrong LE, Winant DM, Swasey PR, Seidie ME, Carter AL,Gehlsen G. Using isokinetic dynamometry to test ambulatory patients with multiple sclerosis. Phys Ther 1983; 63: 1274-9.

58. Krebs DE. Isokinetic, electrophysiologic and clinical functional relationship following Tourniquet-Aided knee Arthrotomy. Phys Ther 1989; 69: 803-15.

59. Montgomery LC, Douglass LW, Deuster PA. Reliability of an isokinetic test of muscle strength and endurance. J Orthop and Sports Phys Ther 1989; 10: 315-22.

60. Perrin D. Relaibility of isokinetic measures (abstract). Athletic Training 1986; 10: 319.

61. Griffin JW. Differences in elbow flexion torque measured concentrically, eccentrically and isometrically. Phys Ther 1987; 67: 1205-9.

62. Baltzopoulus V, Brodie DA. Isokinetic dynamometry: Applications and limitations. Sports Medicine 1989; 8: 101-16.

63. Doss WS , Karpovich PU. A comparison of concentric, eccentric and isometric strength of elbow flexors. J Physiol 1965; 20: 351-3.

64. Walmsley RP, Pearson N, Stymiest P. Eccentric wrist extensor contractions and the force velocity relationship in muscle. J Orthop and Sports Phys Ther 1986; 8: 288-93.

65. Walmsley RP, Szybbo C. A comperative study of the torque generated in the shoulder internal and external rotator muscles in different positions and at varying speeds. J Orthop and Sports Phys Ther 1987; 9: 217-22.

66. Patricia AH, Debra KM, Kelly WR, Scott AH. Effects of position and speed on eccentric and concentric isokinetic testing of the shoulder rotators. J Orthop and Sports Phys Ther 1989; 11: 64-9.

67. Neer CS II, Welsh RP. The shoulder in sports (abstract). Orthop Clin North Am 1977; 8: 583.

68. Greipp JF. Swimmer's shoulder: Influence of flexibility and weight training. Phys Sports Med 1985; 13(8): 92-105.

69. Plamerand E. Fundomentals of musculoskeletal assessment techniques. America: JB. Lippincott Company; 1990: 79-89.

70. Fyfe I, Stanish W. The use of eccentric training and strengthing in the treatment and prevention of tendon injuries. Clin Sports Med 1992; 11: 601-23.

71. Lindle RS, Metter EJ, Lynch NA, Fleg JL, Fozard JL, Tobin J, et al. Age and gender comparisons of muscle strength in 654 woman and men aged 20-93 yr. J Appl Physiol 1997; 83: 1581-7.

72. Wilmore JH, Costil DL. Physiology of sport and exercise. 2nd ed. America: Human kinetics; 1999: 525-7.

73. Moynes DR, Perry J, Antonelli DJ, Jobe FW. Electromyography and motion analysis of the upper extremity in sports. Phys Ther 1986; (66)12: 1905-11.

74. Nuber G, Jobe FW, Perry JK, Moynes DR, Antonelli D. Fine wire EMG analysis of the shoulder during swimming. Am J Sports Med 1986; 14: 7-11.

75. Jobe F, Pink M. Classification and treatment of shoulder dysfunction in the overhead athlete. J Orthop Sports Phys Ther 1993; 8: 427-432.

76. Abrams JS. Special shoulder problems in the throwing athlete: pathology, diagnosis and nonoperative management (abstract). Clin Sports Med 1991; 10: 839-61.

77. Ellenbecker TS. Rehabilitation of shoulder and elbow injuries in tennis players. Clin Sports Med 1995; 14: 87-110.

78. Kibler WB, Chandler TJ, Livingston BP. Shoulder range of motion in elite tennis players. Effect of age and years of tournament play. Am J Sports Med 1996; 24: 279-85.

79. Pappas AM, Zawachi RM, McCarthy CF. Rehabilitation of the pitching shoulder. Am J Sports Med 1985; 13: 223-5.

80. Schwartz E, Warren RF, O' Brien SJ, Fronek J. Posterior shoulder instability. Orthop Clin North Am 1987; 18: 409-19.

81. Richardson AB, Jobe FW, Collins HR. The shoulder in competitive swimming (abstract). Am J Sports Med 1980; 8: 159-63.

82. Neer CS II, Foster CR: Inferior capsular shift for involuntary inferior and multidirectional instability of the shoulder. J Bone Joint Surg 1980; 62A: 897-908.

83. Kennedy JC, Hawkins R, Krissoff WB. Orthopaedic manifestations of swimming (abstract). 1978; 6: 309-22.

84. O' Brien SJ, Warren RF, Schwartz E. Anterior shoulder instability. Orthop Clin North Am 1987; 18: 395-408.

85. Jobe FW, Kvitne RS. Shoulder pain in the overhead or throwing athlete. The relationship of anterior instability and rotator cuff impingement (abstract) Orthop Rev 1989; 18: 963-75.

86. Bigliani LU, Levine WN. Subacromial impingement syndrome. J Bone Joint Surg 1997; 79A: 1854-68.

87. Kamkar A, Irrgang JJ, Whitney SL. Nonoperative management of secondary shoulder impingement syndrome. J Orthop sports Phys Ther 1993; 17: 212-24.

88. Connelly Maddux RE, Kibler WB, Uhl T. Isokinetic peak torque and work values for the shoulder. J Orthop Sports Phys Ther 1989; 10(7): 264-9.

89. Cook EE,Gray VL, Savinor-Nogue E, Medeiros J. Shoulder antagonistic strength ratios: A comparison between college-level baseball pitchers and nonpitchers J Orthop Sports Phys Ther 1987; 8(9): 451-61.

90. Ivey FM, Calhoun JH. Isokinetic testing of shoulder strength: Normal values. Ach Phys Med Rehabil 1985, 66: 384-6.
91. Greenfield BH, Donatelli R, Wooden MJ, Wikes J. Isokinetic evaluation of shoulder Rotational strength between the plane of scapula and the frontal plane. Am J Sports Med 1990; 18(2): 124-8.
92. Hageman PA, Mason DK, Rydlund KW, Humpal SA. Effects of position and speed on eccentric and concentric isokinetic testing of the shoulder rotators. J Orthop Sports Phys Ther 1989; 11(2): 64-9.
93. Walmsley RP, Szybbo C. A comparative study of the torque generated by the shoulder internal and external rotators muscles in different positions and at varying speeds. J Orthop sports Phys Ther 1987; 9(6): 217-22.
94. Alderink GJ, Knuk DJ. Isokinetic shoulder strength of high school and college-aged pitchers. J Orthop sports Phys Ther 1986; 7: 163-72.
95. MacDonald PB, Alexander MJ, Frejuk J. Comprehensive functional analysis of shoulders following complete acromioclavicular separation. Am J Sports Med 1988; 16: 475-80.
96. Hinton RY. Isokinetic evaluation of shoulder rotational strength in high school baseball pitchers. Am J Sports Med 1988; 16: 274-9.
97. Mcmaster WC, Long SC, Caiozzo UJ. Isokinetic torque imbalances in the rotator cuff of the elite water polo players. Am J Sports Med 1991; 19: 72-5.
98. Chandler TJ, Kibler WB, Stracener EC, Ziegler AK, Pace B. Shoulder strength, power and endurance in college tennis players. Am J Sports Med 1992; 20(4):455-8.
99. Gowan ID, Jobe FW, Tibone JE, Perry J, Moynes DR. A comperative electromyographic analysis of the shoulder during pitching. Professional versus amateur pitchers. Am J Sports Med 1987; 15(6): 586-90.
100. Brown LP, Nichues SL, Harrah A, Yavorsky P, Hirshman HP. Upper extremity range of motion and isokinetic strength of the internal and external shoulder rotators in major league baseball players. Am J Sports Med 1988; 16(6): 577-85.

101. Perrin DH, Robertson RJ, Ray RL. Bilateral isokinetic peak torque, torque acceleration energy, power, and work relationships in athletes and nonathletes. J Orthop Sports Phys Ther 1987; 9: 184-9.

APPENDIX

APPENDIX A

THE ETHICAL COMMITTEE ON RESEARCH INVOLVING HUMAN SUBJECT

2 PRANNOK Rd.
BANGKOKNOI
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Tel. (662) 4197000 ต่อ 6405-6
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Siriraj Ethics Committee

Certificate of Approval COA no.Si 035/2006

Protocol Title : Patterns of flexibility, stability and muscular performance in symptomatic shoulders and pain-free shoulders in swimmers.

SiEC number : 132/2549

Principal Investigator/Affiliation : Miss Raveewan Kulimakin / Department of Orthopaedic Surgery and Physical Therapy Faculty of Medicine Siriraj Hospital, Mahidol University

Research site : Faculty of Medicine Siriraj Hospital

Approval includes :

1. Protocol
2. Informed consent form
3. Participant information sheet
4. Principal Investigator : Curriculum vitae

Approval date : February 14, 2006

Expired date : February 13, 2007

This is to certify that Siriraj Ethics Committee is in full Compliance with International Guidelines For Human Research Protection such as Declaration of Helsinki, The Belmont Report, CIOMS Guidelines and the International Conference on Harmonization in Good Clinical Practice (ICH-GCP)

(Prof. Sumalee Nimmannit,M.D.)
Chair Person

March 7, 2006
date

(Clin. Prof. Piyasakol Sakolsatayadorn)
Dean of Faculty of Medicine Siriraj Hospital

March 8, 2006
date

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เอกสารรับรองของคณะกรรมการจริยธรรมการวิจัยในคน
คณะแพทยศาสตร์ศิริราชพยาบาล มหาวิทยาลัยมหิดล

เอกสารนี้เพื่อแสดงว่าคณะกรรมการจริยธรรมการวิจัยในคน ได้พิจารณาและรับรองเอกสารที่เกี่ยวข้องกับโครงการวิจัยดังนี้

ชื่อโครงการวิจัย : รูปแบบของความยืดหยุ่นของข้อไหล่ ความมั่นคงของข้อไหล่และสมรรถภาพของกล้ามเนื้อข้อไหล่ในนักกีฬาว่ายน้ำที่มีอาการปวดข้อไหล่และไม่มีอาการปวดข้อไหล่

ชื่อหัวหน้าโครงการ : น.ส.วรีวรรณ คุอิ่มศิน

หน่วยงานต้นสังกัด : โรงเรียนกายภาพบำบัด ภาควิชาศัลยศาสตร์ออร์โธปิดิกส์ และ กายภาพบำบัด คณะแพทยศาสตร์ศิริราชพยาบาล มหาวิทยาลัยมหิดล

SIEC รหัสโครงการ : 132/2547

เอกสารที่รับรอง : การขอปรับเปลี่ยนโครงร่างวิจัย

- ขอปรับเปลี่ยนชื่อโครงการทั้งภาษาไทยและภาษาอังกฤษ

<u>ชื่อเดิม</u> - รูปแบบของความยืดหยุ่นของข้อไหล่ ความมั่นคงของข้อไหล่และสมรรถภาพของ กล้ามเนื้อข้อไหล่ในนักกีฬาว่ายน้ำที่มีอาการปวดข้อไหล่และไม่มีอาการปวดข้อไหล่

Patterns of flexibility, stability and muscular performance in symptomatic shoulders and pain – free shoulders in swimmers.

<u>ชื่อใหม่</u> - ความยืดหยุ่นของข้อไหล่ ความมั่นคงของข้อไหล่ และสมรรถภาพกล้ามเนื้อของกล้ามเนื้อข้อไหล่ในนักกีฬาว่ายน้ำที่มีอาการปวดข้อไหล่และไม่มีอาการปวดข้อไหล่

Flexibility, stability and muscular performance in symptomatic shoulders and pain – free shoulders in swimmers.

รับรองวันที่ : 19 พฤษภาคม 2549 การประชุมครั้งที่ 9/2549

รับรองโดย : คณะกรรมการจริยธรรมการวิจัยในคน คณะแพทยศาสตร์ศิริราชพยาบาล มหาวิทยาลัยมหิดล

คณะกรรมการจริยธรรมการวิจัยในคน คณะแพทยศาสตร์ศิริราชพยาบาล มหาวิทยาลัยมหิดล ดำเนินการให้การรับรองโครงการวิจัยตามแนวทางหลักจริยธรรมการวิจัยในคนที่เป็นสากล ได้แก่ Declaration of Helsinki, The Belmont Report, CIOMS Guidelines และ The International Conference on Harmonization in Good Clinical Practice (ICH-GCP)

ลงนาม ....

(ศาสตราจารย์เกียรติคุณแพทย์หญิงสุมาลี นิมมานนิตย์)
ประธานคณะกรรมการจริยธรรมการวิจัยในคน

<u>14 มิถุนายน 2549</u>
วันที่

CONSENT FORM

วันที่..........เดือน............................พ.ศ..........

ข้าพเจ้า...อายุ.................ปี อาศัยอยู่บ้านเลขที่..........

ถนน...ตำบล..อำเภอ.......................................

จังหวัด.................................... รหัสไปรษณีย์..................................โทรศัพท์.........................

ขอแสดงเจตนายินยอมให้เด็กในปกครองของข้าพเจ้าเข้าร่วมโครงการวิจัยเรื่อง "รูปแบบของความยืดหยุ่นของข้อไหล่ ความมั่นคงของข้อไหล่ และสมรรถภาพของกล้ามเนื้อข้อไหล่ ในนักกีฬาว่ายน้ำที่มีและไม่มีอาการปวดข้อไหล่"

โดยข้าพเจ้าได้รับทราบรายละเอียดเกี่ยวกับที่มาและจุดมุ่งหมายในการทำวิจัยรายละเอียดขั้นตอนต่างๆ ที่จะต้องปฏิบัติหรือได้รับการปฏิบัติ ประโยชน์ที่คาดว่าจะได้รับของการวิจัย และความเสี่ยงที่อาจจะเกิดขึ้นจากการเข้าร่วมการวิจัย รวมทั้งแนวทางป้องกันและแก้ไขหากเกิดอันตรายขึ้น ค่าตอบแทนที่จะได้รับ ค่าใช้จ่ายที่ข้าพเจ้าจะต้องรับผิดชอบจ่ายเอง โดยได้อ่านข้อความที่มีรายละเอียดอยู่ในเอกสารชี้แจงผู้เข้าร่วมการวิจัยโดยตลอด อีกทั้งยังได้รับคำอธิบายและตอบข้อสงสัยจากหัวหน้าโครงการวิจัยเป็นที่เรียบร้อยแล้ว

ข้าพเจ้าจึงสมัครใจให้เด็กในปกครองของข้าพเจ้าเข้าร่วมโครงการวิจัยนี้ หากข้าพเจ้ามีข้อข้องใจเกี่ยวกับขั้นตอนของการวิจัย หรือหากเกิดผลข้างเคียงที่ไม่พึงประสงค์จากการวิจัยขึ้นกับเด็กในปกครองของข้าพเจ้า ข้าพเจ้าจะสามารถติดต่อผู้วิจัยได้ทุกเวลาที่เบอร์โทรศัพท์ 01-9072423

หากเด็กในปกครองของข้าพเจ้าได้รับการปฏิบัติไม่ตรงตามที่ได้ระบุไว้ในเอกสารชี้แจงผู้เข้าร่วมการวิจัย ข้าพเจ้าจะสามารถติดต่อกับประธานคณะกรรมการจริยธรรมการวิจัยในคนหรือผู้แทนได้ที่ สำนักงานคณะกรรมการจริยธรรมการวิจัยในคน ตึกอดุลยเดชวิกรม ชั้น5 ร.พ. ศิริราช โทร (02) 419-7000 ต่อ 6405

ข้าพเจ้าได้ทราบถึงสิทธิ์ที่เด็กในปกครองของข้าพเจ้าจะได้รับข้อมูลเพิ่มเติมทั้งทางด้านประโยชน และโทษจากการเข้าร่วมการวิจัย และสามารถถอนตัวหรืองดเข้าร่วมการวิจัยได้ทุกเมื่อ โดยจะไม่มีผลกระทบต่อการบริการและการรักษาพยาบาลที่เด็กในปกครองของข้าพเจ้าจะได้รับต่อไปในอนาคตและยินยอมให้ผู้วิจัยใช้ข้อมูลส่วนตัวของเด็กในปกครองของข้าพเจ้าที่ได้รับจากการวิจัย แต่จะไม่เผยแพร่ต่อสาธารณะเป็นรายบุคคล โดยจะนำเสนอเป็นข้อมูลโดยรวมจากการวิจัยเท่านั้น

ข้าพเจ้าได้เข้าใจข้อความในเอกสารชี้แจงผู้เข้าร่วมการวิจัย และหนังสือแสดงเจตนา

ยินยอมนี้โดยตลอดแล้ว จึงลงลายมือชื่อไว้

ลงชื่อ... ผู้เข้าร่วมการวิจัย/ผู้แทนโดยชอบธรรม/วันที่...............

