SHOULDER DYNAMIC STABILITY AND SHOULDER RANGE OF MOTION IN VOLLEYBALL ATHLETES

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SHOULDER DYNAMIC STABILITY AND SHOULDER RANGE OF MOTION
IN VOLLEYBALL ATHLETES

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OPERATIONAL DEFINITIONS

Abduction: Movement of a limb away from the midline of the body

Adduction: Movement of a limb part toward the midline of the body

Active Rang of Motion (AROM): Joint motion that occurs because of muscle contraction.

Acromioplasty: Arthroscopic procedure of the acromion; removal of a small piece of the acromion process surface of the scapular bone.

Afferent response: Carrying the nerve impulses towards the brain and central nervous system; the system of sensation, decision, or reaction.

Agonist: A muscle acting as a prime mover to produce a motion

Anterior: In front of the body part.

Anterior Drawer Test: Test for anterior laxity of the shoulder.

Apprehension: Test to evaluate possible shoulder subluxation.

Arthrometry: The measurement of the range of movement in a joint.

Bursa: Synovial-filled membrane that lies between adjacent structures to limit friction and ease movement.

Central Nervous System (CNS): The brain and spinal cord comprise the central nervous system.

Chronic Injury: Injury with long onset and long duration.

Closed-Kinetic-Chain (CKC) Exercise: Characterizing a motion in which the distal segment of an extremity is weight bearing and the body moves over the arm.

Concavity (Concave): Curving in.

Coracoacromial Arch: The arch is composed of the coracoids process and acromion process on the shoulder.

Distal: Further from the “central” trunk than a more proximal body part.

Dynamic Stabilization: Joint stabilization during movements.

Efferent motor response: Carrying the nerve impulses towards the muscles to move.

Extension: Straightening of a joint so that the two body segments move apart and increase the joint angle.

External Rotation: Rotation away from the center of the body.

Flexion: Bending of a joint so that the two body segments approach each other and decrease the joint angle.

Force Couple: Depressor action by the subscapularis, infraspinatus, and teres minor muscles to stabilize the head of the humerus and to counteract the upward force exerted by the deltoid muscle during abduction of the arm.

Glenohumeral Joint: A joint that is composed by the humeral bone and glenoid fossa at the scapula.

Goldi Tendon Organ (GTO): A stretch receptor found in a series within the musculotendinous structure. It responds to muscle contraction more than muscle stretch to signal force.

Horizontal Abduction: A motion of the upper extremity in a transverse plane away from the midline of the body.

Horizontal Adduction: A motion of the upper extremity in a transverse plane toward the midline of the body.

Humerus: A long bone in the arm.

Hyper-Range of Motion (Hyper-ROM): Extreme mobility beyond the adequate range of motion; in this study, greater than 90° of external rotation at 90° of shoulder abduction and 90° of elbow flexion.

Hypo-Range of Motion (Hypo-ROM): Lack of adequate range of motion; in this study, less than 90° of external rotation at 90° of shoulder abduction and 90° of elbow flexion.

Inferior: Below.

Instability: Giving way or subluxation of a joint during functional activity that causes pain and inability to complete the activity.

Internal Rotation: Rotation towards the center of the body.

Isokinetic Dynamometer: A device that quantitatively measures muscular function through a preset speed of movement.

Joint Capsule: Sac-like structure that encloses the ends of bones in a diarthrodial joint.

Joint Stability: The integrity of a joint when it is placed under a functional load.

Kinematic: The characteristics of movement related to time and space; the effects of joint action.

Kinesthesia: Sensation or feeling of movement; the awareness one has of the spatial relationship of one's body and its parts.

Labrum: A ring of fibrocartilage around the edge of the articular surface of a bone.

Laxity: Losing a natural ligamentous tight and leading to instability.

Ligament resection: Surgical removal of part of a ligament.

Mechanoreceptors: A sensory receptor that responds to mechanical pressure or distraction.

Muscle Spindles: A neuromuscular spindle composed of intrafusal muscle fibers that lie between regular muscle fibers. With its complex afferent and efferent supply, it provides the body with sensory stimulation and motor responses. The muscle spindle is sensitive to stretch, and signals muscle length and rate of change in the muscle's length.

Muscle Strain: Extent of deformation of tissue under loading.

Open-Kinetic-Chain (OKC) Exercise: Characterizing a motion in which the distal segment of an extremity moves freely in space.

Pacinian Corpuscles: Afferent nerve endings that lie throughout the joint capsule and periarticular structures. They are rapidly adapting receptors thought to be compression sensitive, especially during high-velocity changes when the joint accelerates or decelerates as it moves into its limits of motion.

Passive Range of Motion (PROM): Movement that is performed completely by the examiner.

Peak Torque: The maximum point of force to produce rotational movement.

Peel-back mechanism: Biceps tendon pulls the labrum apart due to excessively rotating the shoulder externally.

Posterior: Back of the body part.

Proprioception: The ability to determine the position of a joint in space.

Proximal: Toward the midline of the body; the opposite of distal.

Range of Motion (ROM): Amount of movement within a joint. Range of motion is affected by soft-tissue mobility and can be influenced by strength when performed actively.

Rotator Cuff Muscles: The four muscles groups around the shoulder responsible for to internal and external rotation of the upper arm; superior supinatus, inferior supinatus, teres minor, and subscapularis.

Ruffini Afferent Receptors: These afferent receptors are in the joint capsule on the flexion side of the joint. The Ruffini afferent receptors are slowly adapting and respond more to leads on the connective tissue in which they are contained than to displacement of that connective tissue. These receptors are stimulated by extreme joint motion when the capsule is stressed in extension with rotation.

Scapular Plane (Scapution): Elevation of the shoulder in the scapular plane 30° forward of the frontal plane. This alignment of the glenohumeral joint with the scapula on the rib cage places the rotator cuff in the least stressful position for exercise.

Sensorimotor System: Motor unit or neuron to convey sensory impulses.

Shoulder Impingement: Compression of the tendons of the rotator cuff between a part of the shoulder blade and the head of the humerus.

Shoulder Tendinitis: Inflammation of (a) tendon(s) around the shoulder joint.

Static Stabilization: Joint stabilization without movement.

Stiffness: The resistance of an elastic body to deform by an applied force.

Stress: Positive and negative forces that can disrupt the body's equilibrium.

Styloid Process: A projection of bone on the surface of the distal bone.

Subacromial: Below the acromion process.

Subluxation: Partial or incomplete dislocation of an articulation.

Superior: Above.

Synergistic Contraction: A muscle that assists an agonist muscle.

Torque (Q): The tendency of a force to rotate an object about an axis or pivot.

Translation: Gliding on the joint.

Abstract

Shoulder injuries are one of the most common injuries in athletics, especially the athletes who use overhead motions like volleyball hitters, quarterbacks in football, and baseball pitchers. Approximately 20% of all game and practice injuries were sustained in the shoulder; shoulder muscle strains (11%), shoulder tendinitis (7%), and shoulder subluxation (4%). Those shoulder muscle strain, tendinitis, and subluxation are caused by the glenohumeral joint multidirectional instability; the humeral head moves on the glenoid fossa excessively during the overhead motion due to the weakness of the shoulder and scapular muscles.

The purpose of the study was to determine the shoulder internal rotation peak torque (PT) difference between the normal shoulder range of motion (ROM) and hyper-ROM group with 90° of shoulder abduction and 90° of elbow flexion. Twenty-one highly trained women volleyball athletes who were around Edmond and Oklahoma City area voluntary participated in the study and measured their active shoulder external rotation using the goniometer, as well as their shoulder internal concentric rotation peak torque by using the Biodex isokinetic dynamometer.

There was no significant difference in shoulder internal rotation peak torque between the normal ROM and hyper-ROM with 90° of shoulder abduction and 90° of elbow flexion in this thesis study that indicated there was no shoulder dynamic stability difference in the both groups ($F = 2.763$, $t(15) = .741$, $p = .115$).

Keywords: shoulder, stability, peak torque, range of motion, volleyball

Shoulder Dynamic Stabilization and Shoulder Range of Motion in Volleyball Athletes

Shoulder injuries are one of the most common injuries in athletics, especially the athletes who use overhead motions like volleyball hitters, quarterbacks in football, baseball pitchers, and etc. In previous studies, the shoulder musculoskeletal anatomy, shoulder biomechanics, and shoulder neuromuscular physiology were well analyzed individually. According to the study conducted by Agel, J., Palmieri-Smith, R. M., Dick, R., Wojtys, E. M., & Marshall, S. W. (2007), there were 2,216 injuries from more than 50,000 games and 4,725 injuries from more than 90,000 practices from 1988-1989 through 2003-2004 in NCAA women's volleyball injuries surveillance. Approximately 20% of all game and practice injuries were sustained in the shoulder; shoulder muscle strains (11%), shoulder tendinitis (7%), and shoulder subluxation (4%). These shoulder injuries usually developed over a long time period, called a chronic musculoskeletal injury. Those shoulder muscle strain, tendinitis, and subluxation are caused by the glenohumeral joint multidirectional instability; the humeral head moves on the glenoid fossa excessively during the overhead motion due to the weakness of the shoulder and scapular muscles. These muscles stabilize the shoulder joint and are called dynamic stabilization. To prevent those shoulder injuries in athletics, improving all shoulder muscles stability is necessary. In addition, shoulder flexibility has been considered a key factor in athletic performance. A tight muscle can change the angle of axis of bones and limit the dynamic shoulder motion which leads to a narrow space between the tendon, ligament, and bones. This can increase the capsular friction of the shoulder joint which can put additional stress on the joint and eventually lead to chronic shoulder injuries.

Purpose of the study

The purpose of the study was to determine the difference in shoulder internal rotation peak torque (SPT) between the normal range of motion (ROM) and hyper-ROM groups with 90° of elbow flexion and 90° shoulder abduction. From the study, the investigator might find the baseline to prevent a shoulder injury is due to the chronic shoulder instability in volleyball athletes. If either group demonstrates greater torque through the range of motion, then that group may have better shoulder stability compared with another group, which leads to a better chance at preventing shoulder chronic injuries.

Significance of the study

Recently, increasing shoulder flexibility has been considered fundamental to improve athletic performance and a key factor preventing the chronic shoulder injuries, but not shoulder external range of motion in athletes. The major shoulder injuries such as biceps tendinitis (an inflammation of the long head of biceps brachii tendon), shoulder impingement, rotator cuff muscles pathology, bursitis (an inflammation of bursa), and glenohumeral labrum tear occur from the unstable and laxity of the humerus head on the glenoid fossa. If the glenohumeral joint is unstable and laxity, the humeral head puts extra stress and friction onto the glenohumeral labrum, biceps brachii tendon, rotator cuff muscles, and bursa which are located around the glenohumeral joint, leading to the shoulder injuries. To prevent those unwilling unstable joints, the ligaments, joint capsules, and muscles around the shoulder joint should be worked appropriately in a certain level of strength. In previous studies (Anderson, Deng, Jonson, & Altchek, 2005; Bosa, Sauers, & Herling, 2002; Bosa, Wilk, Jacobson, Scibek, Dover, Reinold, et al., 2005; Ellenbecker & Davies, 2000; Ellenbecker, Mattalino, Elam, & Caplinger, 2000; Flatow, Kelkar, & Rainmondo, 1996; Houglum, 2005; Itoi, Newman, Kuechle, Morrey, & An,1994; Jobe, Pink, Jobe, & Shaffer, 1996; Lephart, Warner, Borsa, & Fu, 1994; McCluskey, & Getz, 2000; Starkey, & Ryan, 2001; Voight & Thomson, 2000; Warner, Micheli, Arslanian, Kennedy, & Kennedy, 1990; Warner, Micheli, Arslanian, Kennedy & Kennedy, 1992), those muscle and ligament structures and mechanism of injuries were well analyzed individually. But a limited study was conducted on both the shoulder external range of motion and dynamic shoulder stability. Additionally, there is not much scientific support that good or poor shoulder external range of motions has a better or worse affect on athletic performances.

Research Question

Is there significant difference in SPT for shoulder (glenohumeral joint) internal rotation between the normal ROM and hyper-ROM groups with 90° of elbow flexion and 90° of shoulder abduction?

Null Hypothesis

There is no significant difference in SPT for active shoulder external rotation between the normal ROM and hyper-ROM groups on the shoulder joint with 90° of elbow flexion and 90° shoulder abduction.

Investigator Hypothesis

There is a significant difference between the groups. The hyper-ROM group will produce more shoulder internal peak torque than the normal ROM group.

Limitations

1. There would be small sample sizes ($N \leq 10$) per group, not representative of a larger athletic population.
2. The researcher could not control participants' shoulder injury history or occurrence.
3. The sitting volleyball group required closed kinetic chain movements which might develop the shoulder differently than those of the other group.
4. The fitness levels of the subjects might not be reflective of "in season".
5. There were no specific guidelines for internal and external rotation range of motion.
6. The athletes might not give a full exertion of shoulder power through their full range of motion during the Biodex testing.

Delimitations

1. The subjects were the same gender group (Female).
2. The subjects were in a similar age group (18- 23 year-old).
3. The subjects had no previous shoulder injuries in the last six months.
4. The researcher was eligible to access the equipment; goniometer and Biodex isokinetic dynamometer.
5. Normal ROM group was between 90°-95° shoulder external rotation and hyper ROM group greater than 100° of shoulder external rotation.
6. The subjects between 96°-99° ROM would not be excluded in the study.
7. The subjects' recruitment was determined by head coaches.

Assumptions

1. The Biodex Isokinetic Dynamometer was an accurate way to measure internal and external shoulder torque.
2. The goniometer was an accurate way to measure internal and external shoulder ROM.
3. The subjects were honest in their medical history of shoulder injuries.
4. The subjects were proficient ball strikers.
5. The subjects were highly skilled athletes with at least with college level experience.
6. The subjects could be accurately measured for proper group determination (normal ROM or hyper ROM groups).
7. The subjects' shoulders were not fatigued before the Biodex measurements.
8. The Biodex test was performed by a skilled technician.
9. The sitting volleyball and "standing" volleyball players were similar in shoulder dynamics.
10. The subjects gave full exertion of shoulder power through their full range of motion during the Biodex measurements.

