RESTING POSTURE AND SUBACROMIAL SPACE IN COLLEGIATE VOLLEYBALL ATHLETES

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ABSTRACT

Jacob N Mir: Resting Posture and Subacromial Space in Collegiate Volleyball Athletes
(Under the direction of William Prentice)

Previous cross sectional research has evaluated posture and subacromial space measurements in overhead athletes. Posture and subacromial space measurements are valid measures to assess for potential factors leading to injury. The primary purpose of this study was to compare postural assessments and potential subacromial space changes between collegiate volleyball players and the general female college population. Twenty-six collegiate female volleyball players and 26 collegiate female students participated in the study. One independent samples t-test was run to analyze change in posture and subacromial space measurements between the volleyball players and students from pre to post-season. Three paired samples t-tests were run to analyze pre- and post-season measures for the volleyball player group, college student groups, and an all-participant group. There was not a change in posture or subacromial space between collegiate volleyball athletes and college female students, however there was a change in forward head angle in all groups.
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CHAPTER I

In the United States, collegiate sports have become very popular and participation continues to grow annually. Currently, there are 23 collegiate sports with more than 480,000 NCAA student athletes. Among those sports, many include an overhead component, whether it is a primary or secondary motion. Volleyball is primarily an overhead, dominant extremity sport. With prolonged and excessive overhead motion, the shoulder girdle goes through significant changes in position and adaptations.

The scapula is an essential “bridge” that provides stability for the cervical spine, glenohumeral joint, and scapulothoracic articulation. Evidence has shown there is a relationship between abnormal biomechanics and shoulder pain in overhead athletes. Faulty scapular movements that are often seen with shoulder pathologies are decreased clavicle retraction, decreased scapular upward rotation, decreased scapular posterior tilt and increased clavicle elevation compared to normal glenohumeral biomechanics. These biomechanical abnormalities can lead to shoulder pain and shoulder pathology. The change in scapular position and orientation can lead to unbalanced length-tension relationships that can affect soft tissue flexibility and muscle performance, therefore changing scapular kinematics. Since the scapula acts as a bridge for the neck and shoulder girdle, optimal scapular movement is essential for proper posture. Poor upper extremity posture can be clinically indicated by forward head positioning and forward shoulder positions, or
forward head rounded shoulder posture (FHRSP). FHRSP has been shown to alter scapular orientation, decrease rotator cuff muscle strength, and decrease glenohumeral range of motion.\(^7\) In the clinic, an upper extremity posture evaluation should be an essential aspect of examination.

The subacromial space can change depending on the position, orientation, and movement of the scapula. When any of these factors are altered, this space is closed down and there is increased compression of the structures under the coracoacromial arch which forms the roof of the subacromial space.\(^8\) Subacromial impingement is one of the most prevalent shoulder pathologies.\(^8\) Narrowing of the subacromial space causes an increase in mechanical compression, which has been identified as a main factor in subacromial impingement.\(^8\) Changes in the size of the subacromial space can be an important marker of subacromial pathologies. It has also been used to monitor progress and determine the outcome of treatment.\(^8\) These findings could indicate a further need for clinical posture assessment and how posture can be analyzed in relation to subacromial space.

**Purpose**

The primary purpose of this study will be to compare postural assessments and potential subacromial space changes between collegiate volleyball players and the general female college population. A secondary purpose of this study is to identify changes in the subacromial space, specifically narrowing or widening, in relation to a clinical postural assessment in the collegiate overhead athlete over the course of the season.
Research Questions and Hypothesis

Research Question 1: Is there a difference in change scores in forward head angle or forward shoulder angle degree measurements in collegiate volleyball players when compared to a college female comparison group from pre- to post-season?

Hypothesis 1: There will be a difference in the change in forward head and forward shoulder posture degree measures from pre- to post-season in collegiate volleyball players compared to a college female comparison group.

Research Question 2: Is there a difference in change scores in subacromial space measurements (cm) in collegiate volleyball players when compared a college female comparison group from pre- to post-season?

Hypothesis 2: There will be a difference in the change in subacromial space measurements (cm) from pre- to post-season in collegiate volleyball players when compared to a college female comparison group.

Research Question 3: Is there a change in forward head angle or forward shoulder angle degree measurements in the dominant limb from pre- to post-season in collegiate volleyball players?

Hypothesis 3: There will be a change in forward head angle or forward shoulder angle from pre- to post-season in collegiate volleyball players.