(...)

ลงชื่อ................................ ผู้ให้ข้อมูลและขอความยินยอม/หัวหน้าโครงการวิจัย/วันที่..........

(................................)

APPENDIX B
DATA COLLECTION FORM

นาย / นางสาว ชื่อ ....นามสกุล .... อายุ...........ปี
ส่วนสูง...........................เซนติเมตร น้ำหนัก..............................กิโลกรัม BMI.........(kg/m^2)
เริ่มเข้ามาเป็นนักกีฬาว่ายน้ำเมื่ออายุ......ปี ท่าว่ายน้ำที่ถนัดที่สุด...................................
ท่าว่ายน้ำที่ใช้ในการฝึกมากที่สุด....................... ประมาณ.......%(ของปริมาณการฝึกในแต่ละวัน)
มือข้างที่ถนัด ข้างขวา ข้างซ้าย
ข้างที่ใช้ในการหายใจขณะว่ายท่าฟรีสไตล์ ข้างขวา ข้างซ้าย ทั้งสองข้าง

1. ข้อมูลเกี่ยวกับปริมาณการฝึกว่ายน้ำ
   1.1 จำนวนชม.ในการฝึก................ชม./ครั้ง
   1.2 จำนวนครั้งในการฝึก................ครั้ง/สัปดาห์
   1.3 ระยะทางในการฝึก....................เมตร/วัน
   1.4 จำนวนเดือนในการฝึก................เดือน/ปี
   1.5 ระยะทางในการว่ายที่ถนัดที่สุด
       ระยะสั้น ระยะกลาง ระยะยาว
2. ข้อมูลเกี่ยวกับการยืดกล้ามเนื้อ
   2.1 ท่านเคยยืดกล้ามเนื้อ ก่อนฝึกว่ายน้ำหรือไม่
       เคย ไม่เคย (หากไม่เคย ให้ท่านข้ามไปตอบในข้อ 3)
   2.2 ถ้าเคย ท่านเริ่มยืดกล้ามเนื้อตั้งแต่อายุ.........ปี
   2.3 ตอนนี้ ท่านยังคงยืดกล้ามเนื้อก่อนฝึกว่ายน้ำหรือไม่
       ยังยืดอยู่ ไม่ได้ยืดแล้ว
   2.4 ท่านยืดกล้ามเนื้อบ่อยแค่ไหน
       ทุกครั้งก่อนฝึก เป็นบางครั้งประมาณ.........ครั้ง/สัปดาห์
   2.5 ท่านยืดกล้ามเนื้อครั้งหนึ่งนาน.........นาที
   2.6 ท่าที่ท่านใช้ในการยืดกล้ามเนื้อ ....

3. ข้อมูลเกี่ยวกับการฝึกความแข็งแรงของกล้ามเนื้อ

3.1 อุปกรณ์ที่ท่านใช้ในการฝึกเพื่อเพิ่มความแข็งแรง

ยกนน. ...กก. ดัมเบล....กก. ยางยืด อื่น ………………

ซึ่งท่าที่ใช้ในการฝึกได้แก่ ……………………………………………………………………

3.2 ขณะนี้ ท่านยังใช้อุปกรณ์นี้อยู่หรือไม่

ยังใช้อยู่ ไม่ใช้แล้ว (เคยใช้นาน.......... เดือน/ปี)

3.3 ถ้าท่านยังใช้อยู่ ท่านใช้บ่อยแค่ไหน

ทุกครั้งก่อนฝึก เป็นบางครั้งประมาณ.........ครั้ง/สัปดาห์

3.4 ท่านใช้อุปกรณ์นี้ครั้งหนึ่งนาน............นาที

4. ข้อมูลเกี่ยวกับการใช้ hand paddle

4.1 ท่านเคยใช้ hand paddle หรือไม่

เคย ไม่เคย (หากไม่เคย ให้ท่านข้ามไปตอบในข้อ 5)

4.2 ถ้าเคย ท่านเริ่มใช้ hand paddle ตั้งแต่อายุ..........ปี

4.3 ขณะนี้ ท่านยังใช้ hand paddle อยู่หรือไม่

ยังใช้อยู่ ไม่ใช้แล้ว (เลิกใช้ เมื่ออายุ.........ปี)

4.4 ถ้าท่านยังใช้อยู่ ท่านใช้บ่อยแค่ไหน

ทุกครั้งที่ฝึก เป็นบางครั้งประมาณ.........ครั้ง/สัปดาห์

4.5 ท่านใช้ hand paddle ร่วมกับการฝึกว่ายน้ำประมาณ.............เมตร/ครั้ง

5. ข้อมูลเกี่ยวกับการใช้อุปกรณ์อื่นๆร่วมกับการฝึกว่ายน้ำ

5.1 ท่านมีการใช้อุปกรณ์อื่นๆร่วมกับการฝึกว่ายน้ำอีกหรือไม่

มี ไม่มี (หากไม่มี ให้ท่านข้ามไปตอบในข้อ 6)

5.2 หากมี ท่านใช้อุปกรณ์อะไรบ้างร่วมกับในการฝึกว่ายน้ำ...

5.3 ท่านใช้บ่อยแค่ไหน

ทุกครั้งร่วมกับการฝึก เป็นบางครั้งประมาณ.........ครั้ง/สัปดาห์

5.4 ปริมาณที่ท่านใช้ประมาณ ....เมตร/ครั้ง

5.5 ขณะนี้ ท่านยังใช้อุปกรณ์เหล่านี้อยู่หรือไม่

ยังใช้อยู่ ไม่ใช้แล้ว (เลิกใช้ เมื่ออายุ.........ปี)

6. ข้อมูลเกี่ยวกับอาการปวดของข้อไหล่

6.1 ท่านเคยมีอาการปวดข้อไหล่หรือไม่

เคย ประมาณช่วงอายุ........ปี ไม่เคย (หากไม่เคย ให้ท่านข้ามไปตอบในข้อ 6.4)

6.2 หากเคย ท่านเคยมีอาการปวดข้อไหล่........ข้าง โดยปวดข้าง....................... และปวดครั้งหนึ่งนาน.........ชม.จึงจะหาย โดยมักมีอาการปวดในช่วง ก่อนฝึก ขณะฝึก หลังจากฝึก........ชม. และอาการปวดมีผลกระทบต่อสถิติในการว่ายหรือไม่

มี (ความเร็วในการว่ายช้าลง) ไม่มี

6.3 หากท่านเคยปวด ท่านทำอย่างไรจึงหายปวด

กินยา พักโดยหยุดการซ้อมเป็นเวลา.....วัน ไปพบแพทย์

ปล่อยให้หายเอง อื่นๆ ....

6.4 ขณะนี้ ท่านมีอาการปวดข้อไหล่หรือไม่ (หากมีอาการปวดให้ท่านกรอกข้อมูลในข้อ 7 และ8ด้วย)

มีอาการ ไม่มีอาการ

6.5 ถ้ามีอาการ ท่านปวดครั้งหนึ่งนานประมาณ............ชม./วัน ปวดขณะว่ายท่า................. โดยปวดข้าง............... บริเวณ.....................

6.6 อาการปวดมีผลกระทบต่อสถิติในการว่ายหรือไม่

มี (ความเร็วในการว่ายช้าลง) ไม่มี

6.7 ในระหว่างนี้ ท่านได้ทำกิจกรรมอะไรอย่างอื่นนอกเหนือไปจากการฝึกว่ายน้ำด้วยหรือไม่

มี โปรดระบุ............................. ไม่มี

7. ให้ท่านวงกลมรอบตัวเลขข้อ ที่ตรงกับอาการปวดข้อไหล่ของท่านในขณะนี้

0 ไม่มีอาการปวด

1 มีอาการปวดข้อไหล่เป็นบางครั้ง และปวดครั้งหนึ่งน้อยกว่า 2 ชม./วัน

2 มีอาการปวดข้อไหล่ครั้งหนึ่งนานมากกว่า 2 ชม./วัน และมีอาการปวดภายหลังจากการซ้อมว่ายน้ำ

3 มีอาการปวดข้อไหล่ ในขณะที่ใช้แขนในการว่ายน้ำ

4 มีอาการปวดข้อไหล่นานถึง 8ชม./วัน โดยอาการปวดนี้มีผลกระทบต่อการซ้อมว่ายน้ำด้วย (เช่น ทำให้ไม่สามารถว่ายน้ำได้คล่องเหมือนเดิม, รู้สึกมีความลำบากในการว่ายน้ำมากขึ้น เป็นต้น)

5 มีอาการปวดข้อไหล่ที่รบกวนมาก โดยจะส่งผลต่อการฝึกหนักด้วย (เช่น ทำให้ไม่สามารถฝึกหนักได้เหมือนเดิม)

6 มีอาการปวดข้อไหล่รุนแรงมาก โดยจะปวดนานถึง 12 ชม./วัน และไม่สามารถฝึกว่ายน้ำหนักได้เลย

8. ให้ท่านทำเครื่องหมายกากบาทบนสเกล ที่ตรงกับระดับความเจ็บปวดของท่านในขณะนี้

ข้อไหล่ข้างขวา

____

0 (ไม่มีอาการปวดเลย) 10 (ปวดมากที่สุด)

ข้อไหล่ข้างซ้าย

____

0 (ไม่มีอาการปวดเลย) 10 (ปวดมากที่สุด)

Assessment form

1. Shoulder examination

General appearance

____

____

____

____

Table B.1 Impingement test

Test	Symptomatic group				Pain-free group			
	Left		Right		Left		Right	
	+	-	+	-	+	-	+	-
- Hawkin - Neer - Empty Can - Resist Ext. Rot. arm abduct 90^0 - Resist Ext. Rot. arm at side - Lift off								

Table B.2 Ligament laxity test

Joint	Symptomatic group				Pain-free group			
	Left		Right		Left		Right	
	+	-	+	-	+	-	+	-
- MCP jt. > 90^0 - Elbow hyperextension - Knee recurvatum - Apposition of thumb								

2. Shoulder flexibility

Table B.3 Range of motion of shoulder jt.

Shoulder ROM	Symptomatic group		Pain-free group	
	Left	Right	Left	Right
Flexion Extension Horizontal abduction Horizontal adduction External rotation - arm abduct 90^0 - arm at side Internal rotation - arm abduct 90^0 - arm at side Abduction				

Table B.4 Anterior and posterior capsule flexibility of shoulder jt.

Capsule of shoulder	Symptomatic group				Pain-free group			
	Left		Right		Left		Right	
	ROM	PAIN	ROM	PAIN	ROM	PAIN	ROM	PAIN
Anterior capsule								
- **Flexion**								
- **Elevation**								
- **Abduction**								
- **Hyperabduction**								
Posterior capsule								
- **Reach behind back**								
- **Flex c max. int. rot.**								
- **Int. rot. c abduct 90^0**								

Table B.5 End feel of motion for muscle length test

Muscle length of shoulder	Symptomatic group				Pain-free group			
	Left		Right		Left		Right	
	tight	no tight	tight	no tight	tight	no tight	tight	no tight
- **Pectoralis major**								
- **External rotators**								
- **Subscapularis**								

3. Shoulder stability

Table B.6 Shoulder instability by drawer test

Stability of shoulder	Symptomatic group								Pain-free group							
	Left				Right				Left				Right			
	0	1+	2+	3+	0	1+	2+	3+	0	1+	2+	3+	0	1+	2+	3+
Anterior (ADT) **Posterior (PDT)** **Inferior (sulcus)**																

4. Shoulder muscular performance

Table B.7 Shoulder strength

Strength (peak torque)	Symptomatic group				Pain-free group			
	Left		Right		Left		Right	
	60^0/ sec	240^0/ sec	60^0/ sec	240^0/ sec	60^0/ sec	240^0/ sec	60^0/ sec	240^0/s ec
1) Conventional **- IR (concentric)** **- ER (concentric)** **2) Functional** **- IR (concentric)** **- ER (eccentric)**								

Table B.8 Conventional and functional strength ratios

Strength ratios (peak torque)	Symptomatic group				Pain-free group			
	Left (%)		Right (%)		Left (%)		Right (%)	
	60^0/ sec	240^0/ sec	60^0/ sec	240^0/ sec	60^0/ sec	240^0/ sec	60^0/ sec	240^0/ sec
- **ER:IR** **Conventional** **1) ER_{con}:IR_{con}** **Functional** **2) ER_{ecc}:IR_{con}**								

APPENDIX C
PILOT STUDY : TEST-RETEST RELIABILITY

The pilot study purposed to investigate the intratester reliability of range of motion and isokinetic measurements of both shoulders. Ten subjects aged from 15 to 21 years included six male and four female swimmers. All subjects were tested the isokinetic strength at 60°/sec and 240°/sec. The shoulder ranges of motion were measured twice with two weeks interval while isokinetic measurement were tested twice in the same day with a 30 minutes interval. Prior to the isokinetic testing, subject performed 5 submaximal contractions. Each subject took 30 seconds rest before starting the real test with 3 maximal contractions.

Kolmogorov Smirnov Goodness of Fit test was used to analyze the distribution of the data. Intratester reliability was determined by using the Intraclass Correlation Coefficients (ICCs). The formula of ICC (3,1) was chosen. The statistically significant level for this study was set at p-value less than 0.05.

Characteristics of subjects are presented in table C.1. Mean and standard deviations of shoulder range of motion and shoulder isokinetic strength at 60°/sec and 240°/sec are shown in tables C.2 and C.3 consecutively. Intratester reliabilities of shoulder range of motion and isokinetic peak torque between the first and second tests are demonstrated in table C.4 and C.5. The raw data of test-retest reliability are shown in tables D.1-D.3.

The intratester reliability of shoulder range of motion was 0.63-0.99 and shoulder isokinetic testing was 0.71-0.96.