Theoretical Foundation

As known in general, the glenohumeral (shoulder) joint has the greatest range of motion of any directions in the human body; 170° to 180° of flexion, 50° to 60° of extension, 170° to 180° of abduction, 90° to 100° of external rotation, and 80° to 90° of internal rotation (Starkey & Ryan, 2001). According to these glenohumeral joint functions, shoulder injuries occur in all athletes, especially the athletes performing overhead arm motions such as baseball, softball, volleyball, tennis, and football (Houglum, 2005). These shoulder injuries are common in these sports because overhead arm motions are high velocity, high force, and high skilled. To perform the activity, all shoulder muscles and ligaments are involved.

All joints in the body are controlled and stabilized in place by static stabilizers and dynamic stabilizers (McCluskey & Getz, 2000). Static stabilizers are recognized as the labrum/meniscus, joint capsule, capsular ligamentous, and intra-articular pressure to connect each bone (McCluskey & Getz, 2000). On the other hand, all muscle groups over the joints are recognized as dynamic stabilizers; deltoid, infraspinatus, supraspinatus, teres minor, biceps brachii, triceps brachii, and subscapularis. on the glenohumeral joint (McCluskey & Getz, 2000). Once these stabilizers lose their functions, the joints get lax and unstable, which causes extra pressure or stress on the other stabilizers on the joint. If this cycle is repeated, it causes injury (Houglum, 2005). The primary function of the rotator cuff is to guide and stabilize the humerus onto the glenoid fossa (Thompson, et al., 1996). Flatow et al. (1996) examined the role of the rotator cuff (RC), the long head of the biceps, and the coracoacromial (CA) arch on active glenohumeral joint (GHJ) kinematics. Six human cadaveric shoulders (average 50 years old) were abducted in the scapular plane using forces along the lines of action of the three heads of the deltoid and cables attached to the tendons of the RC and biceps (Flatow et al., 1996). A coordinate measuring machine tracked markers fixed to the scapular and humerus (Flatow et al., 1996). The intact shoulder was abducted in the scapular plane in 30° increments until maximum abduction was achieved (Flatow et al., 1996). During abduction with intact structures the humeral head remained centered on the glenoid and could be fully abducted in all specimens (Flatow et al., 1996). After complete retracted tears of the supraspinatus were created, the humerus subluxed superiorly, but full active abduction could still be accomplished (Flatow et at., 1996). If the biceps force was then deleted, however, superior subluxation increased to average 6.15 mm, and was limited by contact with the CA arch (Flatow et al., 1992). Furthermore, active abduction averaged only 43° (Flatow et al., 1996). With increased tear size, involving the infraspinatus and subscapularis tendons, abduction became increasingly difficult as the humeral head boutonniered through the massive cuff defect (Flatow et at., 1996). Although a biceps force improved stability, full active abduction was not restored (Flatow et al., 1996). The acromion and CA ligament were observed to provide the final restraint against superior humeral translation (Flatow et al., 1996). After acromioplasty and CA ligament resection, superior humeral head translation increased up to 15.1 mm, in one case with the head coming up antero-superiorly between the coracoids and the anterior edge of the acromion (Flatow et al., 1996). Thompson et al. (1996) also conducted the cadaveric study to define a biomechanical rotator cuff function. A dynamic shoulder testing was used to examine change in middle deltoid muscle force and humeral translation associated with simulated rotator cuff tendon paralyses and various sizes of rotator cuff tears (Thompson et al., 1996). Supraspinatus paralysis resulted in a significant increase (101%) in the middle deltoid force required to initiate abduction (Thompson et al., 1996). This increase diminished to only 12% for full glenohumeral abduction (Thompson et al., 1996). No significant alterations in humeral translation occurred with a simulated supraspinatus paralysis, nor with 1-, 3-, and 5-cm rotator cuff tears, provided the infraspinatus tendon was functional (Thompson et al., 1996). Global tears resulted in an inability to elevate beyond 25° of glenohumeral abduction despite a threefold increase in middle deltoid force (Thompson et al., 1996). These results validated the importance of the supraspinatus tendon during the initiation of abduction (Thompson et al., 1996). Glenohumeral joint motion was not affected when the "transverse force couple" (subscapularis, infraspinatus, and teres minor tendons) remained intact (Thompson et al., 1996). Significant changes in glenohumeral joint motion occurred only if paralysis or anatomic deficiency violated this force couple ($p < .001$) (Thompson et al., 1996). Finally, this model confirmed that rotator cuff disease treatment must address function in addition to anatomy (Thompson et al., 1996).

Additionally, McCluskey & Getz (2000) found that the coordination contraction of the rotator cuff and biceps engage and center the humeral head in the glenoid at a fixed point and compresses the articular surfaces together. This concavity compression mechanism enhances joint stability (McCluskey & Getz, 2000). An injury to the glenoid labrum that interrupts this mechanism adversely affects joint stability (McCluskey & Getz, 2000). The compression force generated by the rotator cuff and biceps muscles is sufficient to contain the humeral head in the glenoid, even when large portions of the joint capsule are sectioned (Thompson et al., 1996).

Teyhen, Miller, Middage, & Kane (2008) conducted the study to determine the relationship between the rotator cuff (RC) fatigue and glenohumeral kinematics in twenty men (27.7 ± 3.6 years) with no shoulder disorders. Fatigue RC strength was measured with a hand-held mechanical dynamometer that was placed proximal to the radial styloid process of the right arm in the exercise position (Teyhen et al., 2008). Rotator cuff fatigue initially was estimated as the inability of the participant to horizontally abduct 5% of the participant's body mass more than 45° from the ground on 3 consecutive attempts (Teyhen et al., 2008). Therefore, RC fatigue was confirmed, after the exercise regimen, and the participant's strength decreased by 40% from the prefatigue strength (Teyhen et al., 2008). To determine the migration of the glenohumeral joint and humeral angle, digital point placement techniques were used (Teyhen et al., 2008). Teyhen et al. (2008) defined migration was the distance between the perpendicular projection of the center of the humeral head to the glenoid line and the center of the glenoid line and the humeral angle was the angle between a line drawn on the medial border of the shaft of the humerus and a line drawn vertically (Teyhen et al., 2008). The results of this study (Teyhen et al., 2008) were that the superior humeral head migration increased by an average of 0.79 mm (range, 0.15-1.18 mm, $p < .001$) during arm elevation after fatigue of the supraspinatus, infraspinatus, and teres minor muscles (Teyhen et al., 2008). Although migration is a multidimensional phenomenon, this magnitude of superior migration may represent a 6% to 40% reduction in subacromial space, which is reported to be between 2 mm and 14 mm (Teyhen et al., 2008). Thus, the subacromial space appears to be compromised more after fatigue of the RTC (Teyhen et al., 2008).

Bosa et al. (2002) addressed that the glenohumeral stiffness response difference between men and women for anterior, posterior, and inferior translation. Borsa et al. (2002) conducted the study on 20 healthy college age subjects with no previous shoulder injury to measure the amount of the participants' glenohumeral joint displacement using an instrumented arthrometer. Force-displacement measures were taken in the anterior, posterior, and inferior directions and displacement forced were applied to the glenohumeral joint with a custom force applicator (Borsa et al., 2002). Translations were measure using an electromagnetic spatial-tracking device (Borsa et al., 2002). Borsa et al. (2002) found that there was a non-significant sex and direction interaction effect ($p > .05$). Also, McQuade, Shelley, & Cvitkovic (1999) conducted a similar study with Borsa et al. (2002). McQuade et al. (1999) applied manual forces and measured shoulder displacement and they were recorded using electromagnetic tracking sensors during clinical stability testing in 21 subjects with normal shoulders. End-range stiffness was calculated by anterior and posterior tests with the arm in neutral, external rotation, and internal rotation position (McQuade et al., 1999). The stiffest position for posterior drawer test was at 180° of abduction with the arm in internal rotation (McQuade et al., 1999). This position was the most compliant position for the anterior drawer test (McQuade et al., 1999). Only by internally rotating the arm did the force-displacement pattern change significantly ($p < .05$; McQuade et al., 1999). For anterior drawer tests, the patterns changed significantly ($p < .05$) only when the arm was in external rotaion (McQuade et al., 1999). Additionally, McQuade et al. (1999) could not find stiffness difference between men and women ($p < .05$; McQuade et al., 1999). McQuade et al. (1999) concluded that the intrinsic stiffness of the glenohumeral joint for clinical laxity tests as described in the study (McQuade et al., 1999) appear to be independent of an individual's body mass, strength, or clinically meaured range of motion, unless stiffness is tested with the arm in the full overhead position (McQuade et al., 1999). Furthermore, the studies (Borsa et al., 2002; McQuade et al., 1999) have demonstrated the protective mechanism of the rotator cuff and biceps on the anterior capsule by reducing strain when the arm is placed in an abducted and externally rotated position and stress is applied. Weak or fatigued rotator cuff muscles increase the risk for stretching injury to the anterior capsule during repetitive overhead activities such as pitching and serving (Borsa et al., 2002; McCluskey & Getz, 2000). Thus, rotator cuff strengthening must be foundation in the prevention and nonoperative treatment of instability in overhead atheltes (McCluskey & Getz, 2000).

Abnormal electromyographic rotator cuff activity and strength patterns have been documented in patients with anterior instability. McMahon, Jobe, Pink, Brault, & Perry (1996) examined the relationship of the electromyographic activity of rotator cuff and scapular muscles between subjects with poterior instability and subjects with normal shoulders. Thirty-eight patients were studied; 23 had anterior instability that was subsequently surgically confirmed, and 15 had normal shoulder (McHahon et at., 1996). Abduction, scapular plane abduction (scaption), and forward flexion were performed over the range of motion and later divided in to 30° intervals (McHahon et at., 1996). In both abduction and scaption, the supraspinatus demonstrated significantly less electromygoraphic activity from 30° to 60° in shoulders with anterior instability compared with normal shoulders ($p < .05$; McHahon et at., 1996). During all three motions, shoulders with anterior instability demonstrated significantly less electromyographic activity in the serratus anterior when compared with normal shoulders (p < .05; McHahon et at., 1996). This occurred at 30° to 120° of abduction and at 0° to 120° of scaption and forward flexion (McMahon et al. 1996).

Warner et al. (1990) also concluded that the imbalance of the internal and external rotator musculature of the shoulder, excess capsular laxity, and loss of capsular flexibility, have all been implicated as etiologic factors in glenohumeral instability and impingement syndrome based on clinical observation. In the study (Warner et al., 1990), there were 53 subjects; 15 asymptomatic volunteers, 28 patients with glenohumeral instability, and 10 patients with impingement syndrome. Range of motion was evaluated by a goniometer in all patients and laxity assessment was performed in anterior, posterior, and inferior humeral head translation grading on a scale of 0 to 3 (Warner et al., 1990). Additionally, isokinetic strength assessment was performed using the Biodex Clinical Data Station with test speeds of 90° and 180°/sec (Warner et al., 1990). Internal and external rotator ratios and strength deficits were calculated for both peak torque and total work (Warner et al., 1990). Patients with impingement demonstrated marked limitation of shoulder motion and minimal laxity on drawer testing (p < .05; Waterne et al., 1990). Both anterior and multidirectional instability patients had excessive external rotation as well as increased capsular laxity in all directions (p < .05; Warner et al., 1990). 68% of the patients with instability had significant impingement signs in addition to apprehension and capsular laxity (Warner et al., 1990). Isokinetic testing of asymptomatic subjects demonstrated 30% greater internl rotator strength in the dominant shoulder (Warner et al., 1990). Comparison of all three experimental groups demonstrated significant difference between internal and external rotator ratios for both peak torques and total work (*p* < .05; Warner et al., 1990). Warner et al. (1990) concluded that there appeared to be a dominant tendency with regard to internal rotator strength in asymptomatic individuals. Impingement syndrome and anterior instability have significant differences in both strength patterns of the rotator muscles and flexibility and laxity of the shoulder (Warner et al., 1990).