Research Question 4: Is there a change in subacromial space (cm) in the dominant limb from pre- to post-season in collegiate volleyball players?

Hypothesis 4: There will be a change in subacromial space measurements (cm) from pre- to post-season in collegiate volleyball players.
CHAPTER II

Participation and Injury in the volleyball athlete

Volleyball is a very popular sport in the United States with over 17,000 participants at the collegiate level.\(^1\) According to Agel et al. (2007) and the NCAA injury Surveillance System, over 16 years the incidence rate of injury was 4.58 injuries per 1000 athlete-exposures during games and 4.10 injuries per 1000 athlete-exposures during practice, both accounting for approximately 20% of upper extremity injuries.\(^9\) Reeser et al. (2015) followed collegiate volleyball athletes over a 4-year period and found that shoulder injuries were the 3\(^{rd}\) most prevalent injury and concluded that overhead hitting was the predominant cause of shoulder pathology\(^10\). Repetitive overhead hitting commonly exposes the shoulder joint to overuse injuries in volleyball.

Volleyball hitting motion at the shoulder joint

The volleyball hitting motion is a complex maneuver that engages both the dynamic and static stabilizers of the shoulder. It has been divided into 5 categories; approach, takeoff, arm cocking, arm acceleration, and follow-through.\(^11\) Focusing on just the shoulder movement of the volleyball hit, Rokito et al. (1998) categorized the movement into windup, arm cocking, acceleration, deceleration, and follow-through.\(^12\)

The arm is abducted and externally rotated in the cocking phases and rapidly transitions into horizontal adduction and maximum external rotation of the shoulder.
During this transition, the humeral head migrates posteriorly and the rotator cuff becomes active to maintain glenohumeral stability. At this point, the upper limb accelerates and the shoulder is positioned in flexion and internal rotation with elbow extension. During the deceleration and follow through, the external rotators are eccentrically contracting to counteract the high internal rotation velocity and anterior shear force that is acting on the glenohumeral joint.\textsuperscript{11,13} This motion can lead to overuse and can make the glenohumeral joint susceptible to adaptive changes and potential injury.

Electromyography (EMG) has shown that different musculature around the shoulder girdle needs to be recruited throughout each phase of the overhead motion. During the acceleration phase of the overhead motion, the arm is positioned in maximal external rotation until the ball is hit. The glenohumeral internal rotators rapidly contract and create an internal rotation velocity force between 4000-7000 degrees per second.\textsuperscript{12,13} EMG shows high activity of the teres minor to provide posterior stabilization during the motion. However, the EMG of the infraspinatus was relatively low. Although both muscles have similar functions and anatomical location, they have different firing patterns and optimal mechanical positions.\textsuperscript{12,13}

During the deceleration phase of the hitting motion, EMG showed higher levels of activity with the teres minor and infraspinatus as the muscles eccentrically contract to slow the internal rotation movement and stabilize the humeral head.\textsuperscript{12} Additionally, the supraspinatus showed the highest EMG amplitude during the deceleration phase as it functions to stabilize the humeral head during the overhead hitting motion.\textsuperscript{12}
Although there was higher EMG activity of the rotator cuff during the deceleration phase, it was lower than EMG activity observed in overhead baseball and football athletes.\textsuperscript{12,13} One of the primary functions of the rotator cuff is to generate shoulder compressive forces to counteract distraction forces occurring at the glenohumeral joint.\textsuperscript{3,12-14} During the baseball and football throw there are greater forces at the shoulder compared to the volleyball hit due to significant mechanical differences with the weight of the projectile. The weighted balls create a greater distraction force on the arm and as they are released, the arm may be traveling faster and require greater rotator cuff activity for deceleration.\textsuperscript{12,13} Additionally, as the hand strikes the ball during the volleyball hit, there is an equal and opposite force that assists in slowing down the forward moving hand. This helps explain the relatively low EMG activity of the rotator cuff during the volleyball hit compared to the baseball and football throw.\textsuperscript{12,13}