Table C.1 Means and standard deviations of age, weigth and heigth of subjects

Parameters	Athletes	
	Mean	SD
Age (yrs)	16.3	1.16
Weigth (kg)	60.9	5.26
Heigth (cm)	17.18	7.22
BMI (kg/m^2)	20.6	0.96

Table C.2 Means and standard deviations of both shoulder range of motion

Parameters	Range of motion (°)			
	First test		Second test	
	Lt.	Rt.	Lt.	Rt.
Flexion	184.6±4.09	182.5±3.34	183.8±4.44	182.5±3.84
Extension	60.5±7.25	62.0±5.37	60.6±7.17	62.2±5.12
Horizontal abduction	45.5±1.58	45.5±2.51	46.5±2.42	46.0±3.16
Horizontal adduction	123.0±6.75	121.0±7.38	123.2±4.96	122.2±5.71
External rotation with abduct 90°	92.0±5.37	92.1±3.41	91.6±5.38	92.1±3.21
External rotation with arm at side	73.5±9.73	75.0±8.50	73.1±9.92	75.4±7.66
Internal rotation with abduct 90°	69.5±7.25	68.8±4.21	70.2±5.99	69.7±4.45
Internal rotation with arm at side	85.5±4.38	84.0±3.94	85.0±4.08	84.9±3.54
Abduction	184.1±1.29	184.4±2.59	183.7±1.42	184.1±2.64

Table C.3 Means and standard deviations of peak torque of both shoulder at 60°/sec and 240°/sec

Parameters	Peak torque (Nm)			
	First test		Second test	
	Lt.	Rt.	Lt.	Rt.
Conventional mode				
IR_{con}60°/sec	34.74±12.5	39.02±11.24	31.47±9.34	40.14±11.28
IR_{con}240°/sec	41.31±10.26	46.17±8.62	39.94±8.72	47.21±8.75
ER_{con}60°/sec	27.44±6.55	23.54±9.52	27.37±8.26	23.72±10.65
ER_{con}240°/sec	33.57±7.42	30.1±9.55	35.37±8.31	28.86±11.3
Functional mode				
IR_{con}60°/sec	29.25±12.52	38.99±11.56	29.82±12.91	38.36±9.97
IR_{con}240°/sec	36.68±14.77	44.49±8.73	37.54±15.82	45.79±10.93
ER_{ecc}60°/sec	33.99±13.43	46.38±13.59	35.12±13.38	45.29±11.23
ER_{ecc}240°/sec	39.69±14.36	48.86±9.95	40.87±14.93	53.6±11.49

Table C.4 Intratester reliability of shoulder range of motion between the first and second tests

Parameters	Reliability of shoulder	
	Lt.	Rt.
Flexion	0.9707	0.9313
Extension	0.9990	0.8918
Horizontal abduction	0.6397	0.7509
Horizontal adduction	0.9468	0.9393
External rotation with abduct 90°	0.9531	0.8686
External rotation with arm at side	0.9860	0.9335
Internal rotation with abduct 90°	0.9697	0.9374
Internal rotation with arm at side	0.9302	0.7323
Abduction	0.6848	0.9019

Table C.5 Intratester reliability of isokinetic performance of both shoulder between the first and second tests at 60°/sec and 240°/sec

Parameters	Reliability of shoulder	
	Lt.	Rt.
Conventional mode		
IR_{con}60°/sec	0.8821	0.8763
IR_{con}240°/sec	0.8055	0.8355
ER_{con}60°/sec	0.9047	0.8971
ER_{con}240°/sec	0.9421	0.9122
Functional mode		
IR_{con}60°/sec	0.9171	0.7101
IR_{con}240°/sec	0.9600	0.9203
ER_{ecc}60°/sec	0.9629	0.7595
ER_{ecc}240°/sec	0.9637	0.7203

APPENDIX D

RAW DATA OF TEST-RETEST RELIABILITY

Table D.1 Characteristics of subjects

Subjects No.	Age (yrs)	Weigth (kg)	Heigth (cm)	BMI (kg/m^2)
1.	18	60	168	21.3
2.	17	63	174	20.8
3.	15	68	178	21.5
4.	16	63	173	21.0
5.	16	53	162	20.2
6.	16	69	180	21.3
7.	17	55	167	19.7
8.	15	60	176	19.4
9.	15	56	160	21.9
10.	18	62	180	19.1
Mean	16.3	60.9	171.8	20.6
SD	1.16	5.26	7.22	0.96

Table D.2 Shoulder range of motion (°) of the first and second tests

Subj. No.	Parameters	Range of motion (°)			
		First test		Second test	
		Lt.	Rt.	Lt.	Rt.
1.	Flexion	182	183	180	180
	Extension	45	55	45	55
	Horizontal abduction	45	50	50	50
	Horizontal adduction	125	115	125	115
	External rotation with abduct 90°	90	90	90	92
	External rotation with arm at side	90	90	90	90
	Internal rotation with abduct 90°	70	63	70	65
	Internal rotation with arm at side	90	80	90	85
	Abduction	185	185	186	185
2.	Flexion	185	182	184	183
	Extension	60	70	60	65
	Horizontal abduction	50	45	50	50
	Horizontal adduction	125	115	125	120
	External rotation with abduct 90°	80	93	80	90
	External rotation with arm at side	75	70	70	70
	Internal rotation with abduct 90°	75	70	77	75
	Internal rotation with arm at side	90	90	90	90
	Abduction	182	182	183	182
3.	Flexion	185	185	182	184
	Extension	65	65	65	65
	Horizontal abduction	45	45	50	45
	Horizontal adduction	125	125	125	125
	External rotation with abduct 90°	95	90	96	92
	External rotation with arm at side	60	85	60	80

Table D.2 Shoulder range of motion (°) of the first and second tests (cont.)

Subj. No.	**Parameters**	**Range of motion (°)**			
		First test		**Second test**	
		Lt.	**Rt.**	**Lt.**	**Rt.**
	Internal rotation with abduct 90°	70	70	70	70
	Internal rotation with arm at side	85	80	85	80
	Abduction	185	185	183	185
4.	Flexion	185	180	185	180
	Extension	70	70	70	70
	Horizontal abduction	45	40	45	40
	Horizontal adduction	105	105	110	110
	External rotation with abduct 90°	90	90	90	90
	External rotation with arm at side	70	70	70	70
	Internal rotation with abduct 90°	70	70	70	70
	Internal rotation with arm at side	80	80	80	85
	Abduction	183	185	182	185
5.	Flexion	195	190	195	192
	Extension	60	60	60	60
	Horizontal abduction	45	47	45	50
	Horizontal adduction	130	130	127	128
	External rotation with abduct 90°	95	96	95	95
	External rotation with arm at side	75	75	75	73
	Internal rotation with abduct 90°	70	70	70	70
	Internal rotation with arm at side	80	80	80	85
	Abduction	185	190	185	190

Table D.2 Shoulder range of motion (°) of the first and second tests (cont.)

Subj. No.	Parameters	Range of motion (°)			
		First test		Second test	
		Lt.	Rt.	Lt.	Rt.
6.	Flexion	182	180	181	180
	Extension	60	60	60	60
	Horizontal abduction	45	45	45	45
	Horizontal adduction	125	125	125	125
	External rotation with abduct 90°	95	90	95	92
	External rotation with arm at side	60	60	60	65
	Internal rotation with abduct 90°	75	70	75	72
	Internal rotation with arm at side	90	85	85	85
	Abduction	185	185	185	183
7.	Flexion	185	180	185	180
	Extension	60	60	60	60
	Horizontal abduction	45	46	45	45
	Horizontal adduction	125	125	125	125
	External rotation with abduct 90°	90	92	90	90
	External rotation with arm at side	70	75	70	75
	Internal rotation with abduct 90°	70	70	70	70
	Internal rotation with arm at side	80	85	80	82
	Abduction	182	183	182	185
8.	Flexion	182	185	181	185
	Extension	55	55	56	57
	Horizontal abduction	45	45	45	45
	Horizontal adduction	120	120	120	122

Table D.2 Shoulder range of motion (°) of the first and second tests (cont.)

Subj. No.	Parameters	Range of motion (°)			
		First test		Second test	
		Lt.	Rt.	Lt.	Rt.
	External rotation with abduct 90°	90	90	90	90
	External rotation with arm at side	70	70	70	70
	Internal rotation with abduct 90°	50	60	55	60
	Internal rotation with arm at side	90	85	90	87
	Abduction	184	184	183	183
9.	Flexion	185	180	185	181
	Extension	60	60	60	60
	Horizontal abduction	45	45	45	45
	Horizontal adduction	125	125	125	125
	External rotation with abduct 90°	95	90	90	90
	External rotation with arm at side	80	75	80	76
	Internal rotation with abduct 90°	70	70	70	70
	Internal rotation with arm at side	85	85	85	80
	Abduction	185	185	185	183
10.	Flexion	180	180	180	180
	Extension	70	65	70	70
	Horizontal abduction	45	47	45	45
	Horizontal adduction	125	125	125	27
	External rotation with abduct 90°	100	100	100	100
	External rotation with arm at side	85	80	86	85
	Internal rotation with abduct 90°	75	75	75	75
	Internal rotation with arm at side	85	90	85	90
	Abduction	185	180	183	180

Table D.3 Shoulder peak torque (Nm) of the first and second tests at 60°/sec and 240 °/sec

Subj. No.	Parameters	Peak torque 60°/sec (Nm)				Peak torque 240°/sec (Nm)			
		First test		Second test		First test		Second test	
		Lt.	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.
1.	**Conventional mode**								
	$IR_{concentric}$	33.0	45.1	34.7	43.5	38.6	43.8	34.6	47.0
	$ER_{concentric}$	30.2	22.5	33.8	18.3	31.5	29.5	36.3	21.9
	Functional mode								
	$IR_{concentric}$	30.9	41.3	25.4	34.8	25.4	38.7	31.8	42.8
	$ER_{eccentric}$	34.3	54.6	29.2	47.4	32.9	52.4	34.0	45.1
2.	**Conventional mode**								
	$IR_{concentric}$	26.0	31.2	25.3	39.2	35.8	42.8	38.4	47.5
	$ER_{concentric}$	26.3	15.4	26.6	14.5	33.6	26.1	36.4	22.1
	Functional mode								
	$IR_{concentric}$	25.5	36.2	25.3	37.9	33.5	41.5	35.4	42.6
	$ER_{eccentric}$	27.4	38.3	30.6	41.2	32.0	38.6	42.4	48.1
3.	**Conventional mode**								
	$IR_{concentric}$	46.9	45.3	39.5	44.1	46.4	45.9	56.1	49.1
	$ER_{concentric}$	26.3	30.8	25.5	27.7	31.6	37.3	36.2	37.1
	Functional mode								
	$IR_{concentric}$	43.7	43.6	54.6	54.5	61.7	58.1	70.5	57.5
	$ER_{eccentric}$	54.3	53.4	57.8	60.9	62.9	65.0	65.6	63.6

Table D.3 Shoulder peak torque (Nm) of the first and second tests at 60°/sec and 240°/sec (cont.)

Subj. No.	Parameters	Peak torque 60°/sec (Nm)				Peak torque 240°/sec (Nm)			
		First test		Second test		First test		Second test	
		Lt.	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.
4.	**Conventional mode**								
	$IR_{concentric}$	57.9	44.0	49.5	44.9	60.7	45.5	50.5	45.1
	$ER_{concentric}$	33.1	30.1	39.2	34.4	36.9	39.0	42.3	36.7
	Functional mode								
	$IR_{concentric}$	51.1	38.2	45.8	45.4	55.7	48.9	53.5	48.5
	$ER_{eccentric}$	51.5	42.3	55.6	54.2	58.7	47.2	61.9	66.1
5.	**Conventional mode**								
	$IR_{concentric}$	34.8	27.0	25.0	28.7	36.3	34.3	35.3	38.4
	$ER_{concentric}$	23.5	18.5	23.6	20.0	34.7	24.7	33.3	28.7
	Functional mode								
	$IR_{concentric}$	19.1	21.7	24.8	27.5	31.3	31.0	34.1	28.6
	$ER_{eccentric}$	22.3	25.5	27.6	30.4	35.4	33.5	37.3	35.3
6.	**Conventional mode**								
	$IR_{concentric}$	46.1	51.8	34.7	42.3	43.8	59.9	35.6	50.2
	$ER_{concentric}$	30.3	26.9	25.2	36.6	32.7	41.0	32.5	36.7
	Functional mode								
	$IR_{concentric}$	28.9	54.9	32.8	39.9	41.4	42.3	40.9	47.4
	$ER_{eccentric}$	36.9	37.6	32.5	44.7	50.1	58.1	46.2	61.0

Table D.3 Shoulder peak torque (Nm) of the first and second tests at 60°/sec and 240°/sec (cont.)

Subj. No.	Parameters	Peak torque 60°/sec (Nm)				Peak torque 240°/sec (Nm)			
		First test		Second test		First test		Second test	
		Lt.	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.
7.	**Conventional mode**								
	$IR_{concentric}$	12.2	22.9	16.0	22.2	24.5	39.7	28.8	37.1
	$ER_{concentric}$	19.7	10.0	18.6	11.9	29.2	21.3	29.4	16.7
	Functional mode								
	$IR_{concentric}$	14.1	21.5	13.0	19.8	18.9	35.6	20.3	34.1
	$ER_{eccentric}$	19.5	27.0	22.4	26.1	25.1	37.8	25.3	40.3
8.	**Conventional mode**								
	$IR_{concentric}$	40.0	45.1	32.8	56.5	51.9	60.9	46.7	68.7
	$ER_{concentric}$	40.5	36.5	39.8	41.9	49.8	43.8	50.0	51.1
	Functional mode								
	$IR_{concentric}$	37.6	55.9	34.3	48.0	45.9	56.5	42.5	66.1
	$ER_{eccentric}$	43.9	67.1	42.0	52.1	46.8	51.0	46.2	67.5
9.	**Conventional mode**								
	$IR_{concentric}$	26.7	25.3	24.3	26.4	32.4	39.1	31.7	41.7
	$ER_{concentric}$	18.0	14.1	14.0	14.3	19.9	15.9	18.2	15.7
	Functional mode								
	$IR_{concentric}$	11.8	41.7	14.0	35.3	17.1	42.8	15.5	39.5
	$ER_{eccentric}$	13.9	42.6	16.5	39.6	19.0	48.3	18.6	48.7

Table D.3 Shoulder peak torque (Nm) of the first and second tests at 60°/sec and 240°/sec (cont.)

Subj. No.	Parameters	Peak torque 60°/sec (Nm)				Peak torque 240°/sec (Nm)			
		First test		Second test		First test		Second test	
		Lt.	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.
10.	**Conventional mode**								
	$IR_{concentric}$	27.8	52.5	32.9	53.6	42.7	49.8	41.7	47.3
	$ER_{concentric}$	26.5	20.6	27.4	17.6	35.8	22.4	39.1	21.9
	Functional mode								
	$IR_{concentric}$	29.8	34.9	28.2	40.5	35.9	49.5	30.9	50.8
	$ER_{eccentric}$	35.9	55.4	37.0	56.3	34.0	56.7	31.2	60.3

APPENDIX E
RESULTS OF PILOT STUDY

The purpose of this pilot study was to compare shoulder flexibility, stability and muscle strength between pain-free shoulder and symptomatic shoulder in swimmers. The subjects in this study were ten female athletes and six male athletes with aged from 15 to 21 years. Half of female and male subjects were symptomatic group and the other half were pain-free group. All subjects were tested ligament laxity, range of motion, anterior and posterior capsule flexibility, muscle length, drawer tests and shoulder rotator muscle strength with Con-Trex human isokinetic at 60°/sec and 240°/sec. Prior to testing, the subject performed 5 submaximal contractions for each velocity. Each session allowed 30 seconds rest before starting the real test with 3 maximal contractions.

RESULTS

E.1 Characteristics of Subjects

Sixteen athletes were recruited and allocated into either the pain-free or the symptomatic group. The characteristics of female and male athletes in each group are presented in tables E.1 and E.2 respectively. Both groups were similar in age, weight, height and body mass index (BMI).

Table E.1 Characteristics of female subjects

Subject's characteristics	Pain-free group (n=5)	Symptomatic group (n=5)
Age (years)	16.2 ± 0.84	15.4 ± 0.55
Weight (kg)	53.3 ± 2.64	53.0 ± 4.85
Height (cm)	164.4 ± 3.78	162.4 ± 3.05
BMI ($kg.m^{-2}$)	19.74 ± 0.62	20.1 ± 1.89

Table E.2 Characteristics of male subjects

Subject's characteristics	Pain-free group (n=3)	Symptomatic group (n=3)
Age (years)	16.67 ± 2.08	17.33 ± 2.08
Weight (kg)	65.33 ± 4.16	62.67 ± 2.52
Height (cm)	175.0 ± 2.65	173.0 ± 6.56
BMI ($kg.m^{-2}$)	21.24 ± 0.62	20.96 ± 1.89

E.2 Pattern of Shoulder Flexibility

E.2.1 Shoulder flexibility of female athlete

The results of shoulder capsule flexibility and shoulder muscle length of female athletes in both groups showed no tigthness of either capsules or muscles. Thus, two groups were not different in capsule flexibility and muscle length.

The comparisons between pain-free group and symptomatic group on shoulder range of motion showed that the range of motions of all directions in symptomatic group tended to be less than pain-free group.

Table E.3 Shoulder range of motion of female athletes

ROM of shoulder (degrees)	Pain-free group (n=5)		Symptomatic group (n=5)	
	Lt.	Rt.	Lt.	Rt.
Flexion	183.2±1.30	183.2±1.64	182.8±1.95	182.8±1.64
Extension	63.0±2.74	63.0±2.74	61.0±2.24	61.0±2.24
Horizontal abduction	48.0±2.74	47.0±2.74	46.0±2.24	45.0±3.54
Horizontal adduction	125.4±0.89	125.6±1.34	123.0±4.47	123.0±4.47
Abduction	182.6±0.55	183.4±1.14	182.4±0.55	183.8±1.30
Int. rot. with 90° abduction	71.4±3.13	71.4±2.19	70.4±0.89	71±2.24
Ext. rot. with 90° abduction	91.6±2.07	92.0±2.12	90.0±3.08	91.0±1.41
Int. rot. with arm at side	83.0±4.47	85.4±4.56	81.0±2.24	81.8±2.05
Ext. rot. with arm at side	73.0±2.74	73.6±2.19	72.0±2.74	73.6±2.51

E.2.2 Shoulder flexibility of male athlete

The shoulder capsule flexibility and muscle length of male athletes in both groups also showed no tigthness of capsules and muscles.