As mentioned previously, the shoulder joint injuries such as biceps tendinitis, labrum tear, and glenohumeral ligament dysfunction occurs by the repeated unwilling cycle which is the malfunction of the shoulder joint static and dynamic stabilizers (Starkey & Ryan, 2001). The interaction between the static and dynamic stabilizer is mediated by the sensorimotor system, which is proprioception (Riemann & Lephart, 2002). The sensorimotor system encompasses the sensory, motor, and central integration and processing components involved in maintainig functional joint stability (Lephart, Riemann, & Fu, 2000). Sensory information, proprioception, travels through afferent pathways to the central nervous system (CNS), where it is integrated with input from other levels of the nervous system, eliciting efferent motor responses (neuromuscular control) vital to coordinated movement patterns and functional stability, which is the balance between the static and dynamic stabilization through the functional activity (Myers & Lephart, 2000). Proprioception is defined as the afferent information concerning the three submodalities of joint position sense, kinesthesia, and sensation of resistance (Riemann & Lephart, 2002; Myers & Lephart, 2000). Myers & Lephart (2000) defined that joint position sense as the ability to consciously recognize where one's joint is oriented in space, while kinesthesia describes one's ability to consciously appreciate joint motion. Also, Myers & Lephart (2000) defined sensation of resistance as one's ability to appreciate force generated within a joint. The proprioceptive information provided by the mechanoreceptors present within the musculotendinous (Goldi tendon organs and muscle spindles), capsuloligamentous (Ruffini afferent and Pacinian Corpuscles), and cutaneous structures are appreciated at three distinct levels of motor control in the CNS; the brain stem, the cerebral cortex, and the cerebllum (Grigg, 1994; Myers & Lephart, 2000). The unconscious activation of dynamic restraints occurring in preparation and in response to joint motion and loading for the purpose of maintaining functional joint stability is termed neuromuscular control (Riemann & Lephart, 2002). Several neuromuscular control mechanisms contributing to functional joint stability will be including coactivation of glenohumearl and scapulothoracic muscular, reflex stabilization, preparatory activation, and muscle stiffness (Myers & Lephart, 2000). Inman, Saunders, & Abbot (1944) first described force couples resulting from coactivation of the dynamic stabilizers around the shoulder, providing joint stability. Contraction of the subscapularis muscle counteracts contraction of the infraspinatus and teres minor muscles in the frontal plane, while contraction of the deltoid muscle counteracts contraction of the lower rotator cuff muscles such as infraspinatus, teres minor, and subscapularis in the transverse plane (Inman et al., 1944). Force couples are believed to produce joint compression (Lephart et al., 1994). The rotator cuff musculature is essential for dynamic stability by centralizing the humeral head within the glenoid fossa, preventing excessive humeral translation (Rogol, Ernst, & Perrin, 1998; McMullen & Uhl, 2000). The force couple also exists at the scapulothoracic articulation (Myers & Lephart, 2000). The upward scapular rotation necessary for full glenohumeral abduction results from combined action by the trapezius and serratus anterior muscles

(Voight & Thomson, 2000). In addition to the trapezius-serratus anterior force couple, synergistic contraction of all scapular-stabilization musculature provides a firm base of support for movement of the humerus at the glenoid by drawing the scapula to the thorax (Voight & Thomson, 2000; Kibler, 1991). As the head of the humerus moves on the glenoid fossa, the scapula simultaneously rotates, keeping the glenoid fossa and humeral head in proper alignment (Voight & Thomson, 2000; Kibler, 1991). Proper alignment is believed to provide an optimal length-tension relationship for the rotator cuff, which is important for glenohumeral dynamic stability (Kibler, 1991).

To improve these proprioceptive reposition sense and static/dynamic stabilizer in the shoulder, recent studies have recommended performing both open kinetic chain (OKC) and closed kinetic chain (CKC) exercises (Ellenbecker & Davies, 2000; Kibler, 1991; Lephart, Riemann, & Fu, 2000; Lephart et al., 1994; McMullen & Uhl, 2000; Myers & Lephart, 2000; Riemann & Lephart, 2002; Rogol et al., 1998; Voight & Thomson, 2000). The study from Rogol et al. (1998) specifically described the effects of OKC versus CKC exercise on joint reposition sense of the shoulder in adolescent athletes. There were thirty nine subjects, with no previous shoulder injury, participated in this study (Rogol et al., 1998). The subjects were randomly assigned to the group; group one was performed an OKC exercise; group two was performed a CKC exercise; and group three did no upper extremity exercise, the control group (Rogol et al., 1998). To measure the shoulder joint stability, Rogol et al. (1998) used a Cybex II isokinetic dynamometer in passive and active shouluder internal and external rotation. Rogol et al., (1998) positioned the subjects supine on the Upper Body Exercise Table with the shoulder joint axis aligned with the axis of rotation of the Cybex. Each subject's arm was placed in 90° of elbow flexion, 90° of shoulder abduction, and neutral rotation (Rogol et al., 1998). For the passive joint reposition test, Rogol et al (1998) instructed subjects to relax while the shoulder was moved by the experimenter to one of the three predetermined angles and held for a total of ten seconds. Once the shoulder was returned to the neutral position, the subject's shoulder was passively repositioned to the test position (Rogol et al., 1998). The angle at which this occurred was recorded and subtracted from the initial, predetermined angle (Rogol et al., 1998). This difference was termed the error (Rogol et al., 1998). The procedure was repeated twice at the same angle, and an average of the absolute value of the tree errors was used for statistical analysis (Rogol et al., 1998). Active testing was conducted using the same methods, except each subject actively moved the shoulder to the predetermined test angle with the researchers' guideline, then returned to the neutral position before attempting to actively replicate the angle. After six weeks of training in each group, subjects performed the post-test in the same manner of the pre-test (Rogol et al., 1998). In the six week training session, the subjects in OKC performed three sets of 15 repetitions of the supine dumbell press three days a week and in CKC performed three sets of 15 repetitions of standard push-up three days a week (Rogol et al., 1998). The results of this study were both the OKC and CKC groups showed significant decreases in mean error score from pre-test to post-test in comparison with the control group, which mean significantly improved joint reposition sense from pre-test to post-test when compared with the control group ($F_{2,36} = 29.29$, $p < .01$; Rogol et al., 1998). There was no significant difference between the two exercise groups (Rogol et al., 1998).

Synergistic scapular muscle actions allow proper positioning and stability of the scapula while maintaining the glenohumeral center of rotation throughout arm motion (McMullen & Uhl, 2000). Scapular dyskinesis is often present with glenohumeral pathology, such as instability, muscular weakness, inflexibility, and loss of scapular control (Warner et al., 1992). In shoulder kinetic chain exercise, intervention to normalize scapular movement and stabilization leads attempting to load the rotator cuff (McMullen & Uhl, 2000). A primary role of the rotator cuff is to compress the humeral head in the glenoid and provide dynamic glenohumeral stability (Itoi et al., 1994). To do this effectively, the rotator cuff must operate from a stable scapular base and meet minimum strength requirements (Voight & Thomson, 2000). Exercising the rotator cuff without scapular stability could increase the risk of glenohumeral translation, create pain in rehabilitation, and increase the risk of further injury (McMullen & Uhl, 2000). Dillman, Murray, Hintermeister (1994) and Kibler et al (1995) found that CKC exercises promote co-contraction of rotator cuff musculature at submaximal levels. Applying axial compression through the glenohumeral joint, as in CKC exercises, decreases glenohumeral translation at various levels of elevation (Dillman et al., 1994 & Kibler et al., 1995). Therefore, CKC exercises have an important role in shoulder rehabilitation program (McMullen & Uhl, 2000).

Some studies have been conducted in specific athletics. Crawford & Sauers (2006) conducted a study to compare glenohumeral joint laxity and stiffness between the throwing and non-throwing shoulders of high school baseball pitchers. In the study (Crawford & Sauers, 2006), 22 high school baseball pitchers (age 16 ± 1, height = 178.51 ± 7.66 cm, mass = 75.43 ± 13.24 kg) with no shoulder injury history participated.

Crawford & Sauers (2006) used computerized stress arthrometry to measure glenohumeral joint laxity and stiffness. Anterior glenohumeral joint laxity and stiffness measures were obtained with the shoulder in 90° of abduction and both neutral rotation and 90° of external rotation (Crawford & Sauers, 2006). Posterior laxity and stiffness measures were obtained with the shoulder in 90° of abduction and neutral rotation (Crawford & Sauers, 2006). In glenohumeral joint laxity, the interaction of side (throwing and non-throwing) and shoulder test position (anterior in neutral rotation, anterior at 90° of external rotation, posterior in neutral rotation) was not statistically significant ($F_{2,42} = 1.16$, $p = .33$; Crawford & Sauers, 2006). No statistically significant difference was seen between the throwing and non-throwing shoulders for total anterior-posterior laxity ($F_{1,21} = .25$, $p = .63$; Crawford & Sauers, 2006). In glenohumeral joint stiffness, the interaction of side and position was not statistically significant ($F_{2,42} = 1.90$, $p = .16$; Crawford & Sauers, 2006). A statistically significant difference was noted for the main effects of side ($F_{1,21} = 4.37$, $p = .049$) and position ($F_{2,42} = 81.85$, $p < .0001$; Crawford & Sauers, 2006). As a result in both shoulders, glenohumeral joint laxity was less and glenohumeral joint stiffness was greater when the shoulder was tested in the functional throwing position (anterior 90° of external rotation) than in the anterior at neutral and posterior at neutral positions (Crawford & Sauers, 2006). In the functional throwing position, anterior laxity was approximately 3 mm less and stiffness was approximately 2.5 N/mm more than in the anterior-neutral and posterior-neutral test positions (Crawford & Sauers, 2006). Crawford & Sauers (2006) considered a reduction in laxity of approximately 3 mm (24%) to be clinically significant, and it is comparable with the difference in anterior glenohumeral joint laxity reported between men and women (approximately 3.1 mm, 27%). Also, as the results were shown, no clinically significant differences in anterior glenohumeral laxity and stiffness between the throwing and non-throwing shoulders (Crawford & Sauers, 2006). These findings fail to support the theory of microinstability, which suggests that attenuation of the anterior stabilizing structures may lead to increased anterior glenohumeral joint laxity, with a concomitant decrease in anterior joint stiffness (Jobe et al., 1996). Side-to-side symmetry in anterior laxity between the throwing and non-throwing shoulders of healthy baseball players is consistent with other studies (Crawford & Sauers, 2006). In addition, Ellenbecker et al. (2000) found no significant difference in anterior glenohumeral joint laxity between the dominant and non-dominant throwing arms of 20 professional baseball playerss using a manual force of 15 daN during stress radiography measurements. Bosa et al. (2005) also found no significant difference in side-to-side comparisons of glenohumearl joint laxity in the throwing and non-throwing arms in 33 professional baseball players using an ultrasoud scanner with a transducer prociding 10 daN of force. Sethi, Tibone, & Lee (2004) reported an increase in total anterior-posterior laxity of the throwing shoulders of asymptomatic collegiate and professional baseball players using an instrumented manual examination, but this difference was small for global laxity (approximately 4 mm), and they failed to report anterior and posterior laxity individually.

Additionally, Crawford & Sauers (2006) found no significant differences in posterior glenohumeral laxity and stiffness between the throwing and non-throwing shoulders as provided in the previous data. These findings fail to support the “peel-back” theory, in which athletes who throw overhead develop a thickened and fibrotic posterior capsule, leading to altered translational kinematics (Anderson et al., 2005; Ellenbecker &

Davies, 2000; Ellenbecker et al., 2000; Flatow et al., 1996; McCluskey & Getz, 2000). If the posterior capsule was contracted as the result of chronic overhead throwing, Crawford & Sauers (2006) would expect to have observed a significant decrease in posterior glenohumeral joint laxity, with a concomitant increase in posterior glenohumeral joint stiffness in the shoulder abducted to 90°.

Grossman et al. (2005) evaluated 10 cadaver shoulders before and after surgically tightening the posterior capsule and reported a significant reduction in internal rotation range of motion (average decrease, 8.8 ± 2.3°; $p = 0.02$) but no significant difference in posterior translation. Anderson et al. (2005) examined the effects of surgically tightening the posterior capsule in 8 cadaver shoulders. Contracture of the posterior capsule led to a significant decrease in internal rotation at 0° and 90° of abduction and an anterior displacement of coupled anterior-posterior translation (Anderson et al., 2005). Theoretically, a tight posterior capsule that limits internal rotation would be expected to decrease posterior joint laxity and increase stiffness in the 90° of abduction and neutral-rotation position (Anderson, et al., 2005). These findings are supported by Downar & Sauers (2005). Downar & Sauers (2005) conducted a study to evaluate clinical measures of shoulder mobility in 27 professional baseball players in order to examine differences between the throwing and the non-throwing shoulders and to describe chronic adaptations to throwing. Downar & Sauers (2005) recorded scapular upward rotation at 4 levels of humeral elevation in the scapular plane (rest, 60°, 90°, and 120°); posterior shoulder tightness; and passive isolated glenohumeral joint internal and external range of motion. The results were that scapular upward rotation was significantly greater in the throwing shoulder (14.3 ± 6.5°) than in the non-throwing shoulder (10.6 ± 6.1°) at 90° of humeral elevation (*p* = .04) (Downar & Sauers, 2005). No statistical difference was shown in posterior shoulder tightness between the throwing (30.2 ± 4.6 cm) and the non-throwing (28.0 ± 4.8 cm) shoulder (*p* = .09) (Downar & Sauers, 2005). In addition, the throwing shoulder exhibited a statistically significant decrease in isolated glenohumeral internal rotation (56.6 ± 12.5°) compared with the non-throwing shoulder (68.6 ± 12.6°, *p* = .001), with a concomitant increase in isolated glenohumeral external rotation (throwing = 108.9 ± 9.0°, non-throwing = 101.9 ± 5.9°, *p* = .0014) (Downar & Sauers, 2005). The throwing shoulder exhibited significant differences in scapular and glenohumeral mobility compared with the non-throwing shoulder (Downar & Sauers, 2005).

According to the previous studies (Verna, 1991; Burkhart, Morgan, & Kibler, 2003), we could see the athletes who perform repetitive overhead throwing have hyperexternal rotation and hypointernal rotation on the shoulder, which leads to the various injuries. Verna (1991) was addressed the relationship of glenohumeral internal rotation deficit (GIRD) with shoulder dysfunction in throwing athletes. Verna studied 39 professional baseball pitchers during spring training. The pitchers had 25° or less of total internal rotation and found that 60% of them developed shoulder injuries which the pitchers needed to stop throwing during the study period. Burkhart (2003) performed the manual shoulder stretching for 22 major league pitchers in daily treatment to minimize GIRD during the 1997, 1998, and 1999 professional baseball season. During those seasons, Burkhart (2003) reported no innings lost, no intra-articular problems, and no surgical procedures in these 22 pitchers. These reports establish that a prophylactic focused posteroinferior capsular stretching is successfully minimize GIRD and is effective in preventing secondary intra-articular problems.

The study, conducted by Stickley, Hetzler, Freemyer, & Kimura (2008), identified the difference in internal and external shoulder rotation strength ratios based on the peak torque of thirty-eight female adolescent club volleyball athletes. The result of the study was that there was no difference in internal and external shoulder rotator peak torque between subjects with or without a shoulder injury history 6 months before the study, but there was difference in shoulder peak torque ratio of internal to external rotation between the two groups, no-injury and previous injured group (*p* = .02) (Stickley et al., 2008). Those results indicated if an athlete has less than 1.0 volleyball spiking ratio in concentric internal shoulder rotation and eccentric external shoulder external rotation, the athletes have higher risk for shoulder injury because of the shoulder dynamic stability deficiency. On the other word, if the athlete has equal or more than 1.0 spiking ratio, the athlete have a high chance to prevent further shoulder injury or back to the normal or better athletic performance from a shoulder injury.