**Volleyball injury risk factors**

To meet the demands of an overhead sport such as volleyball, there is a natural adaptation that results in hypomobility and hypermobility within the shoulder complex that is evident compared to non-overhead athletes.\textsuperscript{15} Over time, overhead activity leads to secondary changes to the glenohumeral joint capsule, ligaments, labrum, surrounding musculature, and osseous structures.\textsuperscript{15} This typically presents with increased external rotation range of motion with decreased internal rotation.\textsuperscript{15} Modifiable risk factors for shoulder overuse pathologies in volleyball players include hitting style, weakness in external shoulder rotation strength, limited internal shoulder rotation, scapular malposition, inferior medial border prominence, coracoid
pain and malposition, dyskinesis of scapular movement (SICK scapula), weak core stability, large increases in training load, and position,\textsuperscript{16} and posterior capsule tightness.\textsuperscript{17} Non-modifiable risk factors are previous shoulder injuries, age, and playing history.\textsuperscript{16} Modifiable risk factors are the main focus of this thesis, primarily glenohumeral internal rotation deficit (GIRD), posterior capsule tightness, and SICK scapula.

\textit{GIRD}

GIRD is a condition that is often seen in the dominant arm of overhead athletes and it is described as an excessive increase in glenohumeral external rotation with subsequent decrease in internal rotation.\textsuperscript{15} GIRD is hypothesized to be a natural adaptation that occurs in overhead athletes. It is theorized to result from subtle microtrauma to the static and dynamic structures in the shoulder from repetitive overhead activity, contracture of the posteroinferior joint capsule, and osseous adaptations of the humerus.\textsuperscript{18} In regard to GIRD, Wilk at al. (2009) created the total-rotational-motion (TRM) concept, which is the measurement of glenohumeral internal rotation plus external rotation. Normal TRM is approximately 180 degrees, with a majority of the motion coming from external rotation in overhead athletes.\textsuperscript{15} This repetitive stress and alteration in normal range of motion may predispose the shoulder girdle to injury.\textsuperscript{19}

Reeser et al. (2010) looked at physical examination findings on 276 volleyball players in relation to scapular dyskinesis and GIRD. They found that 60% of participants had abnormal scapular mechanics predominantly on the dominant side.\textsuperscript{20} The authors also noted significantly decreased internal rotation scores in the
dominant shoulder compared to the non-dominant shoulder with a mean difference in glenohumeral internal rotation of 8.9 degrees. The average internal rotation of the dominant shoulder was 46.1 degrees, while the average of the non-dominant shoulder was 55 degrees.20

These anatomical adaptations have shown differences when comparing limbs bilaterally and between throwers vs non-throwers.21 Myers et al. (2006) found that upper extremity dependent athletes with pathological internal impingement had significantly greater GIRD, which may indicate an association between thickened posterior shoulder elements and impingement.18 Many authors have found GIRD to be an important cause of postural deviations, likely increasing the risks of impingement, increasing anterior tilting and decreasing rotator cuff strength.19

Increased protraction combined with GIRD potentially increases and promotes subacromial and internal impingment.19

Posterior capsule tightness

Tightness in the posterior capsule and subsequent GIRD, has been associated with the inhibition of scapular stabilizing muscles and can lead to scapular dyskinesis.7 Burkhart et al. (2003) concluded that the posteroinferior capsular contracture is the first abnormality that creates a “pathological cascade.”7 Posteroinferior contracture develops due to repetitive microtrauma that leads to the development of scar tissue on the posterior capsule. This contracture forces the humeral head to abnormally translate during abduction and external rotation, decreasing the subacromial space.22

Clabbers, et al. (2007) found in a cadaveric study that with extreme posterior
capsular tightness there was a trend for humeral head translation in the posterior-superior direction.\textsuperscript{17,19} The buildup of scar tissue is believed to be a major contributor to GIRD; however, it is unclear whether it is the posterior capsule or the posterior rotator cuff that is the root of the problem.\textsuperscript{23} GIRD decreases scapular upward rotation and increases anterior tilting and protraction.\textsuperscript{2,5,19,24} Posterior capsule tightness and GIRD can alter normal function of the shoulder girdle, which has a critical impact on postural assessment.\textsuperscript{19}

**SICK scapula**

SICK scapula refers to an overuse muscular fatigue syndrome that alters scapular position, leading to greater scapular protraction and anteroinferior tilting, resulting in alternations in subsequent scapular kinematics.\textsuperscript{5} Clinically, this presents as a depressed scapula and shoulder with a prominent inferior medial scapular border and tightness within the pectoralis minor as the coracoid tilts inferiorly and shifts laterally away from the midline.\textsuperscript{5} This change in resting scapular position alters normal kinematic motion of the shoulder during overhead motion and can have a possible effect on changes leading to impingement within the subacromial space.\textsuperscript{25,26}