The data of shoulder range of motion of both groups are presented in table E.4. Almost all of shoulder ranges of motions of the symptomatic group were lesser than those of the pain-free group.

Table E.4 Shoulder range of motion of male athletes

ROM of shoulder (°)	Pain-free group (n=3)		Symptomatic group (n=3)	
	Lt.	Rt.	Lt.	Rt.
Flexion	184.3±1.15	183.7±1.53	181.0±1.00	180.7±0.57
Extension	66.7±2.89	66.7±2.89	56.7±5.77	58.3±2.89
Horizontal abduction	45.0±0.00	45.0±0.00	46.7±2.89	46.7±2.89
Horizontal adduction	125.0±0.00	125.0±0.00	123.3±2.89	121.7±5.77
Abduction	183.7±1.15	184.7±0.58	183.00±2.00	182.3±2.52
Int. rot. with abduct 90°	73.3±2.89	72.3±2.52	70.0±0.00	68.3±2.89
Ext. rot. with abduct 90°	94.0±1.73	93.3±1.53	90.0±0.00	90.0±0.00
Int. rot. with arm at side	82.7±2.52	83.3±2.89	81.7±2.89	83.3±2.89
Ext. rot. with arm at side	76.7±2.89	74.3±5.13	72.7±2.52	73.3±2.89

E.3 Pattern of Shoulder Instability

The joint laxity tests in this study composed of passive hyperextension metacarpal joint parallel of the forearm, passive apposition of the thumb to the flexor aspect of the forearm, elbow hyperextension more than 10 degrees and knee hyperextension more than 10 degrees. The subject would be determined to have overall joint laxity when three or more than three of these tests were positive. Number of athletes with positive joint laxity test are presented in tables E.5 and E.7.

In this study, shoulder laxity tests consisted of anterior drawer test, posterior drawer test and sulcus sign. The test results were catgorized into three levels. Number of athletes presenting shoulder instability are presented in tables E.6 and E.8.

In female athletes the results showed a higher tendency of joint laxity in the pain-free group compared to symptomatic group. As well as, shoulder instability in symptomatic group were more than in pain-free group.

For the male athletes, the results showed a less tendency of joint laxity of the pain-free group compared to the symptomatic group.

Table E.5 The results of joint laxity test in female athletes

Joint laxity test	Number of pain-free group		Number of symptomatic group	
	Lt.	Rt.	Lt.	Rt.
Posotive	3	3	1	1
Negative	2	2	4	4
Total	5	5	5	5

Table E.6 The results of shoulder laxity tests in female athletes

Shoulder laxity	Number of pain-free group (n=5)		Number of symptomatic group (n=5)	
	Lt.	Rt.	Lt.	Rt.
Anterior Drawer Test				
- 0	-	-	1	1
- 1+	4	4	4	4
- 2+	1	1	-	-
- 3+	-	-	-	-
Posterior Drawer Test				
- 0	2	2	3	3
- 1+	3	3	2	2
- 2+	-	-	-	-
- 3+	-	-	-	-
Sulcus Sign				
- 0	1	1	1	1
- 1+	4	4	4	4
- 2+	-	-	-	-
- 3+	-	-	-	-

Table E.7 The results of joint laxity test in male athletes

Joint laxity test	Number of pain-free group		Number of symptomatic group	
	Lt.	Rt.	Lt.	Rt.
Posotive	1	1	2	2
Negative	2	2	1	1
Total	3	3	3	3

Table E.8 The results of shoulder laxity tests in male athletes

Shoulder laxity	Number of pain-free group (n=3)		Number of symptomatic group (n=3)	
	Lt.	Rt.	Lt.	Rt.
Anterior Drawer Test				
- 0	-	-	-	-
- 1+	2	2	2	2
- 2+	1	1	1	1
- 3+	-	-	-	-
Posterior Drawer Test				
- 0	2	2	1	1
- 1+	1	1	1	1
- 2+	-	-	1	1
- 3+	-	-	-	-
Sulcus Sign				
- 0	-	-	-	-
- 1+	1	1	2	2
- 2+	2	2	1	1
- 3+	-	-	-	-

E.4 Pattern of Shoulder Muscle Strength

The shoulder muscle strength of athletes were measured in term of peak torque (Nm) and ratio of peak torque (%) at 60°/sec and 240°/sec in supine position.

E.4.1 Shoulder muscle strength of female athletes

The peak torques of conventional muscles are presented in table E.9. The results of pilot study found that all of conventional and functional muscle peak torques of in symptomatic group were less than those of pain-free group.

The data of shoulder rotator peak torque ratios are presented in table E.11. Almost all of muscle strength ratios in symptomatic group were more than in pain-free group, except ratio of ER_{ecc} : IR_{con} at 60°/sec of left shoulder.

Table E.9 Shoulder conventional muscle peak torque (Nm) of female athletes

Conventional muscle strength (Nm)	**Pain-free group (n=5)**		**Symptomatic group (n=5)**	
	Lt.	**Rt.**	**Lt.**	**Rt.**
Internal Rotation (60°/sec)	31.80±4.22	40.16±9.40	25.52±5.82	19.24±5.0
External Rotation (60°/sec)	17.48±2.06	22.76±6.03	15.60±4.1	14.06±2.5
Internal Rotation (240°/sec)	34.34±6.47	34.08±9.18	27.50±3.7	25.58±2.99
External Rotation (240°/sec)	21.44±1.67	22.70±7.06	18.94±4.03	18.90±3.83

Table E.10 Shoulder functional muscle peak torque (Nm) of female athletes

Functional muscle strength (Nm)	**Pain-free group (n=5)**		**Symptomatic group (n=5)**	
	Lt.	**Rt.**	**Lt.**	**Rt.**
Internal Rotation (60°/sec)	28.36±5.19	35.18±7.35	24.50±5.3	24.30±5.24
External Rotation (60°/sec)	36.04±3.86	39.92±8.64	28.68±6.75	29.74±6.36
Internal Rotation (240°/sec)	31.58±6.5	33.92±8.28	23.86±6.62	25.94±4.75
External Rotation (240°/sec)	40.00±5.12	41.32±8.55	30.34±6.38	33.74±4.31

Table E.11 Shoulder muscle strength ratio (%) of female athletes

Muscle strength ratio (%)	Pain-free group (n=5)		Symptomatic group (n=5)	
	Lt.	**Rt.**	**Lt.**	**Rt.**
ER_{con} : IR_{con} (60°/sec)	55.50±7.55	57.10±10.11	65.92±10.68	74.18±24.42
ER_{con} : IR_{con} (240°/sec)	63.56±7.74	66.46±9.51	69.14±10.34	69.50±14.51
ER_{ecc} : IR_{con} (60°/sec)	129.12±17.88	116.82±25.04	115.8±11.60	123.24±13.05
ER_{ecc} : IR_{con} (240°/sec)	129.00±19.87	118.56±17.86	129.48±17.38	131.24±9.70

E.4.2 Shoulder muscle strength of male athletes

The peak torque of conventional muscle strength are presented in table E.12. All conventional and functional muscle peak torques of symptomatic group was lesser than those of pain-free group.

The data of peak torque ratios are presented in table E.14. Almost all of muscle strength ratio in symptomatic group were more than in pain-free group, except ratio of ER_{con} : IR_{con} at 60°/sec.

Table E.12 Shoulder conventional muscle peak torque (Nm) of male athletes

Conventional muscle strength (Nm)	Pain-free group (n=3)		Symptomatic group (n=3)	
	Lt.	**Rt.**	**Lt.**	**Rt.**
Internal Rotation (60°/sec)	57.53±6.88	54.60±11.31	33.33±7.18	37.77±2.95
External Rotation (60°/sec)	39.00±8.85	37.53±5.80	19.93±3.95	26.07±1.72
Internal Rotation (240°/sec)	51.83±5.83	47.73±5.71	35.17±7.75	33.33±2.50
External Rotation (240°/sec)	34.10±4.81	34.97±4.69	23.00±2.00	27.50±4.82

Table E.13 Shoulder functional muscle peak torque (Nm) of male athletes

Functional muscle strength (Nm)	Pain-free group (n=3)		Symptomatic group (n=3)	
	Lt.	Rt.	Lt.	Rt.
Internal Rotation (60°/sec)	49.27±4.55	53.00±13.19	31.7±6.85	33.93±2.50
External Rotation (60°/sec)	55.77±4.03	61.73±14.86	39.20±7.47	46.77±4.91
Internal Rotation (240°/sec)	46.03±2.01	49.47±13.32	29.87±6.47	30.30±3.56
External Rotation (240°/sec)	58.40±2.50	59.77±9.06	38.60±5.41	43.20±8.97

Table E.14 Shoulder muscle strength ratio (%) of male athletes

Muscle strength ratio (%)	Pain-free group (n=3)		Symptomatic group (n=3)	
	Lt.	Rt.	Lt.	Rt.
ER_{con} : IR_{con} (60°/sec)	67.53±10.77	70.27±15.12	60.03±2.50	70.23±8.91
ER_{con} : IR_{con} (240°/sec)	66.30±11.34	67.10±13.17	66.77±9.57	82.23±9.80
ER_{ecc} : IR_{con} (60°/sec)	113.33±2.82	112.07±8.89	124.23±5.18	137.63±5.07
ER_{ecc} : IR_{con} (240°/sec)	127.10±9.26	130.17±12.78	132.37±25.50	143.10±28.97

APPENDIX F
RAW DATA OF THE STUDY

Table F.1 Characteristics of female athletes

Subject No.	Pain-free group				Symptomatic group			
	Age (yrs)	Weight (kg)	Height (cm)	BMI (kg/m^2)	Age (yrs)	Weight (kg)	Height (cm)	BMI (kg/m^2)
1.	15	51.0	160.0	19.9	15	51.0	165.0	18.7
2.	16	52.5	166.0	19.1	15	46.0	159.0	18.2
3.	17	55.0	169.0	19.3	15	59.0	160.0	23.0
4.	17	57.0	166.0	20.7	16	55.0	166.0	20.0
5.	16	51.0	161.0	19.7	16	54.0	162.0	20.6
6.	16	47.0	154.0	19.8	15	52.0	160.0	20.3
7.	15	47.0	159.0	18.6	21	55.0	160.0	21.5
8.	16	50.0	160.0	19.5	15	57.0	169.0	20.0
9.	20	64.0	170.0	22.1	17	61.0	169.0	21.4
10.	16	48.0	164.0	17.8	15	61.0	173.0	20.4
11.	16	47.5	158.0	19.0	15	51.0	160.0	19.9
12.	16	62.0	170.0	21.5	15	49.0	162.0	18.7
13.	15	57.0	158.0	22.8	16	52.0	165.0	19.1
14.	15	66.5	172.0	22.5	15	53.0	165.0	19.5
15.	15	47.0	161.0	18.1	16	47.0	160.0	18.4
Mean	16.07	53.50	163.20	20.03	15.80	53.53	163.67	19.98
SD	1.28	6.53	5.39	1.57	1.57	4.60	4.22	1.31

Table F.2 Characteristics of male athletes

Subject No	Pain-free group				Symptomatic group			
	Age(yrs)	Weight(kg)	Height(cm)	BMI(kg/m^2)	Age(yrs)	Weight(kg)	Height(cm)	BMI(kg/m^2)
1.	16	63.0	172.0	21.3	18	60.0	167.0	21.5
2.	19	74.0	176.0	23.9	19	62.0	180.0	19.1
3.	15	72.0	177.0	23.0	15	56.5	172.0	19.1
4.	20	76.0	176.0	24.5	17	64.9	174.0	21.4
5.	18	70.0	179.0	21.8	15	68.0	178.0	21.5
6.	15	66.5	175.0	21.7	16	69.0	180.0	21.3
7.	17	69.0	169.0	24.2	16	66.0	181.0	20.1
8.	16	61.5	177.0	19.6	16	78.0	185.0	22.8
9.	19	74.0	176.0	23.9	17	79.0	187.0	22.6
10.	15	60.0	177.0	19.2	15	58.0	172.0	19.6
Mean	17.00	68.60	175.40	22.31	16.40	66.14	177.60	20.90
SD	1.89	5.65	2.88	1.90	1.35	7.70	6.28	1.35

Table F.3 Shoulder conventional muscle peak torque (Nm) at 60°/sec of female athletes

Subject No	Pain-free group				Symptomatic group			
	Internal Rotation (con.)		External Rotation (con.)		Internal Rotation (con.)		External Rotation (con.)	
	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.
1.	29.2	33.1	14.8	17.7	28.3	16.2	22.8	15.1
2.	28.6	38.9	18.0	27.4	20.5	20.8	13.3	11.4
3.	28.8	30.5	17.1	18.7	23.7	12.3	12.9	12.2
4.	34.4	44.3	20.5	19.0	34.3	25.0	14.0	13.9
5.	38.0	54.0	17.0	31.0	20.8	21.9	15.0	17.7
6.	26.8	25.5	18.0	20.6	19.8	15.9	12.1	14.7
7.	28.6	34.1	18.9	22.3	32.6	29.1	18.2	21.3
8.	33.8	40.3	20.5	22.9	24.2	27.4	15.5	17.1
9.	32.2	37.6	19.0	24.5	28.3	31.6	19.7	21.2
10.	38.1	40.4	21.3	23.1	30.1	25.4	19.4	20.8
11.	33.5	43.0	22.6	26.2	22.4	28.8	14.3	17.6
12.	29.1	38.7	18.4	23.9	26.2	27.9	17.4	22.5
13.	39.4	41.3	22.3	24.4	21.3	25.6	15.7	18.1
14.	34.0	44.1	22.1	28.8	28.3	30.4	17.2	21.4
15.	34.3	37.2	20.8	22.7	31.2	34.3	20.7	19.2
Mean	32.56	38.87	19.42	23.55	26.13	24.84	16.55	17.62
SD	3.96	6.67	2.26	3.75	4.71	6.29	3.14	3.53

Table F.4 Shoulder conventional muscle peak torque (Nm) at 60°/sec of male athletes

Subject No	Pain-free group				Symptomatic group			
	Internal Rotation (con.)		External Rotation (con.)		Internal Rotation (con.)		External Rotation (con.)	
	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.
1.	49.6	43.0	31.6	37.4	39.8	37.5	23.9	24.2
2.	61.8	65.6	36.6	43.4	34.6	40.2	19.9	26.4
3.	61.2	55.2	48.8	31.8	25.6	34.3	16.0	27.6
4.	47.8	53.5	27.6	33.6	38.2	42.0	25.1	33.1
5.	47.0	43.2	22.9	26.6	37.0	41.5	30.1	36.7
6.	50.5	55.7	35.4	37.2	32.3	42.0	27.0	31.4
7.	67.2	50.2	36.8	25.9	37.6	33.9	19.7	29.7
8.	59.4	60.7	33.7	42.6	35.8	37.3	23.6	27.2
9.	61.8	65.6	36.6	43.4	34.3	38.1	20.9	28.6
10.	53.3	57.8	31.9	40.4	38.4	40.6	26.4	31.7
Mean	55.96	55.05	34.19	36.23	35.36	38.74	23.26	29.66
SD	7.13	7.99	6.80	6.58	4.10	3.01	4.17	3.66

Table F.5 Shoulder conventional muscle peak torque (Nm) at 240°/sec of female athletes

Subject No	Pain-free group				Symptomatic group			
	Internal Rotation (con.)		External Rotation (con.)		Internal Rotation (con.)		External Rotation (con.)	
	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.
1.	30.4	26.2	20.4	18.9	31.1	27.2	21.3	18.1
2.	26.7	24.3	19.0	13.8	27.9	26.9	18.6	15.4
3.	39.3	32.9	22.3	23.5	21.8	25.7	16.1	20.1
4.	32.8	44.0	22.6	24.5	26.4	20.4	14.3	16.0
5.	42.5	43.0	22.9	32.8	30.3	27.7	24.4	24.9
6.	24.0	22.9	15.8	16.2	26.5	20.4	16.5	18.1
7.	26.2	30.7	16.7	19.0	31.9	28.4	21.6	23.3
8.	30.1	34.3	17.9	20.7	22.1	25.2	18.3	19.7
9.	28.8	33.2	17.6	19.4	26.7	29.1	17.1	19.3
10.	34.4	39.7	20.5	24.3	28.2	27.3	16.8	20.2
11.	27.7	38.3	20.9	23.2	24.6	27.1	14.7	16.4
12.	27.1	32.7	16.1	21.3	24.3	26.8	18.2	20.4
13.	33.9	43.5	20.6	27.6	21.7	24.2	14.6	17.3
14.	30.4	33.8	18.7	24.1	27.2	28.1	16.0	23.5
15.	26.7	32.0	17.4	22.3	26.4	27.6	18.6	20.1
Mean	30.73	34.10	19.29	22.11	26.47	26.14	17.81	19.52
SD	5.10	6.65	2.36	4.60	3.20	2.64	2.85	2.79