As shown in the studies, the shoulder joint consists of complicated structures and unstable joint without good dynamic stability, which leads to sustain chronic shoulder injuries easier than the other body structures. To prevent these chronic shoulder injuries such as subluxation, tendinitis, and labrum tearing, it is necessary to prevent the shoulder anterior and/or multidirectional translation by improving the shoulder muscles and its flexibility during the shoulder movements, especially the over-head motion. The researcher would like to determine the difference between the normal range of motion (ROM) and hyper-ROM groups on peak torque on the dominant shoulder joint. If one of the groups performs better peak torque, the group will have a better shoulder stability and they may have a better chance to prevent these chronic shoulder injuries compared with the other group.

Methodology

Participants

The Institutional Review Boards (IRB) of the University of Central Oklahoma (UCO) fully reviewed and approved this study (Appendix A; informed consent form). A total of 20 subjects who were highly-trained and competitive female athletes around Edmond and Oklahoma City area voluntarily participated (21 ± 3 years of age, respectively). The head coaches of the teams gave written permission to recruit participants through the teams (Appendix B; coach consent form). Recruitment of subjects was conducted through a sample of convenience and through investigator solicitation. The subjects appeared to be healthy and active individuals as indicated by the subjects' honesty. If a subject reported an upper extremity injury or pain at the time of testing, the subject was excluded from the testing. Also, if a subject complained of any shoulder injuries, shoulder pain, discomfort, or any issues at the time of testing or during the testing, they were asked not to participate and stop testing.

Procedures of Testing

Preliminary Data Collection Procedure. After the solicitation of the subjects, the testing participants were asked to report to Hamilton Field House or the Wellness Center located on campus of the UCO or McBride Clinic in Edmond, OK. All subjects read and signed the IRB approved informed consent, and then each subject received a 4 digit-code number to blind their name. The subjects used the same code number in both ROM and Biodex data collection. The code sheet was stored in the locked desk and office in the Wantland Hall #015 on campus of the UCO. The data entry sheet and the code sheet were stored separately.

All preliminary, range-of-motion (ROM), and shoulder internal rotation peak torque (SPT) were collected during each testing session (Table 1). Preliminary measures including the subjects' age, height (cm), mass (kg), and shoulder ROM (Table 2) were measured at Hamilton Field House, the Wellness Center at UCO, and McBride Physical Therapy Clinic in Edmond, OK by the investigator. Subjects were excluded based on the following criteria at the testing site: under 18 years of age and history of shoulder injury in the last 6 months.

Range-of-Motion (ROM) Data Collecting Procedure. ROM data was collected and recorded by the investigator. Each subject's ROM in external rotation on the shoulder (glenohumeral (GH)) joint was measured using a goniometer at Hamilton Field House, the Wellness Center at UCO, or McBride Physical Therapy Clinic in Edmond, OK. Before measuring the ROM, all subjects have 5 minutes to warm-up their upper extremities. Measuring the ROM of external rotation on GH will be conducted against gravity; lying on their stomach and with 90° of shoulder abduction and 90° of elbow flexion, actively (AROM); the subject voluntary moved her arm. The investigator is seated next to the lying subject on the dominant side of the subject's shoulder and facing the subject's body. The plate of the goniometer was placed on the sagittal plane of the body and the axis was placed on the horizontal axis of the humerus bone, the olecranon process of the ulna. The fixed arm was pointed to the ground and vertical to the table that the subject was lying on and the measured arm was pointed to the ulnar styloid process.

Biodex Data Collection. To collect each subject's SPT, the investigator used the Biodex isokinetic dynamometer at McBride Physical Therapy Clinic in Edmond, OK. Before the Biodex measurement, all subjects understood and signed the McBride Liability Waiver form (Appendix C; McBride Physical Therapy Clinic Liability Waiver Form). After the subjects signed the Liability Waiver form, each subject performed at least 5 minutes but no more than 15 minutes of warm-up on the upper body ergometer (UBE) to minimize an injury prior to conducting the Biodex measurement. The investigator collected the isokinetic concentric contraction data in shoulder internal rotation with 90° of elbow flexion and 90° of shoulder abduction on the dominant side of the shoulder. The subjects were tested in a seated modified neutral position on the Biodex isokinetic dynamometer chair with 90° of hip flexion and 90° of knee flexion with their back straight. The forearm, elbow, and trunk were fixed by the belts on the Biodex unit. During Biodex testing, the subject's shoulder motion was isolated to the overhead motion occurring during their particular sport, volleyball hitting motion. The subjects performed five repetitions of maximal shoulder internal rotation motion on the Biodex isokinetic dynamometer in 270°/second. It took approximately 15 minutes to collect the SPT data in this testing session including warm-up and cool-down.

Procedures of Grouping

For data analysis, the subjects were classified into two groups, the normal ROM and hyper- ROM groups, by using the data from the ROM data collection (Table 3). The normal ROM group defined the subjects having more than 90° of active shoulder external rotation with 90° of elbow flexion and 90° of shoulder abduction but no more than 95°. The hyper-ROM group defined the subjects having more than 100° of active shoulder external rotation with 90° of elbow flexion and 90° of shoulder abduction. If a subject had less than 90° of active shoulder external rotation, it was recognized as the adhesive shoulder capsule or other shoulder related dysfunctions, and the subject was excluded from data analysis. To further increase the differences between the groups, subjects with 96° - 100° AROM were excluded.

Instrumentation

1. Coach Consent Form – is a document that educates them about the study and given permission to recruit their athletes.
2. Informed Consent Form – is a document that educates the participants about the purpose, procedures, risks, and benefits of the study and obtains their consent before involving them in research, while keeping them informed. The University of Central Oklahoma approved the informed consent.
3. Liability Waiver Form – is a document that acknowledges subjects release of a responsibility of the investigator and McBride Clinic, in the case a subject sustains an injury during the testing.
4. Sliding Weight Scale – is a scale to measure the subject's height and weight.
5. Goniometer – is a piece of plastic plates to measure the range of motion on a joint. The goniometer is known as a reliable tool to measure the range of motion nationwide.
6. Biodex Isokinetic Dynamometer – is the most reliable equipment to measure subjects' strength, peak torque and total work through his/her full range of motion.

Data Analysis

An independent t-test was used to identify a significant difference for the dependent variable (shoulder peak torque (SPT)). Statistical significance was set at an alpha level of .05. Data was analyzed with SPSS 17, between both groups (the normal ROM group and the hyper-ROM group) on both dependant variables (SPT).

Results

The dependent variable in highly-trained volleyball athletes with subsequent discussions of the result that was significant to the stated hypothesis. The purpose of this study was to determine the difference in shoulder peak torque (SPT) between the normal range of motion (ROM) and hyper-ROM groups with 90° of elbow flexion and 90° shoulder abduction. The two groups were categorized by the data based on the active shoulder external range of motion with 90° of elbow flexion and 90° shoulder abduction against the gravity.

Descriptive Data

Data were collected from the University of Central Oklahoma (UCO) Women's Volleyball team, U.S. Paralympic Women's Sitting Volleyball and other volleyball teams around the Oklahoma City area, during a period of approximately two days in the month of April, 2010. A total of 20 subjects completed the study and 1 subject was excluded due to shoulder injury. The combined mean values for subjects for age, height (cm), and weight (kg) were 20.44 ± 1.0 years, 173.99 ± 8.98 cm, and 68.64 ± 11.51 kg (Table 4, Figure 1,2, & 3). The average of the normal ROM group and hyper-ROM group were 93° and 107° from the ROM data collection (Figure 4).

Hypothesis Testing

An independent *t*-test was used to analyze the effects of shoulder peak torque (SPT) and active shoulder external range of motion (ROM) with the null hypothesis being accepted. There was no significant difference between the normal ROM group and hyper-ROM group with 90° of elbow flexion and 90° of shoulder abduction ($F = 2.763$, $t(17) = .741$, $p = .115$). The average shoulder internal peak torque score of the normal ROM group ($M = 21.92$, $SD = 5.21$) was not significantly different from that of hyper-ROM group ($M = 23.52$, $SD = 3.28$) (Table 5).

Discussions

The purpose of the study was to determine the difference between the normal range of motion (ROM) and hyper-ROM groups with 90° of elbow flexion and 90° of shoulder abduction in shoulder peak torque. This chapter expands on the findings and compares them to prior studies conducted on shoulder stability and flexibility.

The result of the study was that there was no significant difference in shoulder internal peak torque between the normal ROM and hyper-ROM with 90° of elbow flexion and 90° shoulder abduction. The results indicated there was no shoulder dynamic stability difference between the groups, which also indicated that the hyper-ROM would not affect the force production during shoulder internal rotation motion through the "full" shoulder range of motion.

Mechanism of Shoulder Injury

In previous studies (Verna, 1991; Crawford & Sauers, 2006; Anderson et al., 2005; Ellenbecker & Davis, 2000; Ellenbecker et al., 2000; Flatow et al., 1996; McCluskey & Getz, 2000), there were two main mechanisms to sustain shoulder swing/spiking injuries; glenohumeral internal rotation deficit (GIRD) and peel-back mechanism (also see Chapter II). GIRD is defined as the loss of the shoulder (glenohumeral) internal rotation degrees of angles of the throwing shoulder compared with the other shoulder. The most effective way to maximize shoulder internal rotation velocity and force is to maximize the arc of rotation, so that hyperexternal rotation in late cocking of the baseball throwing phase (Burkhart et al., 2003). Similar to baseball pitching in order to maximize the impact of the energy to spike the volleyball, the athletes need to have greater velocity of the shoulder swing. This produces greater velocity of the volleyball at the ball hitting point, which is at the end of the acceleration phase of volleyball hitting/spiking. Subjects having hyper-ROM in shoulder external rotation will lead to hypo-ROM in shoulder internal rotation (25° or less of total internal rotation), which causes shoulder dysfunctions such as biceps tendinitis and SLAP (superior labrum anterior to posterior) lesion due to the inferior glenohumeral ligament (IGHL) contracture (also see Chapter II). A peel-back occurs with the arm in the late cocking phase in overhead throwing motion, glenohumeral horizontal abduction and external rotation. The biceps tendon vector sifts to a more posterior position and pulls it out from the labrum, biceps tendinitis and/or SLAP lesion. Since athletes perform the overhead arm swing motion, antero-/postero-inferior glenohumeral joint contracture occurs and the athletes try to find the set point. This is the point to maximize the arc of shoulder rotation which can lead to increase in more external shoulder rotation.

Overall, combining with the result that there was no significant difference between the two shoulder ROM groups, the mechanism of shoulder injury of the overhead arm motion, athletes tend to maximize the arc of shoulder rotation, which increase the shoulder external rotation, that leads to reduced shoulder internal range of motion due to the antero-/postero-inferior glenohumeral ligament/capsule and increase more shoulder external rotation, and then GIRD and/or peel-back mechanisms occur to gain risks of shoulder overhead injuries (Figure 8).

Angle of Shoulder Internal Rotation Peak Torque

According to the results of this study, there was no shoulder force production difference between the two groups. However, the investigator recorded varieties of the angle of peak torque (Figure 8); nine out of 21 subjects measured the shoulder internal rotation peak torque under the neutral (0°) , the others measured the shoulder internal rotation peak torque above the neutral (0°) . The volleyball swing phases are composed of five phases; wind-up, cocking, acceleration, deceleration and follow-up (Plawinski, 2008) (Figure 9). To generate arm swing energy to the volleyball, an athlete needs to produce the peak torque or force at the volleyball hitting point, which is at the end of the acceleration phase; the point maximally activate the shoulder rotator cuff muscles to stabilize the humeral head on the glenoid fossa (Figure 10). If one of the those muscles is weakened or strengthened, the balance holding the humeral head on the glenoid fossa will be changed and will put extra stress onto the other shoulder static and/or dynamic stabilizer.

In this thesis study, the investigator did not set a specific point to measure the peak torque. The investigator measured the point where the peak torque occurred. If the investigator sets the specific arc of shoulder range of motion to measure the peak torque and determines the difference between the same two groups, it may be had a high chance to see a different result.

Shoulder ROM Difference

The study conducted by Dwelly, Tripp, Tripp, Ebeman, & Gorin (2009) showed that the shoulder range of motion changed during an athletic season. Dwelly et al. (2009) determined dominant shoulder external rotation increased during the season (9.69°, $F_{2,96} = 17.43$, $p < .001$). The total arc in the dominant shoulder increased between pre-fall and post-spring measurements (10.99°, $p < .001$). Dwelly’s study (2009) focused on NCAA baseball athletes, but it is still possible to identify the shoulder ROM differences, depending on the season. Additionally, it may affect the grouping of the normal ROM and hyper-ROM groups, since the investigator collected the data during the off-season.

The investigator also recognized 80% of the subjects in the normal ROM group were from the sitting volleyball athletes and 80% of the subjects in the hyper-ROM group were from the regular standing volleyball athletes (Figure 8). There is no research about the shoulder ROM difference between closed kinetic chain (CKC) exercises and open kinetic chain (OKC) exercises, so the investigator could not identify the cause of these results, but it will be a future area of study. However, as mentioned in Chapter II, shoulder dynamic stability is related with the proprioception, joint sensory system (Lephart et al., 2000). Rogol et al. (1998) addressed the effects of CKC and OKC exercises on joint reposition sense, in which both the exercises significantly improved joint reposition sense from pre-test to post-test when compared to the control group ($F_{2,36} = 29.29$, $p < .01$). To maintain and improve shoulder static and dynamic stability, an appropriate shoulder strength training regimen is necessary throughout the full shoulder internal and external range of motion.