**Impingement**

*Subacromial impingement*

Subacromial impingement syndrome (SIS) is the narrowing of the subacromial space, which leads to compression between the acromion and humeral head.\textsuperscript{27-29} This leads to injury of the soft tissue structures such as the subacromial
bursa, supraspinatus and bicep brachii tendon, and glenohumeral labrum. SIS is the most common cause of shoulder pain and has been seen to represent up to 65% of shoulder pain diagnoses. SIS is often categorized as primary or secondary. Primary external impingement is an injury to the rotator cuff caused by the undersurface of the acromion, due to spurring or changes in acromial shape. Bigliani and Levine (1997) classified these change as flat (type I), curved (type II), or hooked (type III) and they can increase the narrowing of the subacromial space and cause impingement.

Secondary external impingement is mechanical narrowing of the subacromial space with functional movements related to glenohumeral instability. This type of impingement is most common in overhead athletes due to the microtrauma caused from repetitive stress to the dynamic and static stabilizers of the shoulder. This increases the demand on the rotator cuff, causing it to fatigue and secondarily causing migration of the humeral head and subsequent impingement. Secondary impingement can also be due to weak scapular stabilizing musculature and the SICK scapula.

**Internal impingement**

Internal impingement naturally occurs when the glenohumeral joint is in an abducted and externally rotated (ABER) position. The undersurface of the posteriosuperior rotator cuff contacts the glenoid labrum and can become impinged by the greater tubercle. Impingement can be exacerbated by overhead biomechanics and adaptations in the volleyball athlete, which can be attributed to either chronic or acute injury mechanisms. Repetitive distraction and rotational
forces lead to microtrauma in the posterior capsule, causing scarring and increased internal impingement.\textsuperscript{7,22,37} There is a pathological shift of the glenohumeral area of joint contact and rotation, which exacerbates posterior-superior impingement and the associated pain and dysfunction.\textsuperscript{37} This shift allows for greater external rotation and lesser internal rotation, increasing the risk of undersurface rotator cuff pathology due to impingement and shear forces.\textsuperscript{37} Additionally, excessive external rotation creates greater torsional stress on the biceps attachment, increasing the risk of labral pathology.\textsuperscript{37}

\textbf{Posture}

\textit{Mechanical effects}

Posture is a composition of the alignment of all the joints in the body at any given moment. Good posture is an alignment that is physiologically and biomechanically efficient.\textsuperscript{14} Scapular posture and positioning is a crucial aspect of the shoulder examination. Clinicians often observe for muscle atrophy, bony contour, scapular winging, inferior angle prominences, and presence of a scar.\textsuperscript{38} These asymmetries are relatively common. However, they do not always present as symptomatic.\textsuperscript{5} Alterations in scapular movements, such as reduced clavicle retraction, scapular upward rotation, scapular posterior tilt, and increased clavicle elevation, have been shown to have an association with shoulder pathology.\textsuperscript{2,14}

An increase in thoracic and cervical curvature and a slouched posture are known to affect scapular orientation, shoulder muscle strength, and shoulder range of motion.\textsuperscript{7} Kebaetse et al. (1999) found that an increase in thoracic spine flexion elevates and anteriorly tilts the scapula at rest, decreases glenohumeral elevation,
and decreases glenohumeral abduction force production.\textsuperscript{34} In the cervical spine, Ludewig and Cook (1996) found that there is altered scapular kinematics with a cervical spine flexion angle of 25 degrees.\textsuperscript{35}

\textit{Muscular effects}

Activation sequencing patterns and muscle performance is decreased with poor posture and scapular malalignments. In subjects with SIS, there are changes in the timing properties of the serratus anterior, upper trapezius, middle trapezius, and lower trapezius. It has been consistently demonstrated that there is decreased serratus anterior strength, over activity and early activation of the upper trapezius, and decreased lower trapezius and middle trapezius activity.\textsuperscript{2,24,26,39,40} These malalignments place the upper trapezius in a chronically shortened position causing over activity, and the serratus anterior and lower trapezius in a chronically lengthened position, resulting in dysfunction in normal scapulothoracic and glenohumeral kinematics.\textsuperscript{24,39,40} The inhibition of these muscles decreases the ability to properly upwardly rotate and posteriorly tip the scapula.\textsuperscript{19} These factors cause a changed axis and lever arm for the rotator cuff musculature, resulting in altered length/tension relationships in the shoulder.\textsuperscript{7}