Table F.6 Shoulder conventional muscle peak torque (Nm) at 240°/sec of male athletes

Subject No	Pain-free group				Symptomatic group			
	Internal Rotation (con.)		External Rotation (con.)		Internal Rotation (con.)		External Rotation (con.)	
	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.
1.	45.1	41.2	33.7	33.9	35.4	33.2	22.8	24.0
2.	55.2	50.2	39.1	40.1	42.8	30.9	25.1	25.5
3.	55.2	51.8	29.5	30.9	27.3	35.9	21.1	33.0
4.	43.1	52.3	25.7	34.3	35.7	38.1	26.2	32.1
5.	48.0	40.4	30.4	28.8	40.9	36.4	32.6	30.3
6.	45.3	47.6	33.6	34.7	30.2	43.0	24.2	30.9
7.	60.9	43.4	37.5	25.3	33.4	32.5	22.1	28.5
8.	50.5	53.1	32.9	35.9	32.7	35.2	21.4	26.2
9.	55.2	50.2	39.1	40.1	30.6	37.4	20.3	29.1
10.	52.2	51.4	30.3	35.7	36.1	39.7	25.2	28.8
Mean	51.07	48.16	33.18	33.97	34.51	36.23	24.10	28.84
SD	5.69	4.78	4.41	4.64	4.77	3.58	3.58	2.91

Table F.7 Shoulder functional muscle peak torque (Nm) at 60°/sec of female athletes

Subject No	Pain-free group				Symptomatic group			
	Internal Rotation (con.)		External Rotation (ecc.)		Internal Rotation (con.)		External Rotation (ecc.)	
	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.
1.	24.8	31.8	30.5	30.3	33.8	29.8	40.4	39.7
2.	21.9	29.7	35.2	47.9	21.9	20.7	27.8	27.0
3.	29.4	28.2	36.6	30.8	23.9	28.8	25.8	29.0
4.	30.4	42.6	36.6	46.0	20.8	24.7	26.1	30.6
5.	35.3	43.6	41.3	44.6	22.1	17.5	23.3	22.4
6.	24.0	22.9	31.4	24.7	20.4	13.3	22.5	15.2
7.	25.7	28.5	31.1	36.4	32.5	36.6	39.6	43.8
8.	30.8	34.2	40.6	45.3	21.8	28.1	30.5	33.9
9.	29.6	33.1	35.7	41.4	27.2	30.4	32.4	36.1
10.	36.4	40.1	42.9	46.2	28.9	30.6	34.7	33.2
11.	28.8	40.7	36.1	47.3	23.2	26.4	28.3	30.9
12.	28.6	36.3	38.2	40.9	25.7	29.3	35.3	36.8
13.	34.8	38.4	41.6	44.2	20.6	24.9	31.4	30.3
14.	32.6	40.2	36.2	41.5	23.7	27.6	37.4	40.2
15.	30.5	38.6	39.1	42.4	30.8	33.5	38.2	36.7
Mean	29.60	35.26	36.88	40.66	25.15	26.81	31.60	32.39
SD	4.21	6.09	3.90	7.01	4.47	6.00	5.89	7.30

Table F.8 Shoulder functional muscle peak torque (Nm) at 60°/sec of male athletes

Subject No	Pain-free group				Symptomatic group			
	Internal Rotation (con.)		External Rotation (ecc.)		Internal Rotation (con.)		External Rotation (ecc.)	
	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.
1.	50.0	46.2	57.3	54.7	31.6	32.2	38.0	44.5
2.	53.4	68.2	58.8	78.8	38.6	36.8	47.2	52.4
3.	44.4	44.6	51.2	51.7	24.9	32.8	32.4	43.4
4.	43.3	46.4	47.4	54.3	36.9	40.5	51.1	57.5
5.	46.2	52.5	56.9	63.7	35.1	38.4	48.2	50.7
6.	45.3	50.4	53.4	60.3	32.5	41.3	42.7	50.0
7.	64.3	58.6	68.2	61.1	36.3	32.1	40.7	44.4
8.	50.2	56.9	59.3	61.4	33.6	37.2	43.2	45.8
9.	55.4	57.2	65.1	63.8	31.8	35.6	43.7	47.1
10.	51.1	53.0	54.3	58.2	34.3	39.0	44.2	45.6
Mean	50.36	53.40	57.19	60.80	33.56	36.59	43.14	48.14
SD	6.31	7.16	6.19	7.54	3.80	3.36	5.32	4.45

Table F.9 Shoulder functional muscle peak torque (Nm) at 240°/sec of female athletes

Subject No	Pain-free group				Symptomatic group			
	Internal Rotation (con.)		External Rotation (ecc.)		Internal Rotation (con.)		External Rotation (ecc.)	
	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.
1.	27.9	23.6	33.0	29.3	32.9	29.6	39.2	39.6
2.	27.3	38.2	36.4	52.2	19.4	23.9	30.7	32.1
3.	36.3	28.1	44.4	38.7	19.1	32.3	23.4	36.9
4.	25.8	35.1	41.6	40.4	18.9	22.4	25.1	30.3
5.	40.6	44.6	44.6	46.0	29.0	21.5	33.3	29.8
6.	22.6	26.1	28.0	26.3	28.0	20.9	28.7	21.7
7.	21.8	28.3	30.2	39.4	32.4	30.4	44.9	47.6
8.	30.4	37.6	41.5	44.7	20.1	26.8	29.2	31.4
9.	35.2	36.4	38.1	40.9	25.3	29.2	34.3	36.7
10.	34.1	37.3	44.3	47.6	26.4	30.1	31.3	38.2
11.	26.2	36.8	37.8	50.4	22.6	25.9	30.1	33.7
12.	24.7	31.4	34.2	42.8	22.8	30.3	32.6	35.4
13.	36.2	40.1	44.0	43.2	19.4	23.7	29.3	32.8
14.	33.6	38.7	39.1	42.3	24.6	27.3	38.9	41.0
15.	26.1	31.9	33.7	40.4	25.8	31.1	36.6	41.4
Mean	29.92	34.28	38.06	41.64	24.45	27.03	32.51	35.24
SD	5.71	5.83	5.40	6.87	4.70	3.77	5.63	6.13

Table F.10 Shoulder functional muscle peak torque (Nm) at 240°/sec of male athletes

Subject No	Pain-free group				Symptomatic group			
	Internal Rotation (con.)		External Rotation (ecc.)		Internal Rotation (con.)		External Rotation (ecc.)	
	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.
1.	47.9	48.6	59.2	67.5	32.5	30.0	44.8	33.4
2.	46.3	63.2	55.6	62.0	34.6	34.0	36.2	51.0
3.	43.9	36.6	60.4	49.8	22.5	26.9	34.8	45.2
4.	35.1	35.5	52.4	52.9	34.2	36.3	50.3	55.3
5.	50.7	42.2	61.4	62.5	30.7	38.0	46.0	56.8
6.	43.5	47.4	55.8	59.1	35.3	40.4	41.8	48.3
7.	56.8	54.2	66.2	62.4	29.5	32.0	38.9	46.9
8.	47.1	57.3	53.1	59.7	34.4	36.3	48.6	50.1
9.	46.3	49.4	55.6	60.2	31.3	34.8	45.2	52.4
10.	48.2	52.9	53.7	61.3	32.2	37.6	46.3	51.2
Mean	46.58	48.73	57.34	59.74	31.72	34.63	43.29	49.06
SD	5.52	8.80	4.37	5.04	3.75	4.05	5.20	6.54

Table F.11 Shoulder conventional muscle strength ratio (ER_{con}:IR_{con}) % at 60°/sec of female athletes

Subject No	Pain-free group		Symptomatic group	
	ER_{con} : IR_{con} (%)		ER_{con} : IR_{con} (%)	
	Lt.	Rt.	Lt.	Rt.
1.	50.7	53.5	80.6	93.2
2.	62.9	70.4	64.9	54.8
3.	59.4	61.3	54.4	99.2
4.	59.8	42.9	57.6	42.9
5.	44.7	57.4	72.1	80.8
6.	67.2	80.8	61.1	92.5
7.	66.1	65.4	61.7	73.2
8.	60.7	56.8	64.0	62.4
9.	59.0	65.2	69.6	67.1
10.	55.9	57.2	64.5	81.9
11.	67.5	60.9	63.8	61.1
12.	63.2	61.8	66.4	80.6
13.	56.6	59.1	73.7	70.7
14.	65.0	65.3	60.8	70.4
15.	60.6	61.0	66.3	56.0
Mean	59.95	61.27	65.43	72.45
SD	6.21	8.32	6.57	15.80

Table F.12 Shoulder conventional muscle strength ratio (ER_{con}:IR_{con}) % at 60°/sec of male athletes

Subject No	Pain-free group ER_{con} : IR_{con} (%)		Symptomatic group ER_{con} : IR_{con} (%)	
	Lt.	Rt.	Lt.	Rt.
1.	63.7	87.0	60.1	64.5
2.	59.2	66.2	57.5	65.7
3.	79.7	57.6	62.5	80.5
4.	57.7	62.8	65.7	78.8
5.	48.7	61.6	81.4	88.4
6.	70.1	66.8	83.6	74.8
7.	54.8	51.6	59.6	61.1
8.	56.7	70.2	65.9	72.9
9.	59.2	66.2	60.9	75.1
10.	59.8	69.9	68.8	78.1
Mean	60.96	65.99	66.60	73.99
SD	8.61	9.32	9.05	8.29

Table F.13 Shoulder conventional muscle strength ratio (ER_{con}:IR_{con}) % at 240°/sec of female athletes

Subject No	Pain-free group ER_{con} : IR_{con} (%)		Symptomatic group ER_{con} : IR_{con} (%)	
	Lt.	Rt.	Lt.	Rt.
1.	50.7	53.5	80.6	93.2
2.	62.9	70.4	64.9	54.8
3.	59.4	61.3	54.4	99.2
4.	59.8	42.9	57.6	42.9
5.	44.7	57.4	72.1	80.8
6.	67.2	80.8	61.1	92.5
7.	66.1	65.4	61.7	73.2
8.	60.7	56.8	64.0	62.4
9.	59.0	65.2	69.6	67.1
10.	55.9	57.2	64.5	81.9
11.	67.5	60.9	63.8	61.1
12.	63.2	61.8	66.4	80.6
13.	56.6	59.1	73.7	70.7
14.	65.0	65.3	60.8	70.4
15.	60.6	61.0	66.3	56.0
Mean	59.95	61.27	65.43	72.45
SD	6.21	8.32	6.57	15.80

Table F.14 Shoulder conventional muscle strength ratio (ER_{con}:IR_{con}) % at 240°/sec of male athletes

Subject No	Pain-free group ER_{con} : IR_{con} (%)		Symptomatic group ER_{con} : IR_{con} (%)	
	Lt.	Rt.	Lt.	Rt.
1.	74.7	82.3	64.4	72.3
2.	70.8	59.3	58.6	82.5
3.	53.4	59.7	77.3	91.9
4.	59.6	65.6	73.4	84.3
5.	63.3	71.3	79.7	83.2
6.	74.2	72.9	80.1	71.9
7.	61.6	58.3	66.2	87.7
8.	65.1	67.6	65.4	74.4
9.	70.8	79.9	66.3	77.8
10.	57.7	69.5	69.8	72.5
Mean	65.12	68.64	70.12	79.85
SD	7.28	8.32	7.24	7.09

Table F.15 Shoulder functional muscle strength ratio (ER_{ecc}:IR_{con}) % at 60°/sec of female athletes

Subject No	Pain-free group ER_{ecc} : IR_{con} (%)		Symptomatic group ER_{ecc} : IR_{con} (%)	
	Lt.	Rt.	Lt.	Rt.
1.	123.0	103.3	119.5	133.2
2.	160.7	161.3	126.9	130.4
3.	124.5	109.2	101.7	100.7
4.	120.4	108.0	125.5	123.9
5.	117.0	102.3	105.4	128.0
6.	130.8	107.9	110.3	114.3
7.	121.0	127.7	121.8	119.7
8.	131.8	132.5	139.9	120.6
9.	120.6	125.1	119.1	118.8
10.	117.9	115.2	120.1	108.5
11.	125.3	116.2	122.0	117.0
12.	133.6	112.7	137.4	125.6
13.	119.5	115.1	152.4	121.7
14.	111.0	103.2	157.8	145.7
15.	128.2	109.8	124.0	109.6
Mean	125.69	116.63	125.59	121.18
SD	11.44	15.30	15.71	10.99

Table F.16 Shoulder functional muscle strength ratio (ER_{ecc}:IR_{con}) % at 60°/sec of male athletes

Subject No	Pain-free group ER_{ecc} : IR_{con} (%)		Symptomatic group ER_{ecc} : IR_{con} (%)	
	Lt.	Rt.	Lt.	Rt.
1.	114.6	118.4	120.3	138.2
2.	110.1	101.9	122.3	142.4
3.	115.3	115.9	130.1	132.3
4.	109.5	117.0	138.5	142.0
5.	123.2	121.3	137.3	132.0
6.	117.9	119.6	131.4	128.1
7.	106.0	104.3	112.1	138.3
8.	118.1	107.9	128.6	123.1
9.	117.5	111.5	137.4	132.3
10.	106.3	109.8	128.9	116.9
Mean	113.85	112.76	128.69	132.56
SD	5.67	6.69	8.45	8.20

Table F.17 Shoulder functional muscle strength ratio (ER_{ecc}:IR_{con}) % at 240°/sec of female athletes

Subject No	Pain-free group ER_{ecc} : IR_{con} (%)		Symptomatic group ER_{ecc} : IR_{con} (%)	
	Lt.	Rt.	Lt.	Rt.
1.	118.3	100.3	119.1	133.8
2.	133.3	136.6	158.2	134.3
3.	122.3	137.7	122.5	114.2
4.	161.2	115.1	132.8	135.3
5.	109.9	103.1	114.8	138.6
6.	123.9	100.8	102.5	103.8
7.	138.5	139.2	138.6	156.6
8.	136.5	118.9	145.3	117.2
9.	108.2	112.4	135.6	125.7
10.	130.0	127.6	118.6	126.9
11.	144.3	137.0	133.2	130.1
12.	138.5	136.3	143.0	116.8
13.	121.5	107.7	151.0	138.4
14.	116.4	109.3	158.1	150.2
15.	129.1	126.6	141.9	133.1
Mean	128.79	120.57	134.35	130.33
SD	13.95	14.64	16.26	13.71

Table F.18 Shoulder functional muscle strength ratio (ER_{ecc}:IR_{con}) % at 240°/sec of male athletes

Subject No	Pain-free group ER_{ecc} : IR_{con} (%)		Symptomatic group ER_{ecc} : IR_{con} (%)	
	Lt.	Rt.	Lt.	Rt.
1.	123.6	138.9	137.8	111.3
2.	120.1	115.5	104.6	150.0
3.	137.6	136.1	154.7	168.0
4.	149.3	149.0	147.1	152.3
5.	121.1	148.1	149.8	149.5
6.	128.3	124.7	118.4	119.6
7.	116.5	115.1	131.9	146.6
8.	112.7	104.2	141.3	138.0
9.	120.1	121.9	144.4	150.6
10.	111.4	115.9	143.8	136.2
Mean	124.07	126.94	137.38	142.21
SD	11.68	15.28	15.35	16.64

Table F.19 ROM of shoulder flexion and extension (°) of female athletes

Subject No	Pain-free group				Symptomatic group			
	Flexion (°)		extension (°)		Flexion (°)		extension (°)	
	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.
1.	183	184	60	60	183	182	60	60
2.	182	184	65	65	183	181	60	60
3.	185	182	65	65	181	182	60	60
4.	184	185	65	65	183	184	60	60
5.	182	181	60	60	184	185	65	65
6.	182	183	65	65	182	184	60	60
7.	185	185	68	70	183	183	63	65
8.	182	181	60	60	184	185	65	65
9.	183	182	63	65	184	184	60	60
10.	184	183	65	65	182	183	65	65
11.	185	183	70	70	181	182	63	61
12.	182	183	60	63	183	184	65	65
13.	185	185	65	65	182	181	63	64
14.	183	183	60	60	184	185	60	60
15.	182	183	65	65	183	184	65	65
Mean	183.27	183.13	63.73	64.20	182.80	183.27	62.27	62.33
SD	1.28	1.30	3.15	3.21	1.01	1.39	2.31	2.47