Conclusions

Summary and Conclusions

The purpose of the study was to determine the shoulder internal rotation n peak torque (PT) difference between the normal shoulder range of motion (ROM) and hyper-ROM group with 90° of shoulder abduction and 90° of elbow flexion. Twenty-one highly trained women volleyball athletes voluntary participated in the study and to measure their active shoulder external rotation using the goniometer, as well as their shoulder internal concentric rotation peak torque by using the Biodex isokinetic dynamometer. There was no significant difference in shoulder internal rotation peak torque between the normal ROM and hyper-ROM with 90° of shoulder abduction and 90° of elbow flexion in this thesis study that indicated there was no shoulder dynamic stability difference in the both groups (F = 2.763, t (15) = .741, p = .115).

From these findings and literature reviews on Chapter II, the mechanism of shoulder injury was more cleared; repetitive volleyball spike/hitting motion will decrease shoulder internal rotation (GIRD) and excessively increase shoulder external rotation (peel-back mechanism), which leads to lack of flexibility and limited shoulder range of motion. Since there is no shoulder torque difference between the shoulder normal ROM group and hyper-ROM group, athletes need to maintain or improve the total shoulder arc of rotation.

Additionally, there were varieties in the angle of peak torque. To maximize the efficiency of volleyball hitting, the athletes should have shoulder internal rotation peak torque at the hitting point, which is the end of the acceleration phase. This proper shoulder strength and flexibility can increase the potential to prevent overhead arm-swing-related shoulder injuries.

Recommendations

1. The investigator should increase the sample sizes to represent a larger population.
2. The investigator should set the point to measure the shoulder internal rotation peak torque to determine the force in the volleyball hitting point.
3. The investigator should use the electricalmyography (EMG) to detect the muscle activity through their shoulder range of motion; the investigator can see the muscle contraction imbalance.
4. The investigator should analyze the hitting motion of each volleyball athlete or sitting/regular volleyball to address the hitting motion difference.
5. The investigator should correct the data during the hitting motion by using different tools such as the motion analyzer to see the difference in the different anatomical plane.
6. The investigator should conduct the test multiple times during the year to see the difference in the seasons; pre-season, in-season, post-season, and off-season.
7. The investigator should conduct the test in the different speeds of Biodex isokinetic dynamometer.

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Tables and Figures

Table 1

Summary of Data Collections and Testing Sessions.

Action	Testing 1	Testing 2
Preliminary Data Collection	x	
ROM Data Collection	x	
Biodex Data Collection		x

Note. ROM = Range of Motion.

Table 2

Descriptions of each Data Collection.

Preliminary Data Collection	Collecting Age, Ht, and Wt
ROM Data Collection	Measuring the shoulder external rotation ROM with 90° of elbow flexion and 90°of shoulder abduction on the dominant side, lying on the stomach and measuring against gravity.
Biodex Data Collection	Collecting the SPT during shoulder internal rotation motion with 90° of elbow flexion and 90° of shoulder abduction at the seated position.

Note. Ht = Height, Wt = Weight, AL = Arm Length, ROM = Range of Motion, SPT = Shoulder Peak Torque, and ST = Shoulder Torque

Table 3

Descriptions of Grouping.

Normal ROM	90° - 95° of active shoulder external rotation with 90° of elbow flexion and 90° of shoulder abduction.
Hyper-ROM	More than 100° of active shoulder external rotation with 90° of elbow flexion and 90̊ of shoulder abduction.
Exclusion ROM 1	Less than 90° of active shoulder external rotation with 90° of elbow flexion and 90° of shoulder abduction.
Exclusion ROM 2	96° - 99° of active shoulder external ration with 90° of elbow flexion and 90° of shoulder abduction.

Note. ROM = Range of Motion.

Table 4

Summary of the descriptive data.

N	**Age (yrs)**	**Height (cm)**	**Weight (kg)**
19	20.44 ± 1.0	173.99 ± 8.98	68.64 ± 11.51

Note. N = Total number of participants

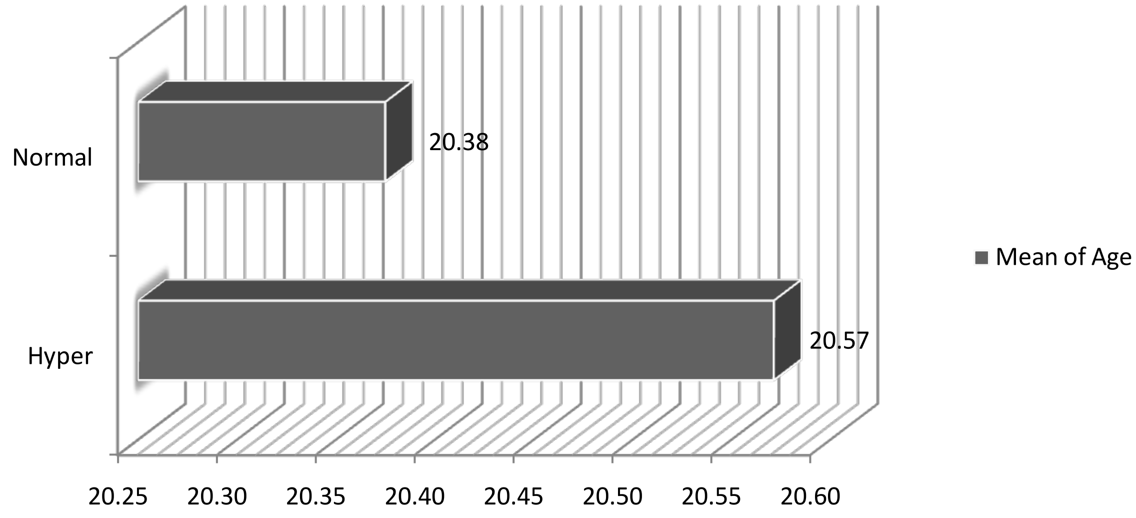


Figure 1 – The bar graph shows the mean age in each group. The mean age in the normal ROM group was 20.38 and in the hyper-ROM group was 20.57.

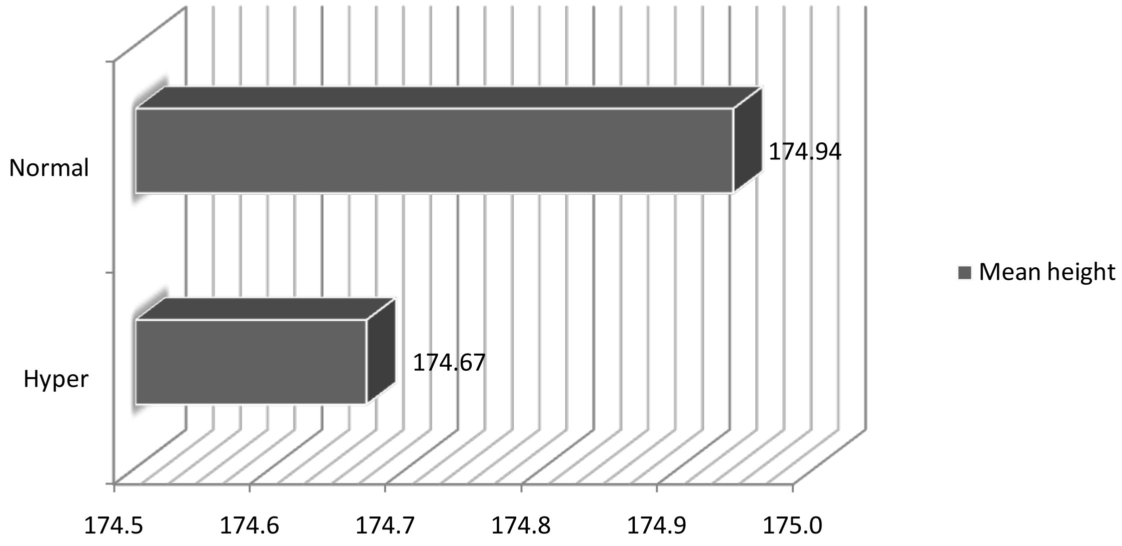


Figure 2 – The bar graph shows the mean height in each group. The mean height in the normal ROM group was 174.94 cm and in the hyper-ROM group was 174.67 cm.

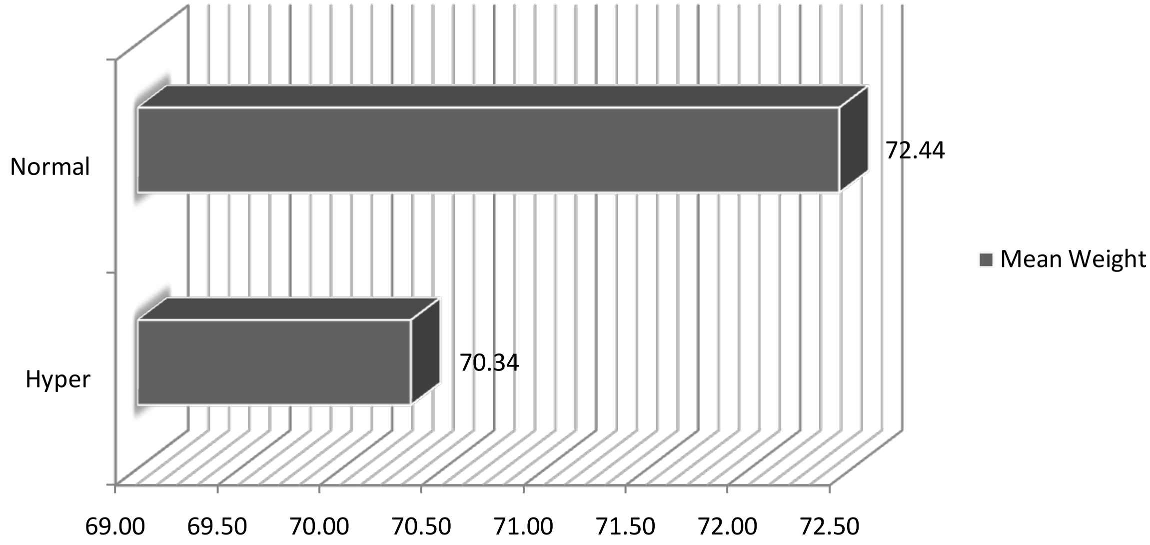


Figure 3 – The bar graph shows the mean weight in each group. The mean weight in the normal ROM group was 72.44 kg and in the hyper-ROM group was 70.34 kg.

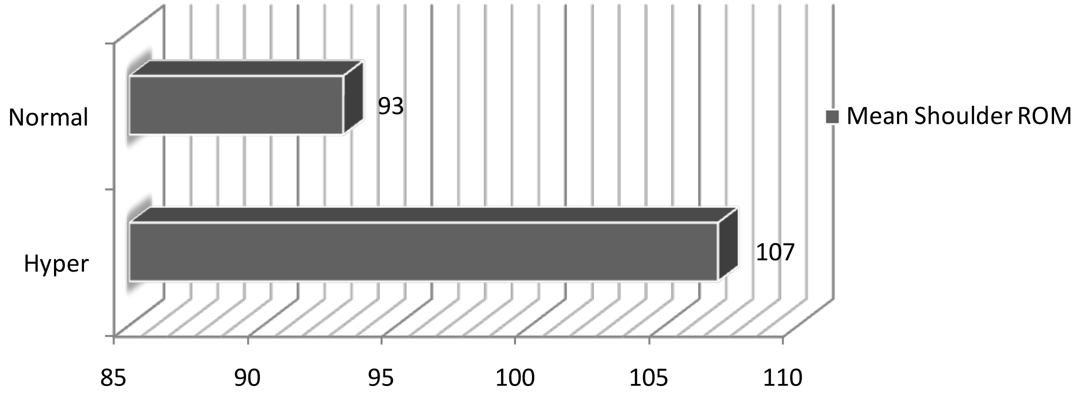


Figure 4 – The bar graph shows the mean shoulder ROM in each group. The mean shoulder ROM in the normal ROM group was 93° and in the hyper-ROM group was 107°. The normal ROM group should be between 90° and 95° and the hyper-ROM group should be more than 100°.

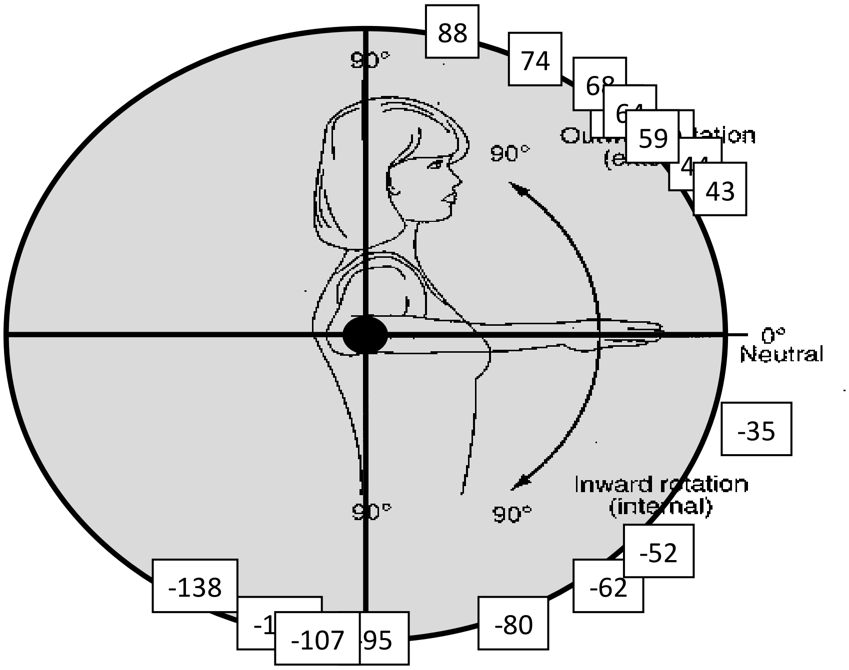


Figure 5 – An image of the shoulder range of motion and point that the investigator recorded the shoulder internal rotation peak torque for in each subject. The number in the box is the angle of shoulder internal rotation peak torque. In this figure, the subject right arm is shown and the dot of the center represents the axis of shoulder rotation, the olacrenon process with 90° of shoulder abduction and 90° of elbow flexion. Nine out of 19 subjects recorded shoulder internal rotation peak torque under the neutral (0°) and the others recorded above neutral (0°).

Table 5

Group	N	Mean of Peak Torque (ft-lbs)	SD
NROM (ave. = 93°)	10	21.92	5.21
HROM (ave. = 107°)	9	23.52	3.27

Note. NROM = Normal Range of Motion, HROM = Hyper Range of Motion, ave. = Average, N = Number of participants, SD = Standard Deviation, ft-lbs = foot-pounds of torque

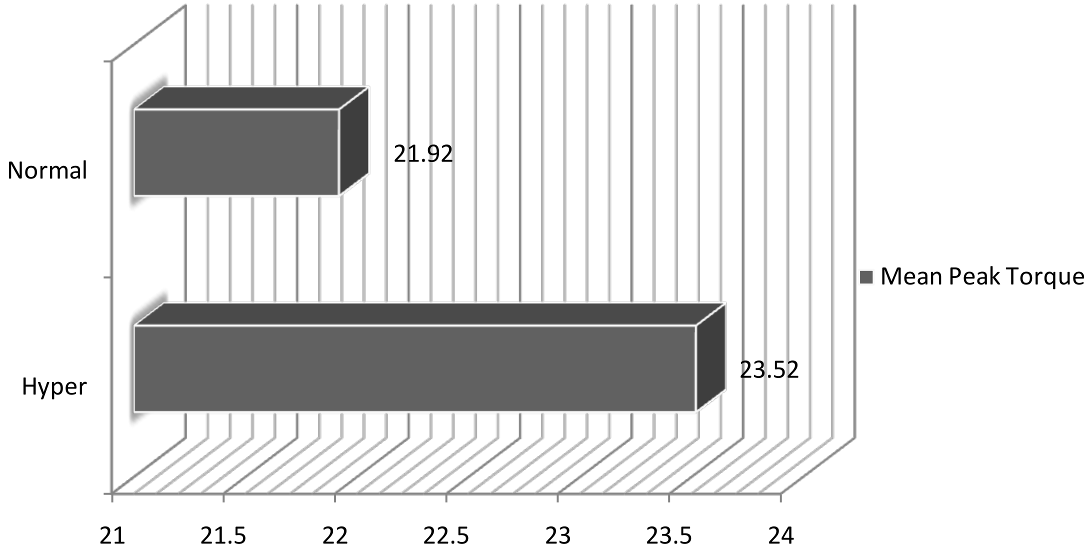


Figure 6 – This graph shows the mean of shoulder internal rotation peak torque in each group. The mean of peak torque in the normal ROM was 21.92 ft-lbs and in the hyper-ROM was 23.52 ft-lbs.

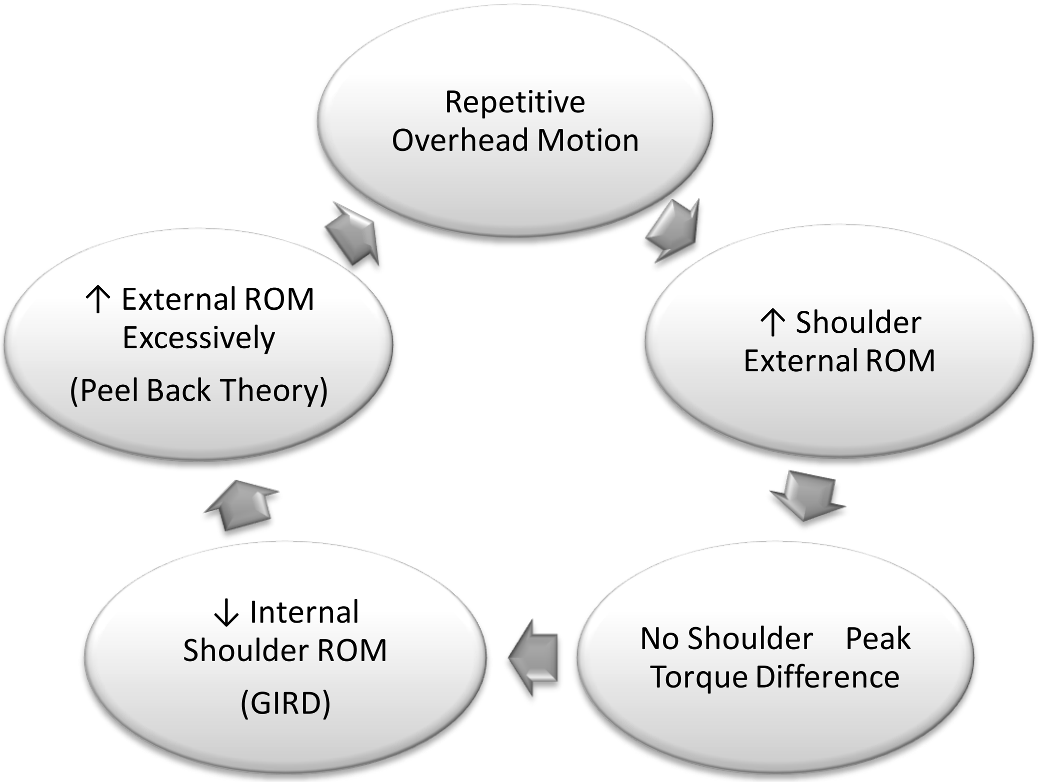


Figure 7 – The flow chart of the mechanism of the overhead thrower/hitter shoulder injury. Upward arrow indicates “increase” and downward arrow indicates “decrease.”

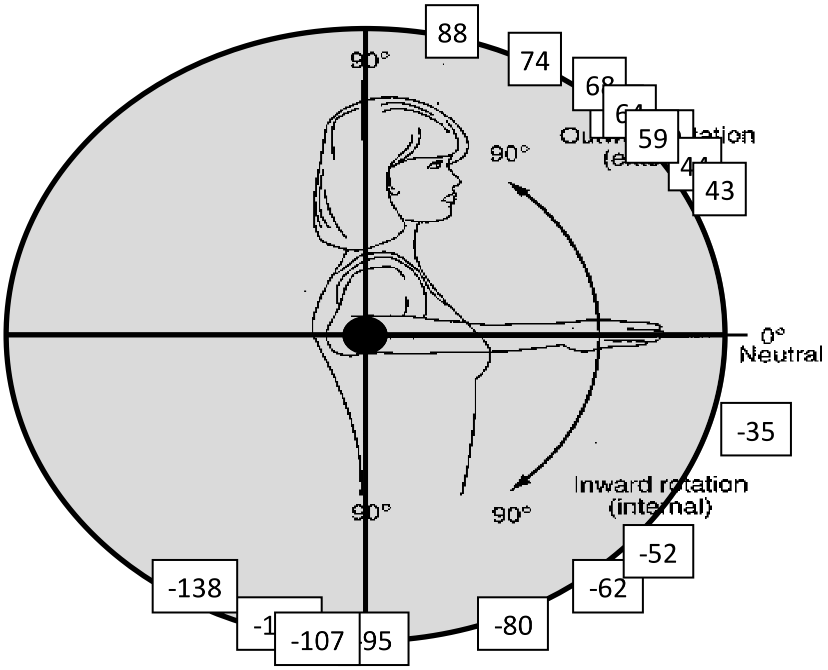


Figure 8 – An image of the shoulder range of motion and point that the investigator recorded the shoulder internal rotation peak torque in each subject. The number in the box is the angle of shoulder internal rotation peak torque. In this figure, the subject faced to right and the dot of the center represents the axis of shoulder rotation, the olacrenon process with 90° of shoulder abduction and 90° of elbow flexion. Nine out of 19 subjects recorded the shoulder internal rotation peak torque under the neutral (0°) and the others recorded above the neutral (0°).

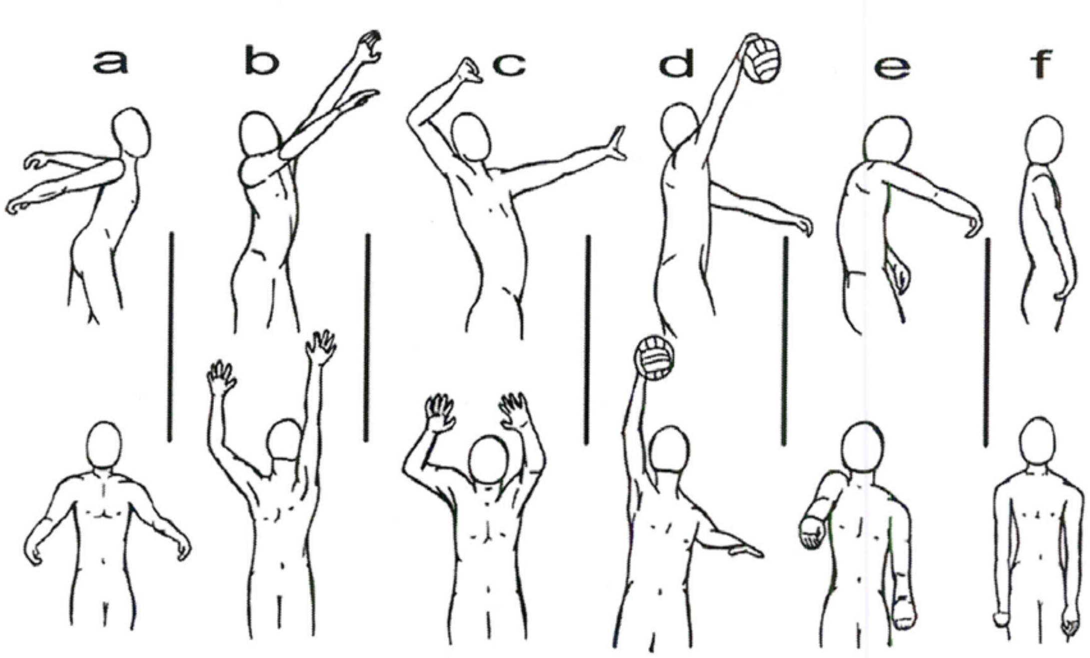


Figure 9 – This picture illustrates the phases of a volleyball hit. The middle row is the view from right to left and the bottom row is the view from anterior to posterior. Phase a-b is wind-up; phase b-c is cocking; phase c-d is acceleration; phase d-e is deceleration; phase e-f is follow-through. Point d is the ball hitting point. (Plawinski, 2008)

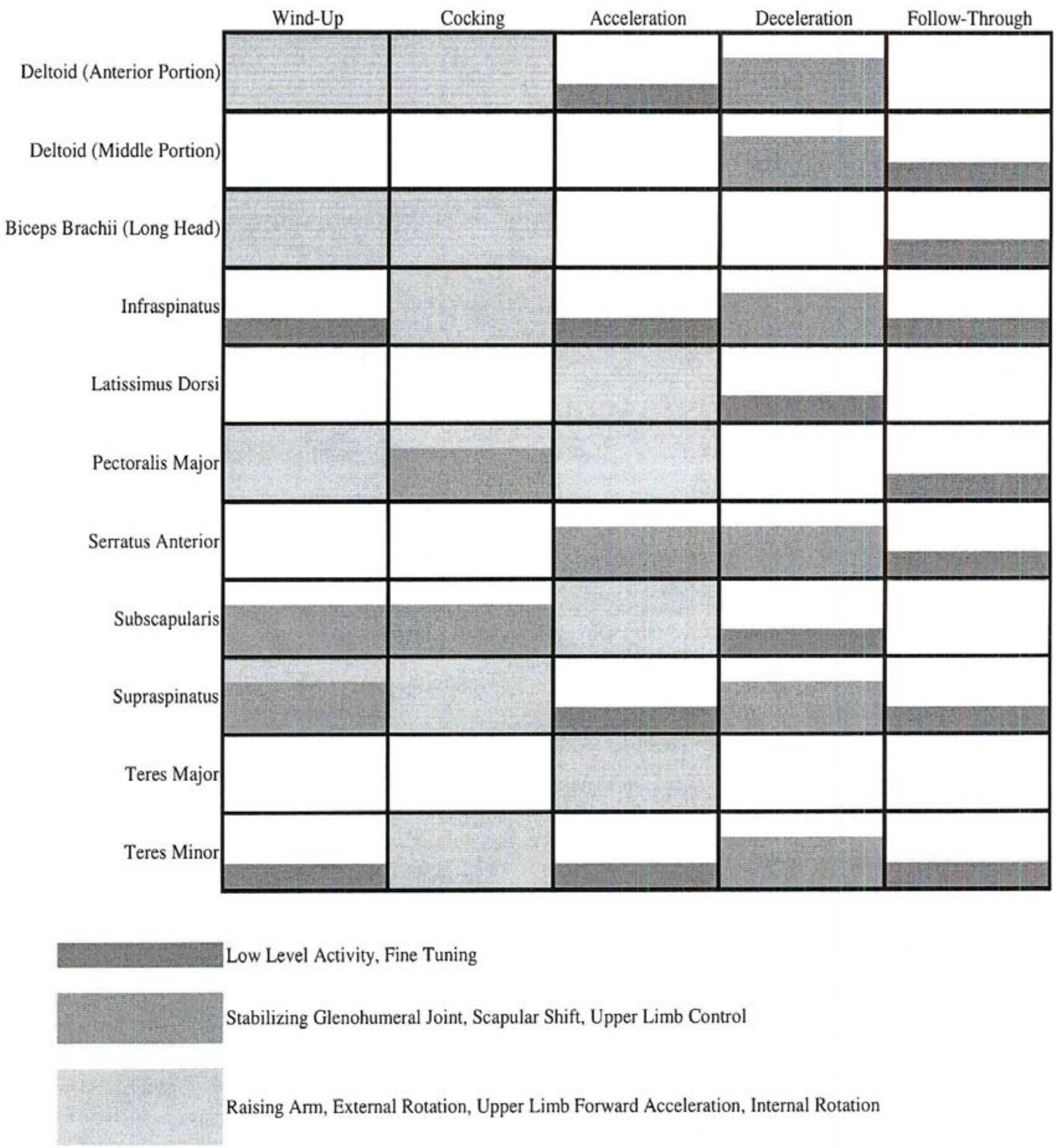


Figure 10 – The scheme represents the shoulder muscular activation through the volleyball swing. (Plawinski, 2008)

APPENDIX A

The University of Central Oklahoma Institution of Research Board

Approved Informed Consent Form

UNIVERSITY OF CENTRAL OKLAHOMA

INFORMED CONSENT FORM

Research Project Title: Shoulder Dynamic Stability and Range of Motion in Volleyball Athletes

Researcher: Kazuma Akehi, ATC/LAT (M.S. Candidate at University of Central Oklahoma)

Purpose of this research: The purpose of the study is to determine the differences in shoulder peak torque (SPT) between the normal range of motion (ROM) and hyper-ROM groups with 90° of elbow flexion and 90° shoulder abduction.