Table F.20 ROM of shoulder flexion and extension (°) of male athletes

Subject No	Pain-free group				Symptomatic group			
	Flexion (°)		extension (°)		Flexion (°)		extension (°)	
	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.
1.	185	184	70	70	180	180	50	55
2.	185	185	65	65	181	181	60	60
3.	183	182	65	65	182	181	60	60
4.	183	183	70	70	182	183	65	65
5.	183	182	65	67	183	182	60	62
6.	184	183	65	65	181	180	65	65
7.	182	183	65	68	184	183	65	65
8.	182	181	65	63	183	182	65	65
9.	185	185	65	65	184	185	60	65
10.	183	184	65	65	183	183	65	65
Mean	183.50	183.20	66.00	66.30	182.30	182.00	61.50	62.70
SD	1.18	1.32	2.11	2.36	1.34	1.56	4.74	3.43

Table F.21 ROM of shoulder horizontal abduction and adduction, shoulder abduction (°) of female athletes

Subj. No	Pain-free group						Symptomatic group					
	Hori. ab. (°)		Hori. ad. (°)		Abduction (°)		Hori. ab. (°)		Hori. ad. (°)		Abduction (°)	
	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.
1.	45	45	125	125	183	184	45	45	125	125	182	183
2.	50	50	125	125	182	183	45	45	125	125	182	185
3.	50	45	125	125	183	182	45	40	115	115	183	185
4.	50	50	127	128	183	185	45	45	125	125	183	182
5.	45	45	125	125	182	183	50	50	125	125	182	184
6.	50	50	125	125	187	185	45	45	125	125	183	182
7.	50	50	125	125	183	184	50	45	120	120	182	184
8.	50	52	125	125	182	183	45	45	125	125	183	183
9.	45	45	125	125	184	185	50	50	125	125	184	184
10.	50	50	127	130	183	183	50	50	125	125	183	182
11.	45	45	125	125	184	183	45	45	125	125	183	182
12.	50	50	125	125	183	185	45	50	125	125	183	185
13.	50	50	128	125	182	184	50	50	125	125	182	183
14.	45	45	125	125	182	183	50	45	125	125	184	184
15.	45	45	125	125	183	185	45	45	125	125	183	184
Mean	48.00	47.80	125.47	125.53	183.07	183.80	47.00	46.33	124.00	124.00	182.80	183.47
SD	2.54	2.76	0.99	1.46	1.28	1.01	2.54	2.97	2.80	2.80	0.68	1.13

Table F.22 ROM of shoulder horizontal abduction and adduction, shoulder abduction (°) of male athletes

Subj. No	Pain-free group						Symptomatic group					
	Hori. ab. (°)		Hori. ad. (°)		Abduction (°)		Hori. ab. (°)		Hori. ad. (°)		Abduction (°)	
	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.
1.	45	45	125	125	183	185	50	50	120	115	185	185
2.	45	45	125	125	185	185	45	45	125	125	183	180
3.	45	45	125	125	183	184	45	45	125	125	181	182
4.	45	50	125	125	183	184	45	45	125	125	183	182
5.	50	55	128	130	183	183	45	45	125	125	183	183
6.	45	45	125	125	183	182	50	45	120	120	182	182
7.	45	50	125	125	184	183	45	45	125	125	183	183
8.	50	50	125	125	183	182	50	50	125	125	184	183
9.	50	50	120	125	185	184	45	50	125	125	184	185
10.	45	45	125	125	183	183	50	50	125	125	184	184
Mean	46.50	48.00	124.80	125.50	183.50	183.50	47.00	47.00	124.00	123.50	183.20	182.90
SD	2.42	3.50	1.93	1.58	0.85	1.08	2.58	2.58	2.11	3.38	1.14	1.52

Table F.23 ROM of shoulder internal rotation and external rotation (°) with arm abduct 90° of female athletes

Subject No	Pain-free group				Symptomatic group			
	Internal rot. (°)		External rot. (°)		Internal rot. (°)		External rot. (°)	
	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.
1.	77	75	90	90	70	70	85	90
2.	70	72	90	90	70	70	90	90
3.	70	70	92	93	70	70	93	92
4.	70	70	95	95	70	70	90	90
5.	70	70	91	92	72	75	92	93
6.	80	80	90	90	70	70	90	93
7.	75	75	94	93	72	70	90	91
8.	70	70	92	94	70	70	92	93
9.	70	75	95	95	70	70	90	90
10.	70	72	93	92	72	75	90	90
11.	70	70	90	92	70	72	91	92
12.	75	75	90	90	70	70	93	92
13.	75	75	92	93	70	70	90	90
14.	70	70	94	95	75	75	92	93
15.	70	70	90	90	70	70	90	92
Mean	72.13	72.60	91.87	92.27	70.73	71.13	90.53	91.40
SD	3.34	3.07	1.92	1.94	1.44	2.07	1.92	1.30

Table F.24 ROM of shoulder internal rotation and external rotation (°) with arm abduct 90° of male athletes

Subject No	Pain-free group				Symptomatic group			
	Internal rot. (°)		External rot. (°)		Internal rot. (°)		External rot. (°)	
	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.
1.	75	75	95	95	70	65	90	90
2.	75	72	95	92	70	70	90	90
3.	70	70	92	93	70	70	90	90
4.	70	70	90	94	70	72	91	93
5.	75	75	92	95	70	70	90	92
6.	70	72	90	92	75	75	93	93
7.	75	80	95	98	70	70	90	91
8.	75	75	90	91	72	75	90	90
9.	70	72	93	91	70	70	92	93
10.	75	75	94	93	72	70	90	90
Mean	73.00	73.60	92.60	93.40	70.90	70.70	90.60	91.20
SD	2.58	3.03	2.12	2.17	1.66	2.87	1.08	1.40

Table F.25 ROM of shoulder internal rotation and external rotation (°) with arm at side of female athletes

Subject No	Pain-free group				Symptomatic group			
	Internal rot. (°)		External rot. (°)		Internal rot. (°)		External rot. (°)	
	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.
1.	75	73	90	90	70	70	80	80
2.	70	70	80	85	70	75	80	82
3.	75	75	80	80	75	76	85	80
4.	75	75	85	90	70	72	80	85
5.	70	75	80	82	75	75	80	82
6.	80	80	90	90	70	70	90	93
7.	75	75	94	93	72	70	90	91
8.	70	70	92	94	70	70	92	93
9.	70	75	95	95	70	70	90	90
10.	70	72	93	92	72	75	90	90
11.	70	70	90	92	70	72	91	92
12.	75	75	90	90	70	70	93	92
13.	75	75	92	93	70	70	90	90
14.	70	70	94	95	75	75	92	93
15.	70	70	90	90	70	70	90	92
Mean	74.73	75.87	82.67	84.33	73.13	74.00	81.33	82.27
SD	2.49	2.90	3.06	3.60	2.53	3.32	2.09	2.22

Table F.26 ROM of shoulder internal rotation and external rotation (°) with arm at side of male athletes

Subject No	Pain-free group				Symptomatic group			
	Internal rot. (°)		External rot. (°)		Internal rot. (°)		External rot. (°)	
	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.	Lt.	Rt.
1.	80	80	85	85	75	75	80	85
2.	75	70	80	80	73	70	85	85
3.	75	73	83	85	70	75	80	80
4.	80	80	85	85	72	75	83	81
5.	75	80	80	80	70	72	80	80
6.	75	75	85	85	75	75	85	85
7.	75	75	80	80	75	73	80	83
8.	80	80	80	85	75	75	80	80
9.	75	75	83	85	75	80	80	80
10.	73	75	85	85	75	75	83	85
Mean	76.30	76.30	82.60	83.50	73.50	74.50	81.60	82.40
SD	2.63	3.55	2.37	2.42	2.12	2.59	2.17	2.41

Table F.27 Swimming experiences of female athletes in pain free group

Sub ject No.	Age (yrs.)	Hand domi nant	Stroke skilled	Dis-tance skilled	Swim exp. (yrs.)	Train-ing amount	Muscle stretch-ing	Instru-ment using	Instru-ment used	Pain exp.	Pain presen-tation	Others activi-ty
1	15	right	free-style	long	9	7000-8000 m./day 5 days/ week	every time before train-ing about 15 mins	weigth 2 kgs and elastic band about 15mins three times/ week, fin800 m./time twice a week	hand paddle since 12 year old 400m. /time three times/ week	pain left shoul-der during train-ing	no pain	-

Table F.27 Swimming experiences of female athletes in pain free group (cont.)

Sub ject No.	Age (yrs.)	Hand domi nant	Stroke skilled	Dis-tance skilled	Swim exp. (yrs.)	Train-ing amount	Muscle stretch-ing	Instru-ment using	Instru-ment used	Pain exp.	Pain presen-tation	Others activi-ty
2	16	right	free-style	short	2	6000 m./day 5 days/ week	every time before train-ing about 15 mins	elastic band, 4-5 times/ week about 20 mins	hand paddle since 14 year old 1000m ./time two times /week fin 400m. /time	no pain	no pain	-
3	17	right	free-style	short	8	3000-6000 m./day 6 days/ week	every time before train-ing about 15 mins	pullboy kick-board fin about 1000 m./time six times/ week	weigth 2 kgs about 30 mins, hand paddle since 13 year old 1000m ./time two times /week	pain both shoul-der during train-ing	no pain	-
4	17	right	free-style	middle	8	5000 m./day 6 days/ week	every time before train-ing about 30 mins	vasa about 20 mins four times/ week	hand paddle since 13 year old 400m. /time three times/ week	pain both shoul-der after train-ing	no pain	-

Table F.27 Swimming experiences of female athletes in pain free group (cont.)

Sub ject No.	Age (yrs.)	Hand domi nant	Stroke skilled	Dis-tance skilled	Swim exp. (yrs.)	Train-ing amount	Muscle stretch-ing	Instru-ment using	Instru-ment used	Pain exp.	Pain presen-tation	Others activi-ty
5	16	right	butter-fly	short	9	7000 m./day 5 days/ week	every time before train-ing about 20 mins	weigth 1 kg about 1 hr. three time /week, elastic band about 10-20 mins three time/ week, fins about 400-500m./ time twice a week	hand paddle since 13 year old 1000m ./time once a week	pain both shoul-der during train-ing	no pain	-
6	16	right	free-style	long	6	7000 m./day 6 days/ week	every time before train-ing about 10 mins	vasa about 15 mins, kick-board about 1000 m./time every time with train-ing	hand paddle since 11 year old 1000m ./time two times /week	no pain	no pain	-

Table F.27 Swimming experiences of female athletes in pain free group (cont.)

Sub ject No.	Age (yrs.)	Hand domi nant	Stroke skilled	Dis-tance skilled	Swim exp. (yrs.)	Train-ing amount	Muscle stretch-ing	Instru-ment using	Instru-ment used	Pain exp.	Pain presen-tation	Others activi-ty
7	15	right	free-style	middle	8	7000 m./day 6 days/ week	every time before train-ing about 10 mins	dum-bell 2 kgs about 30 mins twice a week, pullboy kick-board fins about 1500 m./time every time with train-ing	hand paddle since 12 year old 1000m./time three times/ week	pain both shoul-der after train-ing	no pain	-
8	16	right	breast-stroke	short	5	6000 m./day 5 days/ week	every time before train-ing about 15 mins	pullboy kick-board fins about 1000 m./time every time with train-ing	hand paddle since 12 year old 400m./time two times /week	pain both shoul-der after train-ing	no pain	-
9	20	right	breast-stroke	short	10	6000-8000 m./day 5 days/ week	every time before train-ing about 15 mins	dum-bell 2.5 kgs about 30 mins three times/ week, kick-board fins about 400 m./time every time with train-ing	hand paddle since 13 year old 1000m./time two times /week	ain both shoul-der after train-ing	no pain	-

Table F.27 Swimming experiences of female athletes in pain free group (cont.)

Sub ject No.	Age (yrs.)	Hand domi nant	Stroke skilled	Dis-tance skilled	Swim exp. (yrs.)	Train-ing amount	Muscle stretch-ing	Instru-ment using	Instru-ment used	Pain exp.	Pain presen-tation	Others activi-ty
10	16	right	free-style	long	10	8000 m./day 6 days/ week	every time before train-ing about 20 mins	vasa about 30 mins, fins about 1000 m./time every time with train-ing, hand paddle since 12 year old 400m./ time twice a week	-	pain both shoul-der during train-ing	no pain	-
11	16	right	breast-stroke	middle	8	8000 m./day 6 days/ week	every time before train-ing about 15 mins	elastic band about 15 mins every time before train-ing, dum-bell 2 kgs about 20 mins twice a week, hand paddle since 12 year old 800m. /time twice a week	-	no pain	no pain	-

Table F.27 Swimming experiences of female athletes in pain free group (cont.)

Sub ject No.	Age (yrs.)	Hand domi nant	Stroke skilled	Dis-tance skilled	Swim exp. (yrs.)	Train-ing amount	Muscle stretch-ing	Instru-ment using	Instru-ment used	Pain exp.	Pain presen-tation	Others activi-ty
12	16	right	free-style	short	4	8000 m./day 6 days/ week	every time before train-ing about 30 mins	elastic band about 15 mins every time before train-ing, hand paddle since 12 year old 600m. /time twice a week	-	pain both shoul-der during train-ing	no pain	-
13	15	right	free-style	short	6	8000 m./ day 6 days/ week	every time before train-ing about 15 mins	elastic band about 10 mins five times/ week	hand paddle since 12 year old 600m. /time four times/ week	no pain	no pain	-
14	15	right	free-style	long	8	7000 m./day 6 days/ week	every time before train-ing about 15 mins	dum-bell 2 kgs about 5 mins three times/ week, pullboy kick-board fins about 1000 m./time twice a week	-	no pain	no pain	-

Table F.27 Swimming experiences of female athletes in pain free group (cont.)

Sub ject No.	Age (yrs.)	Hand domi nant	Stroke skilled	Dis-tance skilled	Swim exp. (yrs.)	Train-ing amount	Muscle stretch-ing	Instru-ment using	Instru-ment used	Pain exp.	Pain presen-tation	Others activi-ty
15	15	right	free-style	short	5	6000 m./day 6 days/ week	every time before train-ing about 15 mins	elastic band about 10 mins three times/ week, hand paddle since 11 year old 200m. /time twice a week	-	pain both shoul-der after train-ing	no pain	-

Table F.28 Swimming experiences of female athletes in symptomatic group

Sub ject No.	Age (yrs.)	Hand domi nant	Stroke skilled	Dis-tance skilled	Swim exp. (yrs.)	Train-ing amount	Muscle stretch-ing	Instru-ment using	Instru-ment used	Pain exp.	Pain presen-tation	Others activi-ty
1	15	right	butter-fly	middle	6	6000 m./day 6 days/ week	every time before train-ing about 10 mins	vasa about four times/ week about 15mins hand paddle since 11 year old 500-1000 m./time four times/ week, kick-board five times/ week 200m./ time	-	pain both shoul-der during and after train-ing	pain both shoulder Rt. VAS 4/10 Lt. VAS 3/10	-

Table F.28 Swimming experiences of female athletes in symptomatic group (cont.)

Subject No.	Age (yrs.)	Hand dominant	Stroke skilled	Distance skilled	Swim exp. (yrs.)	Training amount	Muscle stretching	Instrument using	Instrument used	Pain exp.	Pain presentation	Others activity
2	15	right	free-style	short	8	6000 m./day 6 days/ week	five times/ week about 5 mins	dum-bell 2 kgs and elastic band about 10 mins twice a week	hand paddle since 12 year old 1000m./time three times/ week	pain both shoul-der during train-ing	pain both shoulder Rt. VAS 2/10 Lt. VAS 3/10	-
3	15	right	free-style	long	10	5000 m./day 6 days/ week	four times/ week about 10 mins	-	elastic band about 5 mins two times /week, hand paddle since 12 year old 500m. /time two times /week	pain both shoul-der after train-ing	pain both shoulder Rt. VAS 1/10 Lt. VAS 1/10	-
4	16	right	free-style	short	8	6000-7000 m./day 6 days/ week	every time before train-ing about 15 mins	weigth 30 kgs and elastic band about 15-30 mins three times/ week	hand paddle since 13 year old 2000m./time three times/ week, pull-boy about 2000m./time once a week	pain both shoul-der after train-ing	pain both shoulder Rt. VAS 2/10 Lt. VAS 2/10	-

Table F.28 Swimming experiences of female athletes in symptomatic group (cont.)