Procedures: Subjects will be asked to sign the informed consent form and the waiver form in order to participate in the study.

There will be two testing sessions in the study;

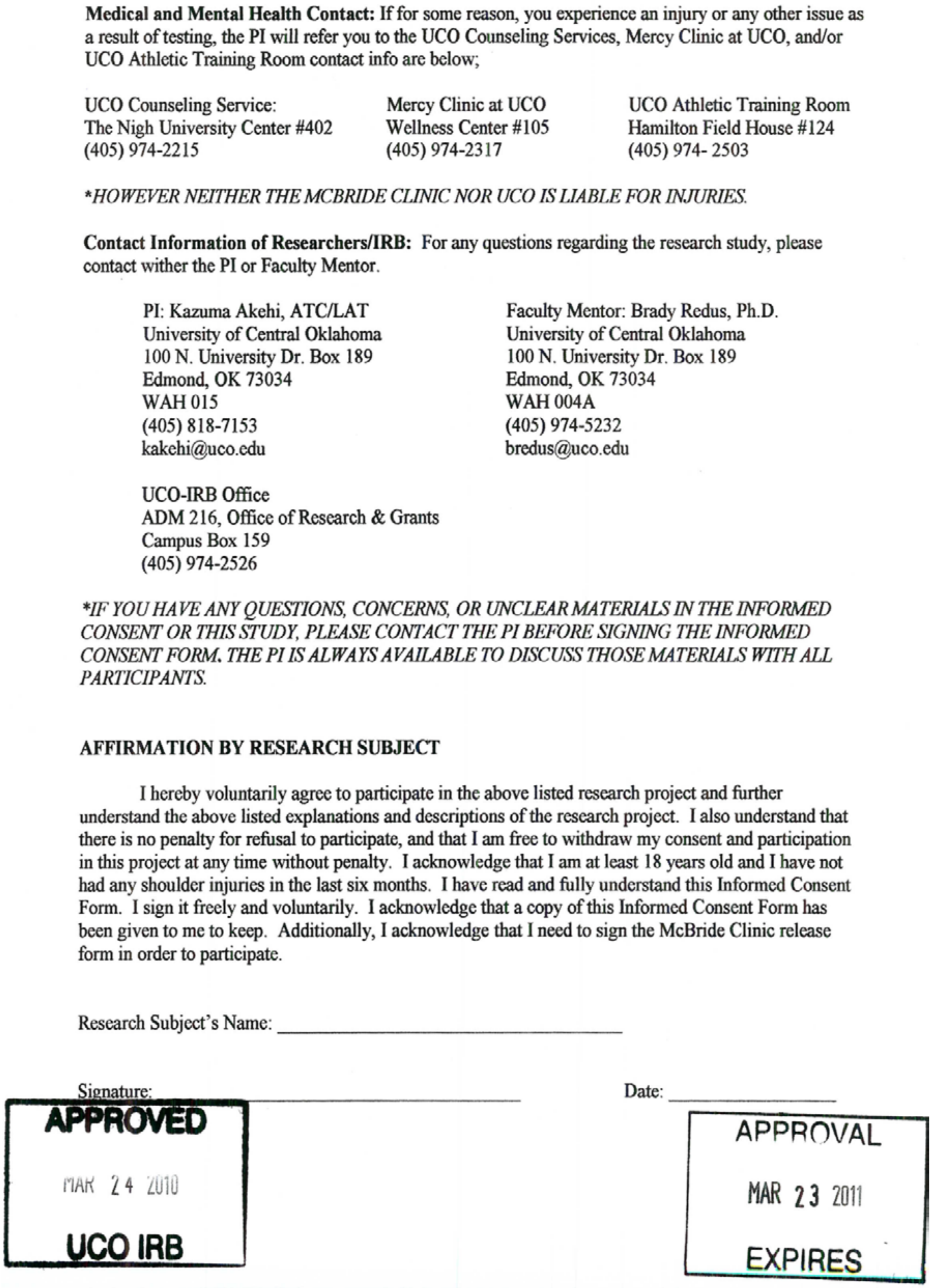
1) Subjects will report to the UCO athletic training room for preliminary data collection including age, height (cm), weight (kg), dominant arm length (cm), range of motion (ROM) data collection; measuring dominant shoulder internal (inward) and external (outward) ROM. Measuring the ROM of internal and external rotation on the shoulder (glenohumeral (GH)) joint will be conducted against gravity; the subject will lay on the stomach and 90° of shoulder abduction and 90° of elbow flexion actively (AROM) and passively (PROM).

2) Subjects will report to the McBride Clinic at Edmond, OK for Biodex isokinetic dynamometer measurements. The subjects will be seated in a modified neutral position of 90° of shoulder abduction and 90° of elbow flexion. Then, the subjects will perform 5 repetitions of shoulder internal and external rotation motion on the Biodex isokinetic dynamometer in 270°/second on the dominant side of the arm; a little resistance during the motion. All testing data will be collected by the primary investigator (PI).

Expected Length of Participation: Subjects will participate in two testing procedures of approximately 40 minutes. The first testing sessions will take approximately 10 minutes. Testing session two will be conducted within 3 days after the first testing session and will also take approximately 30 minutes.

Potential Benefits: Subjects will benefit through having the Biodex isokinetic dynamometer measurements. The Biodex isokinetic dynamometer will provide you with your strength, torque, and peak torque measurements. Also, the subjects may increase the awareness in the shoulder injury prevention based on the testing results. There may not be a direct benefit to the subjects. The PI is available to discuss the testing results with each subject. The PI never shares the individual testing results with anybody until the PI gets the consent from the subjects.

Potential Risks or Discomforts: Subjects may experience physical stress as a result of the Biodex isokinetic dynamometer measurements. During the Biodex isokinetic dynamometer measurements, the subjects should perform the maximum shoulder internal rotation movement to collect peak torque data. To prevent any injuries during the testing, each participant will warm up and cool down for 5 minutes by using the Upper Body Ergometer (UBE). Prior to beginning the testing, the subjects will be reminded that they may withdraw from the test at any point without penalty as is stated in the Informed Consent. The subjects must report their injury history honestly because the subjects' injury history, the last six month prior injuries from the testing date, will affect the testing data.



Medical and Mental Health Contact: If for some reason, you experience an injury or any other issue as a result of testing, the PI will refer you to the UCO Counseling Services, Mercy Clinic at UCO, and/or UCO Athletic Training Room contact info are below;

UCO Counseling Service:
The Nigh University Center #402
(405) 974-2215

Mercy Clinic at UCO
Wellness Center #105
(405) 974-2317

UCO Athletic Training Room
Hamilton Field House #124
(405) 974- 2503

**HOWEVER NEITHER THE MCBRIDE CLINIC NOR UCO IS LIABLE FOR INJURIES.*

Contact Information of Researchers/IRB: For any questions regarding the research study, please contact wither the PI or Faculty Mentor.

PI: Kazuma Akehi, ATC/LAT
University of Central Oklahoma
100 N. University Dr. Box 189
Edmond, OK 73034
WAH 015
(405) 818-7153
kakehi@uco.edu

Faculty Mentor: Brady Redus, Ph.D.
University of Central Oklahoma
100 N. University Dr. Box 189
Edmond, OK 73034
WAH 004A
(405) 974-5232
bredus@uco.edu

UCO-IRB Office
ADM 216, Office of Research & Grants
Campus Box 159
(405) 974-2526

**IF YOU HAVE ANY QUESTIONS, CONCERNS, OR UNCLEAR MATERIALS IN THE INFORMED CONSENT OR THIS STUDY, PLEASE CONTACT THE PI BEFORE SIGNING THE INFORMED CONSENT FORM. THE PI IS ALWAYS AVAILABLE TO DISCUSS THOSE MATERIALS WITH ALL PARTICIPANTS.*

AFFIRMATION BY RESEARCH SUBJECT

I hereby voluntarily agree to participate in the above listed research project and further understand the above listed explanations and descriptions of the research project. I also understand that there is no penalty for refusal to participate, and that I am free to withdraw my consent and participation in this project at any time without penalty. I acknowledge that I am at least 18 years old and I have not had any shoulder injuries in the last six months. I have read and fully understand this Informed Consent Form. I sign it freely and voluntarily. I acknowledge that a copy of this Informed Consent Form has been given to me to keep. Additionally, I acknowledge that I need to sign the McBride Clinic release form in order to participate.

Research Subject's Name: ______________________________

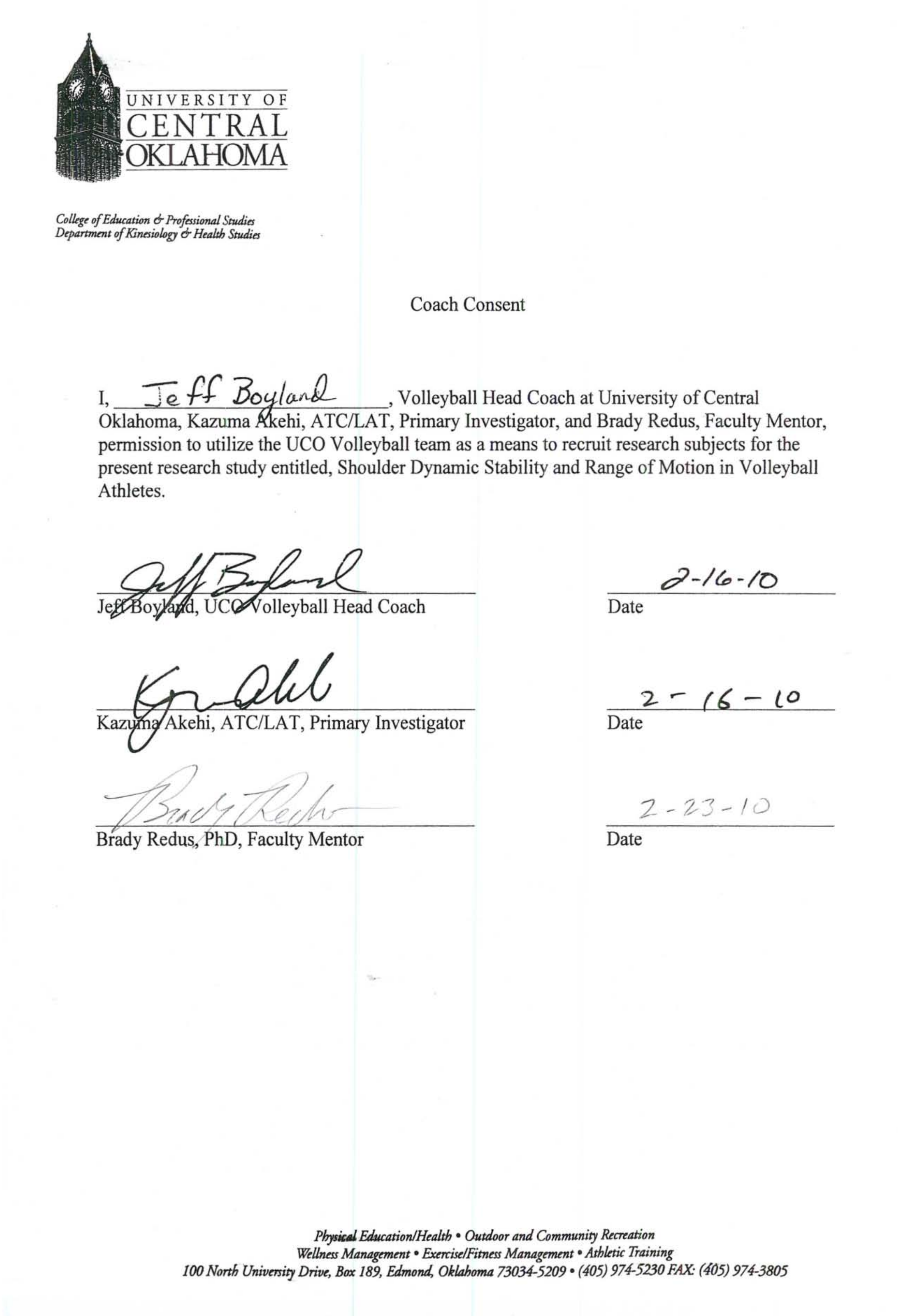
Signature: ______________________________ Date: ________________

APPROVED
MAR 24 2010
UCO IRB

APPROVAL
MAR 23 2011
EXPIRES

APPENDIX B

Coach Consent Form



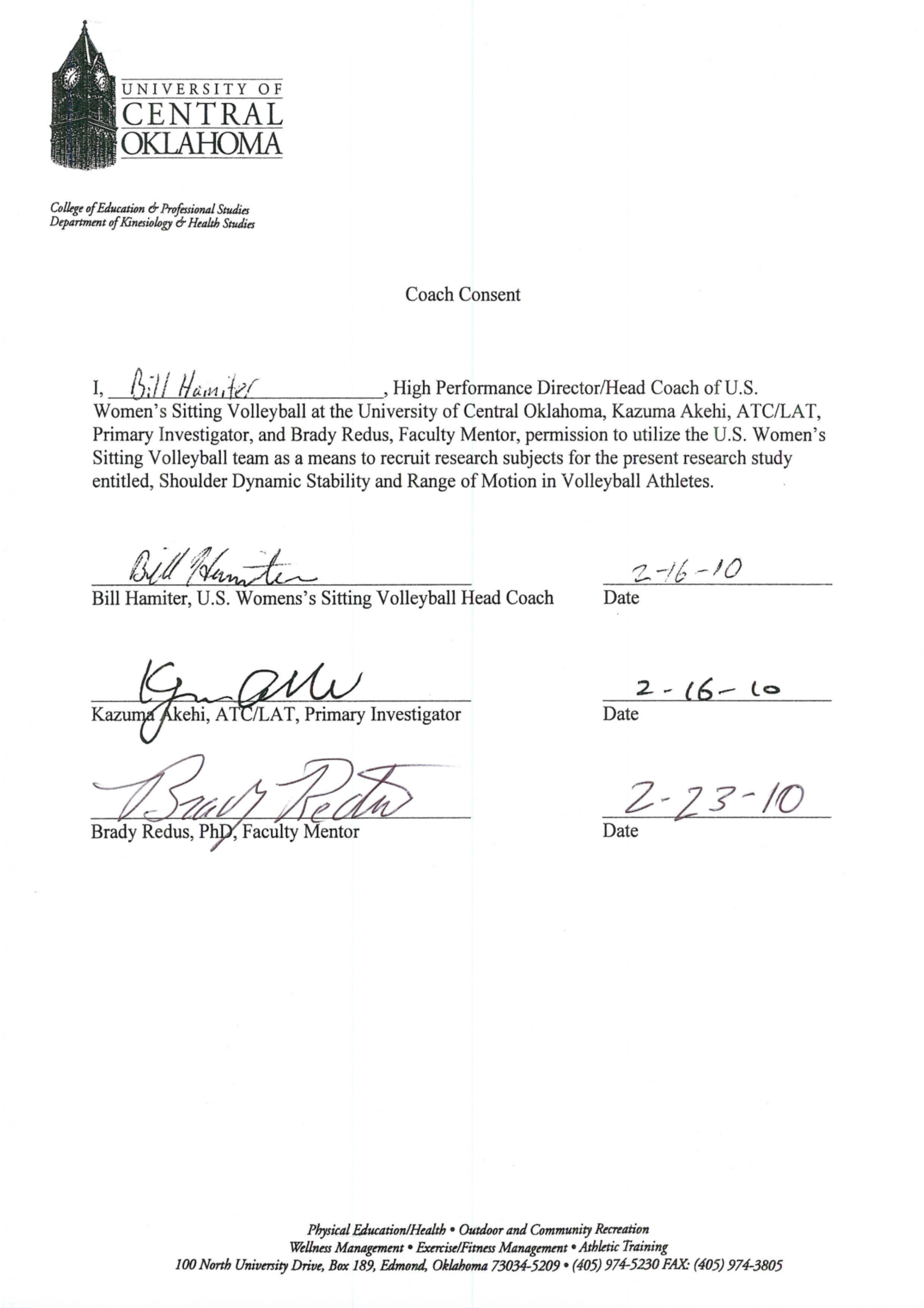
UNIVERSITY OF
CENTRAL
OKLAHOMA

College of Education & Professional Studies
Department of Kinesiology & Health Studies

Coach Consent

I, Jeff Boyland, Volleyball Head Coach at University of Central Oklahoma, Kazuma Akehi, ATC/LAT, Primary Investigator, and Brady Redus, Faculty Mentor, permission to utilize the UCO Volleyball team as a means to recruit research subjects for the present research study entitled, Shoulder Dynamic Stability and Range of Motion in Volleyball Athletes.

Jeff Boyland	2-16-10
Jeff Boyland, UCO Volleyball Head Coach	Date
	2-16-10
Kazuma Akehi, ATC/LAT, Primary Investigator	Date
Brady Redus	2-23-10
Brady Redus, PhD, Faculty Mentor	Date



UNIVERSITY OF
CENTRAL
OKLAHOMA

College of Education & Professional Studies
Department of Kinesiology & Health Studies

Coach Consent

I, Bill Hamiter, High Performance Director/Head Coach of U.S. Women's Sitting Volleyball at the University of Central Oklahoma, Kazuma Akehi, ATC/LAT, Primary Investigator, and Brady Redus, Faculty Mentor, permission to utilize the U.S. Women's Sitting Volleyball team as a means to recruit research subjects for the present research study entitled, Shoulder Dynamic Stability and Range of Motion in Volleyball Athletes.

Bill Hamiter
Bill Hamiter, U.S. Womens's Sitting Volleyball Head Coach

2-16-10
Date

Kazuma Akehi, ATC/LAT, Primary Investigator

2-16-10
Date

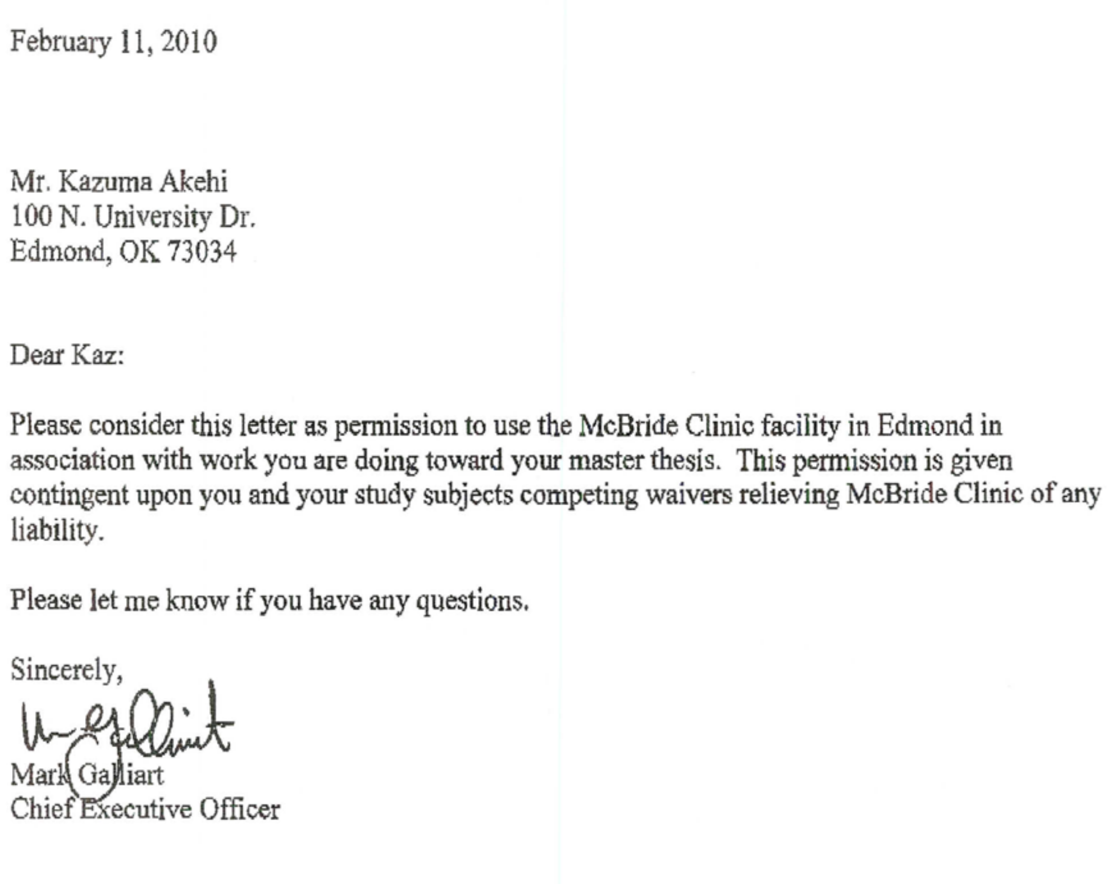
Brady Redus
Brady Redus, PhD, Faculty Mentor

2-23-10
Date

Physical Education/Health • Outdoor and Community Recreation
Wellness Management • Exercise/Fitness Management • Athletic Training
100 North University Drive, Box 189, Edmond, Oklahoma 73034-5209 • (405) 974-5230 FAX: (405) 974-3805

APPENDIX C

The McBride Physical Therapy Clinic Liability Waiver Form



February 11, 2010

Mr. Kazuma Akehi
100 N. University Dr.
Edmond, OK 73034

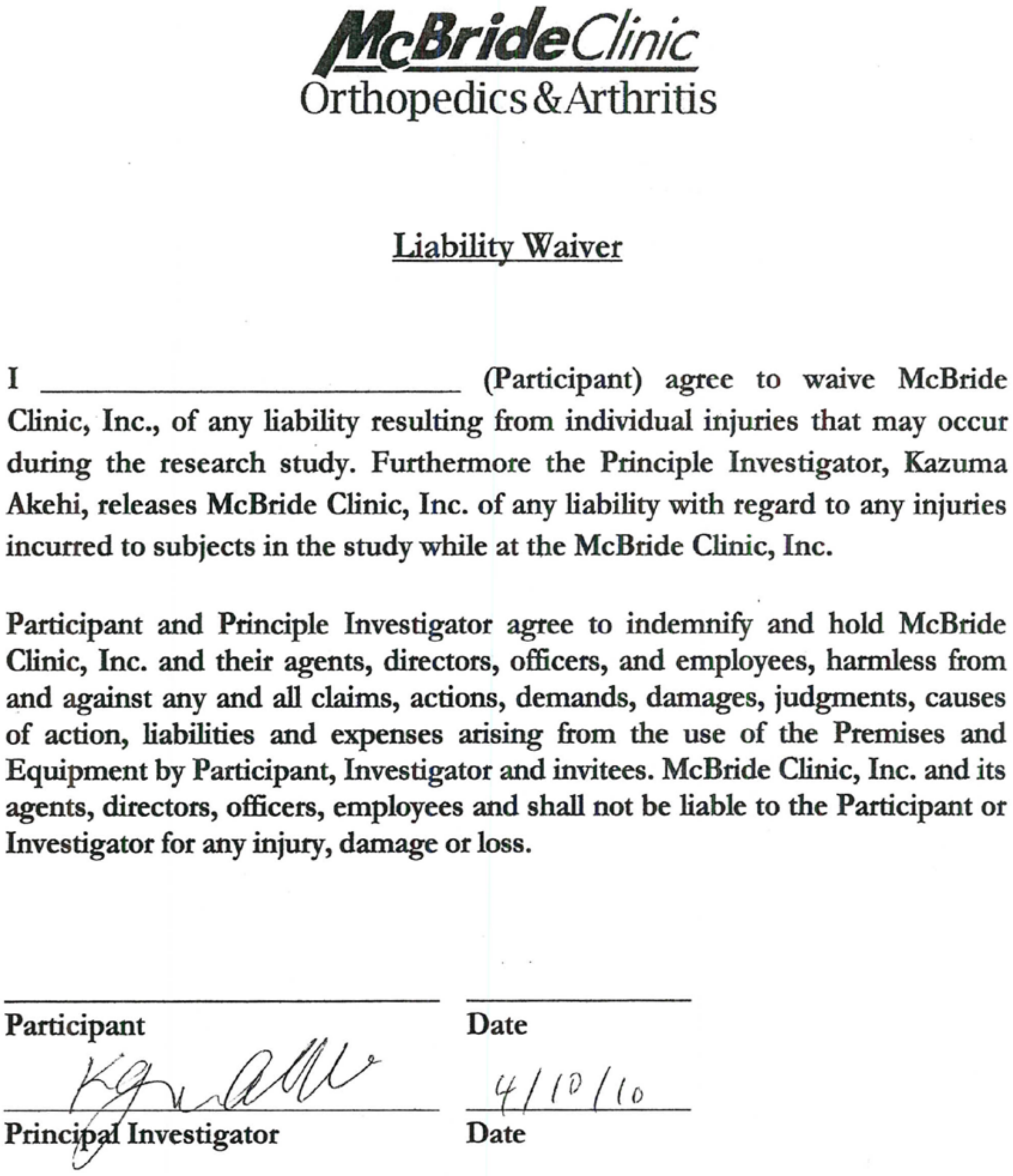
Dear Kaz:

Please consider this letter as permission to use the McBride Clinic facility in Edmond in association with work you are doing toward your master thesis. This permission is given contingent upon you and your study subjects competing waivers relieving McBride Clinic of any liability.

Please let me know if you have any questions.

Sincerely,

Mark Galliart
Chief Executive Officer



McBride Clinic
Orthopedics & Arthritis

Liability Waiver

I ______________________________ (Participant) agree to waive McBride Clinic, Inc., of any liability resulting from individual injuries that may occur during the research study. Furthermore the Principle Investigator, Kazuma Akehi, releases McBride Clinic, Inc. of any liability with regard to any injuries incurred to subjects in the study while at the McBride Clinic, Inc.

Participant and Principle Investigator agree to indemnify and hold McBride Clinic, Inc. and their agents, directors, officers, and employees, harmless from and against any and all claims, actions, demands, damages, judgments, causes of action, liabilities and expenses arising from the use of the Premises and Equipment by Participant, Investigator and invitees. McBride Clinic, Inc. and its agents, directors, officers, employees and shall not be liable to the Participant or Investigator for any injury, damage or loss.

______________________________	______________
Participant	**Date**
______________________________	4/10/10
Principal Investigator	**Date**