Sub ject No.	Age (yrs.)	Hand domi nant	Stroke skilled	Dis-tance skilled	Swim exp. (yrs.)	Train-ing amount	Muscle stretch-ing	Instru-ment using	Instru-ment used	Pain exp.	Pain presen-tation	Others activi-ty
5	16	right	free-style	middle	8	4500-5000 m./day 6 days/ week	four times/ week about 5-10 mins	elastic band about 5 mins twice a week	hand paddle since 13 year old 1000m./time three times/ week	pain both shoul-der during train-ing	pain both shoulder Rt. VAS 3/10 Lt. VAS 3/10	-
6	15	right	butter-fly	middle	6	6000 m./day 6 days/ week	five times/ week about 10 mins	vasa about three times/ week about 10mins hand paddle since 10 year old 1000m./time three times/ week, pullboy 500m./ time three times/ week	-	pain both shoul-der during train-ing	pain both shoulder Rt. VAS 2/10 Lt. VAS 1/10	-
7	21	right	free-style	short	10	6000 m./day 6 days/ week	every time before train-ing about 15 mins	dum-bell 3 kgs and elastic band about 15 mins three times/ week	hand paddle since 13 year old 8000m./time three times/ week	pain both shoul-der during train-ing	pain both shoulder Rt. VAS 5/10 Lt. VAS 6/10	-

Table F.28 Swimming experiences of female athletes in symptomatic group (cont.)

Sub ject No.	Age (yrs.)	Hand domi nant	Stroke skilled	Dis-tance skilled	Swim exp. (yrs.)	Train-ing amount	Muscle stretch-ing	Instru-ment using	Instru-ment used	Pain exp.	Pain presen-tation	Others activi-ty
8.	15	right	free-style	long	8	10000 m./day 6 days/ week	four times/ week about 15 mins	vasa about four times/ week about 30mins hand paddle since 11 year old 2000m. /time twice a week	fins 800m. /time two times /week	pain left shoul-der during train-ing	pain both shoulder Rt. VAS 3/10 Lt. VAS 5/10	-
9	17	right	free-style	short	7	8000 m./day 6 days/ week	four times/ week about 15 mins	weigth 3-5 kgs and elastic band about 15-25 mins five times/ week, hand paddle since 12 year old 1000m. /time every time with train-ing, fins 1000m. /time twice a week	-	pain both shoul-der during train-ing	pain both shoulder Rt. VAS 2/10 Lt. VAS 2/10	-

Table F.28 Swimming experiences of female athletes in symptomatic group (cont.)

Sub ject No.	Age (yrs.)	Hand domi nant	Stroke skilled	Dis-tance skilled	Swim exp. (yrs.)	Train-ing amount	Muscle stretch-ing	Instru-ment using	Instru-ment used	Pain exp.	Pain presen-tation	Others activi-ty
10	15	right	free-style	middle	8	7000 m./day 6 days/ week	every time before train-ing about 10 mins	elastic band about 15 mins four times/ week, hand paddle since 13 year old 1500m. /time three times/ week, fins 3000m. /time three times/ week	-	pain left shoul-der after train-ing	pain both shoulder Rt. VAS 2/10 Lt. VAS 4/10	-
11	15	left	back-stroke	middle	8	7000 m./day 6 days/ week	five times/ week about 10 mins	dum-bell 2.5 kgs about 30mins twice a week, hand paddle since 12 year old 1500m. /time five times/ week, pullboy kick-board, fins about 1500 m./time every time with train-ing	-	pain both shoul-der during train-ing	pain both shoulder Rt. VAS 4/10 Lt. VAS 5/10	-

Table F.28 Swimming experiences of female athletes in symptomatic group (cont.)

Sub ject No.	Age (yrs.)	Hand domi nant	Stroke skilled	Dis-tance skilled	Swim exp. (yrs.)	Train-ing amount	Muscle stretch-ing	Instru-ment using	Instru-ment used	Pain exp.	Pain presen-tation	Others activi-ty
12	15	right	free-style, back-stroke	middle	8	7000 m./day 6 days/ week	five times/ week about 5 mins	dum-bell 2.5 kgs about 30mins twice a week, hand paddle since 12 year old 1500m. /time five times/ week, pullboy kick-board fins about 1500 m./time every time with train-ing	-	pain both shoul-der during train-ing	pain both shoulder Rt. VAS 3/10 Lt. VAS 5/10	-

Table F.28 Swimming experiences of female athletes in symptomatic group (cont.)

Subject No.	Age (yrs.)	Hand dominant	Stroke skilled	Distance skilled	Swim exp. (yrs.)	Training amount	Muscle stretching	Instrument using	Instrument used	Pain exp.	Pain presentation	Others activity
13	16	left	freestyle	long	8	10000 m./day 6 days/ week	every time before training about 10 mins	vasa four times/ week about 20-30mins every time bofore training, hand paddle since 12 year old 1500m. /time three times/ week, fins about 1500 m./time three times/ week	-	pain both shoulder during training	pain both shoulder Rt. VAS 3/10 Lt. VAS 2/10	-
14	15	right	backstroke	middle	6	8000 m./day 6 days/ week	every time before training about 10 mins	elastic band 15 mins four times/ week, hand paddle since 13 year old 1500m. /time twice a week, kickboard, fins 400 m./time every time with training	-	pain both shoulder during training	pain both shoulder Rt. VAS 2/10 Lt. VAS 2/10	-

Table F.28 Swimming experiences of female athletes in symptomatic group (cont.)

Sub ject No.	Age (yrs.)	Hand domi nant	Stroke skilled	Dis-tance skilled	Swim exp. (yrs.)	Train-ing amount	Muscle stretch-ing	Instru-ment using	Instru-ment used	Pain exp.	Pain presen-tation	Others activi-ty
15	16	rigth	back-stroke	short	7	6000 m./day 6days/ week	every time before train-ing about 10 mins	elastic band about 15 mins four times/ week, hand paddle since 13 year old 1000m. /time twice a week, kick-board, fins about 400 m./time every time with train-ing	-	pain both shoul-der during train-ing	pain both shoulder Rt. VAS 3/10 Lt. VAS 2/10	-

Table F.29 Swimming experiences of male athletes in pain free group

Sub ject No.	Age (yrs.)	Hand domi nant	Stroke skilled	Dis-tance skilled	Swim exp. (yrs.)	Train-ing amount	Muscle stretch-ing	Instru-ment using	Instru-ment used	Pain exp.	Pain presen-tation	Others activi-ty
1	16	right	free-style	short	8	5000-7000 m./day 6 days/ week	5-7 times/ week about 15 mins	elastic band and vasa 15-20 mins 3-5 times/ week, hand paddle since 10 year old 500m./ time once a week	-	pain both shoul-der after train-ing	no pain	-

Table F.29 Swimming experiences of male athletes in pain free group (cont.)

Sub ject No.	Age (yrs.)	Hand domi nant	Stroke skilled	Dis-tance skilled	Swim exp. (yrs.)	Train-ing amount	Muscle stretch-ing	Instru-ment using	Instru-ment used	Pain exp.	Pain presen-tation	Others activi-ty
2	15	right	free-style, back-stroke	short	5	4000 m./day 6 days/ week	every time before train-ing about 15 mins	weigth 20 kilos and dum-bell 4 kgs all time before train-ing about 20 mins	hand paddle since 12 year old 1000m ./time three times/ week	no pain	no pain	-
3	15	right	free-style	middle	3	8000 m./day 6 days/ week	every time before train-ing about 20 mins	elastic band about 15 mins twice a week, fin 1000m. /time twice a week	hand paddle since 13 year old 2000m ./time three times/ week	pain both shoul-der during train-ing	no pain	-
4	20	right	butter-fly	middle	10	10000 m./day 6 days/ week	every time before train-ing about 15 mins	weigth 12 kgs about 20 mins twice a week, fins 1000m. /time once a week	hand paddle since 13 year old 2000m ./time three times/ week	pain both shoul-der during train-ing	no pain	-

Table F.29 Swimming experiences of male athletes in pain free group (cont.)

Sub ject No.	Age (yrs.)	Hand domi nant	Stroke skilled	Dis-tance skilled	Swim exp. (yrs.)	Train-ing amount	Muscle stretch-ing	Instru-ment using	Instru-ment used	Pain exp.	Pain presen-tation	Others activi-ty
5	18	right	free-style	short	9	6000 m./day 6 days/ week	every time before train-ing about 15 mins	kick-board 600m. /time every time with train-ing	elastic band about 15 mins three times/ week, hand paddle since 12 year old 1000m./time two times /week	pain rigth shoul-der after train-ing	no pain	-
6	15	right	breast-stroke, back-storke	middle	10	6000 m./day 5 days/ week	every time before train-ing about 15 mins	elastic band about 10 mins once a week, pullboy kick-board fins about 2000 m./time every time with train-ing	hand paddle since 12 year old 1000m./time two times /week	pain both shoul-der during train-ing	no pain	-
7	17	right	back-stroke	middle	8	7000 m./day 6 days/ week	every time before train-ing about 15 mins	elastic band 10 mins four times/ week, fins 800 m./time twice a week	hand paddle since 13 year old 500 m./ time two times/ week	pain rigth shoul-der after train-ing	no pain	-

Table F.29 Swimming experiences of male athletes in pain free group (cont.)

Sub ject No.	Age (yrs.)	Hand domi nant	Stroke skilled	Dis-tance skilled	Swim exp. (yrs.)	Train-ing amount	Muscle stretch-ing	Instru-ment using	Instru-ment used	Pain exp.	Pain presen-tation	Others activi-ty
8	16	right	free-style	short	9	5000-6000 m./day 6 days/ week	every time before train-ing about 20 mins	dum-bell 4 kilos about 20 mins four times/ week, kick-board about 1000 m./time four times/ week	hand paddle since 11 year old 3000m ./time three times/ week	no pain	no pain	-
9	19	right	free-style	short	10	6000 m./day 3 days/ week	every time before train-ing about 15 mins	dumbel l 6 kilos about 15 mins once a week, elastic band about 15 mins twice a week	hand paddle since 10 year old 500m. /time once a week, kick-board about 1000m ./time every time with train-ing	pain both shoul-der during train-ing	no pain	-
10	15	right	free-style	middle	8	5000-6000 m./day 6 days/ week	every time before train-ing about 20 mins	dum-bell 6 kgs about 20 mins three times/ week	hand paddle since 12 year old 1000m ./time two times/ week	pain both shoul-der during train-ing	no pain	-

Table F.30 Swimming experiences of male athletes in symptomatic group

Subject No.	Age (yrs.)	Hand dominant	Stroke skilled	Distance skilled	Swim exp. (yrs.)	Training amount	Muscle stretching	Instrument using	Instrument used	Pain exp.	Pain presentation	Others activity
1	18	right	free-style	short	10	5000 m./day 6 days/ week	every time before training about 10 mins	elastic band about 30 mins twice a week	hand paddle since 10 year old 1000m./time four times/ week	pain both shoulder after training	pain both shoulder Rt. VAS 2/10 Lt. VAS 1/10	-
2	19	left	free-style	short	8	5000 m./day 6 days/ week	every time before training about 10 mins	hand paddle since 12 year old 2000m. /time twice a week	dumbell 5 kgs and elastic band about 5 mins four times/ week	pain both shoulder after training	pain both shoulder Rt. VAS 1/10 Lt. VAS 1/10	-
3	15	right	butterfly	short	7	6000 m./day 6 days/ week	every time before training about 10 mins	elastic band about 15 mins four times/ week	hand paddle since 12 year old 1500m./time three times/ week	pain both shoulder after training	pain both shoulder Rt. VAS 1/10 Lt. VAS 4/10	-

Table F.30 Swimming experiences of male athletes in symptomatic group (cont.)

Sub ject No.	Age (yrs.)	Hand domi nant	Stroke skilled	Dis-tance skilled	Swim exp. (yrs.)	Train-ing amount	Muscle stretch-ing	Instru-ment using	Instru-ment used	Pain exp.	Pain presen-tation	Others activi-ty
4	17	right	free-style	short	7	6000-7500 m./day 6 days/ week	two times/ week about 20 mins	kick-board 500 m./time three times /week	weigth 50 kgs about 10 mins four times/ week, hand paddle since 11 year old 5000m./time two times/ week	pain both shoul-der during train-ing	pain both shoulder Rt. VAS 4/10 Lt. VAS 4/10	-
5	15	right	free-style	short	6	7000-8000 m./day 6 days/ week	two times/ week about 15 mins	elastic band about 10 mins three times/ week, hand paddle since 13 year old 2000m./time three times /week	-	pain both shoul-der during train-ing	pain both shoulder Rt. VAS 2/10 Lt. VAS 2/10	-
6	16	right	back-stroke	middle	8	6000 m./day 6 days/ week	every time before train-ing about 5 mins	elastic band 20 mins twice a week, hand paddle since 13 year old 5000m./time once a week	-	pain both shoul-der during train-ing	pain both shoulder Rt. VAS 3/10 Lt. VAS 2/10	-

Table F.30 Swimming experiences of male athletes in symptomatic group (cont.)

Subject No.	Age (yrs.)	Hand dominant	Stroke skilled	Distance skilled	Swim exp. (yrs.)	Training amount	Muscle stretching	Instrument using	Instrument used	Pain exp.	Pain presentation	Others activity
7	16	left	free-style	short	8	6000 m./day 6 days/ week	every time before training about 10 mins	elastic band 20 mins three times/ week, hand paddle since 13 year old 2000m. /time three times/ week, fins and kick-board 1000 m./time twice a week	-	pain both shoulder after training	pain both shoulder Rt. VAS 3/10 Lt. VAS 3/10	-
8	16	right	back-stroke	short	11	10000 m./day 6 days/ week	every time before training about 10 mins	dumbbell 5 kgs 30 mins three times/ week, hand paddle since 7 year old 4000m. /time four times/ week	fins 1000m./time four times/ week	pain both shoulder during training	pain both shoulder Rt. VAS 3/10 Lt. VAS 5/10	-

Table F.30 Swimming experiences of male athletes in symptomatic group (cont.)

Subject No.	Age (yrs.)	Hand dominant	Stroke skilled	Distance skilled	Swim exp. (yrs.)	Training amount	Muscle stretching	Instrument using	Instrument used	Pain exp.	Pain presentation	Others activity
9	17	right	free-style	middle	8	8000 m./day 6 days/ week	every time before training about 15 mins	elastic band 30 mins twice a week, hand paddle since 13 year old 1000m. /time three times/ week	-	pain both shoulder during training	pain both shoulder Rt. VAS 4/10 Lt. VAS 4/10	-
10	15	right	butter-fly	middle	7	7000m./ day 6 days/ week	every time before training about 15 mins	elastic band 20 mins every time before training, hand paddle since 12 year old 3000m. /time every time with training, fins pullboy 3000-4000 m./time every time with training	-	pain left shoulder during training	pain both shoulder Rt. VAS 2/10 Lt. VAS 4/10	-

Table F.31 Shoulder tests of female athletes in pain-free group

Sub ject No.	Impin-gement tests		Liga-ment laxity tests		Capsule flexibility		Muscle length tests		Shoulder stability	
	L	R	L	R	L	R	L	R	L	R
1	-	-	+	+	hyperabduct-ion 90^0, reach behind back at T_3	hyperabduct-ion 90^0, reach behind back at T_3	no tightness	no tightness	ADT 2+ PDT 1+ sulcus 1+	ADT 2+ PDT 1+ sulcus 1+
2	-	-	-	-	hyperabduct-ion 100^0, reach behind back at T_5	hyperabduct-ion 100^0, reach behind back at T_5	no tightness	no tightness	ADT 1+ PDT 0 sulcus 1+	ADT 1+ PDT 0 sulcus 1+
3	-	-	-	-	hyperabduct-ion 100^0, reach behind back at T_4	hyperabduct-ion 100^0, reach behind back at T_4	no tightness	no tightness	ADT 1+ PDT 0 sulcus 0	ADT 1+ PDT 0 sulcus 0
4	-	-	+	+	hyperabduct-ion 100^0, reach behind back at T_3	hyperabduct-ion 100^0, reach behind back at T_3	no tightness	no tightness	ADT 1+ PDT 1+ sulcus 1+	ADT 1+ PDT 1+ sulcus 1+
5	-	-	+	+	hyperabduct-ion 90^0, reach behind back at T_3	hyperabduct-ion 110^0, reach behind back at T_5	no tightness	no tightness	ADT 1+ PDT 1+ sulcus 1+	ADT 1+ PDT 1+ sulcus 1+
6	-	-	-	-	hyperabduct-ion 100^0, reach behind back at T_5	hyperabduct-ion 100^0, reach behind back at T_7	no tightness	no tightness	ADT 1+ PDT 0 sulcus 1+	ADT 1+ PDT 0 sulcus 1+
7	-	-	-	-	hyperabduct-ion 90^0, reach behind back at T_7	hyperabduct-ion 90^0, reach behind back at T_{10}	no tightness	no tightness	ADT 1+ PDT 0 sulcus 1+	ADT 1+ PDT 0 sulcus 1+
8	-	-	-	-	hyperabduct-ion 120^0, reach behind back at T_5	hyperabduct-ion 120^0, reach behind back at T_5	no tightness	no tightness	ADT 0 PDT 0 sulcus 1+	ADT 0 PDT 0 sulcus 1+
9	-	-	-	-	hyperabduct-ion 90^0, reach behind back at T_3	hyperabduct-ion 90^0, reach behind back at T_5	no tightness	no tightness	ADT 1+ PDT 1+ sulcus 1+	ADT 1+ PDT 1+ sulcus 1+
10	-	-	+	+	hyperabduct-ion 90^0, reach behind back at T_9	hyperabduct-ion 90^0, reach behind back at T_9	no tightness	no tightness	ADT 1+ PDT 0 sulcus 1+	ADT 1+ PDT 0 sulcus 1+

Table F.31 Shoulder tests of female athletes in pain-free group (cont.)

Sub ject No.	Impin-gement tests		Liga-ment laxity tests		Capsule flexibility		Muscle length tests		Shoulder stability	
	L	R	L	R	L	R	L	R	L	R
11	-	-	-	-	hyperabduct-ion 100^0, reach behind back at T_4	hyperabduct-ion 100^0, reach behind back at T_5	no tightness	no tightness	ADT 1+ PDT 0 sulcus 0	ADT 1+ PDT 0 sulcus 0
12	-	-	+	+	hyperabduct-ion 90^0, reach behind back at T_3	hyperabduct-ion 90^0, reach behind back at T_3	no tightness	no tightness	ADT 1+ PDT 1+ sulcus 1+	ADT 1+ PDT 1+ sulcus 1+
13	-	-	-	-	hyperabduct-ion 90^0, reach behind back at T_5	hyperabduct-ion 90^0, reach behind back at T_5	no tightness	no tightness	ADT 1+ PDT 0 sulcus 1+	ADT 1+ PDT 0 sulcus 1+
14	-	-	-	-	hyperabduct-ion 100^0, reach behind back at T_3	hyperabduct-ion 100^0, reach behind back at T_5	no tightness	no tightness	ADT 1+ PDT 1+ sulcus 1+	ADT 1+ PDT 1+ sulcus 1+
15	-	-	-	-	hyperabduct-ion 100^0, reach behind back at T_5	hyperabduct-ion 100^0, reach behind back at T_5	no tightness	no tightness	ADT 1+ PDT 0 sulcus 1+	ADT 1+ PDT 0 sulcus 1+

Table F.32 Shoulder tests of female athletes in symptomatic group

Sub ject No.	Impingement tests		Liga-ment laxity tests		Capsule flexibility		Muscle length tests		Shoulder stability	
	L	R	L	R	L	R	L	R	L	R
1	Hawkin + Empty can +	Hawkin + Empty can +	+	+	hyperabduct-ion 100^0, reach behind back at T_7	hyperabduct-ion 100^0, reach behind back at T_7	no tight-ness	no tight-ness	ADT 1+ PDT 1+ sulcus 1+	ADT 1+ PDT 1+ sulcus 1+
2	Empty can +	-	-	-	hyperabduct-ion 110^0, reach behind back at T_7	hyperabduct-ion 110^0, reach behind back at T_7	no tight-ness	no tight-ness	ADT 1+ PDT 0 sulcus 1+	ADT 1+ PDT 0 sulcus 1+
3	Hawkin +	Hawkin +	-	-	hyperabduct-ion 100^0, reach behind back at T_5	hyperabduct-ion 100^0, reach behind back at T_5	no tight-ness	no tight-ness	ADT 0 PDT 0 sulcus 1+	ADT 0 PDT 0 sulcus 1+
4	Hawkin +	Hawkin +	-	-	hyperabduct-ion 100^0, reach behind back at T_4	hyperabduct-ion 100^0, reach behind back at T_7	no tight-ness	no tight-ness	ADT 1+ PDT 1+ sulcus 1+	ADT 1+ PDT 1+ sulcus 1+

Table F.32 Shoulder tests of female athletes in symptomatic group (cont.)

Sub ject No.	Impingement tests		Liga-ment laxity tests		Capsule flexibility		Muscle length tests		Shoulder stability	
	L	R	L	R	L	R	L	R	L	R
5	Hawkin +	Hawkin +	-	-	hyperabduct-ion 100^0, reach behind back at T_4	hyperabduct-ion 100^0, reach behind back at T_6	no tight-ness	no tight-ness	ADT 1+ PDT 0 sulcus 0	ADT 1+ PDT 0 sulcus 0
6	Resist Ext.Rot. arm ab. 90^0 + Resist Ext.Rot. arm at side +	Resist Ext.Rot. arm ab. 90^0 + Resist Ext.Rot. arm at side +	-	-	hyperabduct-ion 90^0, reach behind back at T_7	hyperabduct-ion 90^0, reach behind back at T_7	no tight-ness	no tight-ness	ADT 1+ PDT 1+ sulcus 1+	ADT 1+ PDT 1+ sulcus 1+
7	Hawkin + Neer +	Hawkin + Neer +	-	-	hyperabduct-ion 90^0, reach behind back at T_7	hyperabduct-ion 90^0, reach behind back at T_7	no tight-ness	no tight-ness	ADT 1+ PDT 0 sulcus 1+	ADT 1+ PDT 0 sulcus 1+
8	Hawkin +	Hawkin +	-	-	hyperabduct-ion 100^0, reach behind back at T_3	hyperabduct-ion 100^0, reach behind back at T_5	no tight-ness	no tight-ness	ADT 1+ PDT 1+ sulcus 1+	ADT 1+ PDT 1+ sulcus 1+
9	Hawkin + Empty can +	Hawkin + Empty can +	+	+	hyperabduct-ion 100^0, reach behind back at T_7	hyperabduct-ion 100^0, reach behind back at T_9	no tight-ness	no tight-ness	ADT 2+ PDT 0 sulcus 1+	ADT 2+ PDT 0 sulcus 1+
10	Hawkin + Neer + Empty can + Resist Ext.Rot. arm ab. 90^0 + Resist Ext.Rot. arm at side +	Hawkin + Neer + Empty can +	+	+	hyperabduct-ion 100^0, reach behind back at T_5	hyperabduct-ion 100^0, reach behind back at T_5	no tight-ness	no tight-ness	ADT 1+ PDT 1+ sulcus 1+	ADT 1+ PDT 1+ sulcus 1+
11	Hawkin + Neer + Empty can +	Hawkin + Neer + Empty can +	+	+	hyperabduct-ion 80^0, reach behind back at T_5	hyperabduct-ion 80^0, reach behind back at T_5	no tight-ness	no tight-ness	ADT 1+ PDT 1+ sulcus 1+	ADT 1+ PDT 1+ sulcus 1+

Table F.32 Shoulder tests of female athletes in symptomatic group (cont.)

Sub ject No.	Impingement tests		Liga- ment laxity tests		Capsule flexibility		Muscle length tests		Shoulder stability	
	L	R	L	R	L	R	L	R	L	R
12	Hawkin +	Hawkin +	+	+	hyperabduct-ion 80^0, reach behind back at T_9	hyperabduct-ion 80^0, reach behind back at T_9	no tight-ness	no tight-ness	ADT 2+ PDT 0 sulcus 1+	ADT 2+ PDT 0 sulcus 1+
13	Hawkin +	Hawkin +	+	+	hyperabduct-ion 100^0, reach behind back at T_5	hyperabduct-ion 100^0, reach behind back at T_7	no tight-ness	no tight-ness	ADT 1+ PDT 1+ sulcus 1+	ADT 2+ PDT 1+ sulcus 1+
14	Hawkin +	Hawkin + Resist Ext.Rot. arm ab. 90^0 +	+	+	hyperabduct-ion 160^0, reach behind back at T_7	hyperabduct-ion 160^0, reach behind back at T_7	no tight-ness	no tight-ness	ADT 2+ PDT 2+ sulcus 2+	ADT 2+ PDT 2+ sulcus 2+
15	Hawkin +	Hawkin +	+	+	hyperabduct-ion 140^0, reach behind back at T_{10}	hyperabduct-ion 140^0, reach behind back at T_{10}	no tight-ness	no tight-ness	ADT 2+ PDT 0 sulcus 1+	ADT 2+ PDT 0 sulcus 1+

Table F.33 Shoulder tests of male athletes in pain-free group

Sub ject No.	Impingement tests		Liga- ment laxity tests		Capsule flexibility		Muscle length tests		Shoulder stability	
	L	R	L	R	L	R	L	R	L	R
1	-	-	-	-	hyperabduct-ion 140^0, reach behind back at T_4	hyperabduct-ion 140^0, reach behind back at T_4	no tight-ness	no tight-ness	ADT 1+ PDT 0 sulcus 2+	ADT 1+ PDT 0 sulcus 2+
2	-	-	+	+	hyperabduct-ion 90^0, reach behind back at T_5	hyperabduct-ion 90^0, reach behind back at T_7	no tight-ness	no tight-ness	ADT 2+ PDT 1+ sulcus 2+	ADT 2+ PDT 1+ sulcus 2+
3	-	-	-	-	hyperabduct-ion 90^0, reach behind back at T_5	hyperabduct-ion 90^0, reach behind back at T_5	no tight-ness	no tight-ness	ADT 1+ PDT 0 sulcus 1+	ADT 1+ PDT 0 sulcus 1+
4	-	-	-	-	hyperabduct-ion 90^0, reach behind back at T_3	hyperabduct-ion 90^0, reach behind back at T_3	no tight-ness	no tight-ness	ADT 0 PDT 0 sulcus 0	ADT 0 PDT 0 sulcus 0

Table F.33 Shoulder tests of male athletes in pain-free group (cont.)

Sub ject No.	Impingement tests		Liga-ment laxity tests		Capsule flexibility		Muscle length tests		Shoulder stability	
	L	R	L	R	L	R	L	R	L	R
5	-	-	-	-	hyperabduct-ion 100^0, reach behind back at T_7	hyperabduct-ion 100^0, reach behind back at T_7	no tight-ness	no tight-ness	ADT 1+ PDT 0 sulcus 1+	ADT 1+ PDT 0 sulcus 1+
6	-	-	-	-	hyperabduct-ion 90^0, reach behind back at T_7	hyperabduct-ion 90^0, reach behind back at T_7	no tight-ness	no tight-ness	ADT 0 PDT 0 sulcus 0	ADT 0 PDT 0 sulcus 0
7	-	-	+	+	hyperabduct-ion 90^0, reach behind back at T_7	hyperabduct-ion 90^0, reach behind back at T_7	no tight-ness	no tight-ness	ADT 2+ PDT 0 sulcus 1+	ADT 2+ PDT 0 sulcus 1+
8	-	-	+	+	hyperabduct-ion 95^0, reach behind back at T_7	hyperabduct-ion 95^0, reach behind back at T_5	no tight-ness	no tight-ness	ADT 2+ PDT 0 sulcus 1+	ADT 2+ PDT 0 sulcus 1+
9	-	-	+	+	hyperabduct-ion 100^0, reach behind back at T_{10}	hyperabduct-ion 100^0, reach behind back at T_{10}	no tight-ness	no tight-ness	ADT 1+ PDT 0 sulcus 1+	ADT 1+ PDT 0 sulcus 1+
10	Resist Ext.Rot. arm ab. 90^0 + Resist Ext.Rot. arm at side +	Resist Ext.Rot. arm ab. 90^0 + Resist Ext.Rot. arm at side +	-	-	hyperabduct-ion 100^0, reach behind back at T_3	hyperabduct-ion 100^0, reach behind back at T_5	no tight-ness	no tight-ness	ADT 1+ PDT 1+ sulcus 1+	ADT 1+ PDT 1+ sulcus 1+

Table F.34 Shoulder tests of male athletes in symptomatic group

Sub ject No.	Impingement tests		Liga-ment laxity tests		Capsule flexibility		Muscle length tests		Shoulder stability	
	L	R	L	R	L	R	L	R	L	R
1	Hawkin + Empty can +	Hawkin + Empty can +	-	-	hyperabduct-ion 125^0, reach behind back at T_7	hyperabduct-ion 120^0, reach behind back at T_7	no tight-ness	no tight-ness	ADT 1+ PDT 1+ sulcus 1+	ADT 1+ PDT 1+ sulcus 1+
2	Hawkin +	Hawkin +	+	+	hyperabduct-ion 125^0, reach behind back at T_5	hyperabduct-ion 125^0, reach behind back at T_3	no tight-ness	no tight-ness	ADT 2+ PDT 2+ sulcus 2+	ADT 2+ PDT 2+ sulcus 2+

Table F.34 Shoulder tests of male athletes in symptomatic group (cont.)

Sub ject No.	Impingement tests		Liga-ment laxity tests		Capsule flexibility		Muscle length tests		Shoulder stability	
	L	R	L	R	L	R	L	R	L	R
3	Hawkin +	Hawkin +	+	+	hyperabduct-ion 90^0, reach behind back at T_5	hyperabduct-ion 90^0, reach behind back at T_5	no tight-ness	no tight-ness	ADT 1+ PDT 0 sulcus 1+	ADT 1+ PDT 0 sulcus 1+
4	Hawkin +	Hawkin +	-	-	hyperabduct-ion 90^0, reach behind back at T_5	hyperabduct-ion 90^0, reach behind back at T_5	no tight-ness	no tight-ness	ADT 1+ PDT 1+ sulcus 1+	ADT 1+ PDT 1+ sulcus 1+
5	Hawkin + Empty can +	Hawkin + Empty can +	-	-	hyperabduct-ion 110^0, reach behind back at T_{10}	hyperabduct-ion 110^0, reach behind back at T_{10}	no tight-ness	no tight-ness	ADT 1+ PDT 0 sulcus 1+	ADT 1+ PDT 0 sulcus 1+
6	Hawkin +	Hawkin +	+	+	hyperabduct-ion 100^0, reach behind back at T_4	hyperabduct-ion 100^0, reach behind back at T_8	no tight-ness	no tight-ness	ADT 2+ PDT 0 sulcus 1+	ADT 2+ PDT 0 sulcus 1+
7	Hawkin + Resist Ext.Rot. arm ab. 90^0 +	Hawkin +	-	-	hyperabduct-ion 80^0, reach behind back at T_5	hyperabduct-ion 80^0, reach behind back at T_{10}	no tight-ness	no tight-ness	ADT 1+ PDT 0 sulcus 1+	ADT 1+ PDT 0 sulcus 1+
8	Hawkin + Neer + Empty can +	Hawkin + Neer + Empty can +	-	-	hyperabduct-ion 100^0, reach behind back at T_7	hyperabduct-ion 100^0, reach behind back at T_7	no tight-ness	no tight-ness	ADT 2+ PDT 1+ sulcus 1+	ADT 2+ PDT 1+ sulcus 1+
9	Hawkin +	Hawkin +	+	+	hyperabduct-ion 100^0, reach behind back at T_7	hyperabduct-ion 100^0, reach behind back at T_7	no tight-ness	no tight-ness	ADT 2+ PDT 1+ sulcus 2+	ADT 2+ PDT 1+ sulcus 2+
10	Hawkin + Empty can +	Hawkin + Empty can +	-	-	hyperabduct-ion 80^0, reach behind back at T_{10}	hyperabduct-ion 80^0, reach behind back at T_{10}	no tight-ness	no tight-ness	ADT 1+ PDT 0 sulcus 1+	ADT 1+ PDT 0 sulcus 1+

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