Individuals with FHRSP may show alterations in electromyography (EMG) data in the musculature surrounding the shoulder girdle and glenohumeral joint. Kwon et al. (2015) looked at forty subjects with FHRSP and surface EMG data on the sternocleidomastoid, upper trapezius, lower trapezius, and serratus anterior during an overhead task. Subjects were divided into a neutral head group, ideal posture group, and corrected head position group. EMG muscle activity data showed
a significant difference between upper trapezius and serratus anterior activity within groups, concluding that the ideal posture group and corrected position group had improved shoulder kinetics and movement patterns. Alterations to muscular firing patterns can increase tissue stress and risk of injury. It is commonly seen that patients with FHRSP and overuse shoulder pathologies have increased upper trapezius activity and decreased serratus anterior and lower trapezius activation during shoulder motions.

Postural assessment

FHRSP can be defined as “excessive anterior orientation of the head or glenohumeral joint relative to the vertical plumb line of the body.” Thigpen et al (2010) established that ideal posture is FHA <36 degrees and FSA <22 degrees, and poor posture FHA>46 degrees and FSA>52 degrees, which can lead to altered scapular kinematics and muscle activity that can result in shoulder pain. FHRSP is problematic because it can alter mechanics of the scapula by changing the activity of the musculature surrounding the cervical and thoracic region. This causes altered force couples between the overactive upper trapezius, underactive lower trapezius, and serratus anterior. The altered force couples can cause problematic changes in scapular motion, resulting in pain and injury. Patients with FHRSP have exhibited increased thoracic kyphosis angle and greater anterior and upward tilt of the scapula, which may be associated with shoulder or scapular pain.

General population

FHRSP is a condition that is present in the general population as well as the athletic population. Neck and shoulder pain are very prevalent, occurring within 21%
of the population,\(^6\) and up to 60% of people throughout their lifetime.\(^2,32,45\) This condition is commonly due to long-term sitting, such as excessive computer use, causing thoracic kyphosis and anteriorly positioned shoulders.\(^2,22,41\) In the student population, the use of text messaging continues to expand, with 91% of phone users in the United States texting, emailing, or instant messaging.\(^46\) Excessive cell phone use is often exhibited in college students and increases cervical neck flexion (FHA), resulting in over activity of the upper trapezius and other musculoskeletal disorders (MSD).\(^46\) Long term sitting\(^2\), computer use\(^47\), texting\(^46\), and backpack use\(^48\) can all contribute to FHRSP in students, increasing the risk of MSD.

**Subacromial Space**

Subacromial space, also termed acromiohumeral distance (AHD), is defined the distance measured between the inferior aspect of the humeral head, the anterior aspect and surface of the anterior third of the acromion, coracoacromial ligament, and acromioclavicular ligament.\(^31,49,50\) Normal AHD distance measurements in a neutral position have been identified between 6-12mm with sonography\(^51\) and 10-15mm with x-ray.\(^52\) These measures represent the typical values that would be observed in a population assumed to have normal shoulder function.

Decreased SA and LT activity have been linked to changes in functional scapular motion.\(^53\) These changes can adversely affect scapular position and result in reduced scapular upward rotation, increased scapular anterior tilt, and scapular winging.\(^2,5,19,24,53\) The upward rotation and posterior tilting of the scapula are critical to elevate the acromion, thus, widening the subacromial space.\(^53\) Bdaiwi et al. (2015) used neuromuscular electrical stimulation on the serratus anterior and lower
trapezius to increase upward rotation and posterior tilting. They found that the stimulation of these muscles created an increase in subacromial space when measured with diagnostic ultrasound showing that proper posture and scapular orientation can help widen the subacromial space and reduce compression of the contents that run underneath.\textsuperscript{53}

Lewis, et al. (2005) examined forward head posture in relation to subacromial space with sagittal and frontal plane postural measurements. The authors evaluated 60 asymptomatic subjects and 60 subjects with SIS. The authors concluded that a static postural assessment and SIS did not show any statistically significant findings and faulty static posture does not ensure SIS, concluding that there is a need for further research.\textsuperscript{29} These studies have yet to look at subacromial space measurements in relation to a clinically based postural assessment.

Instrumentation

\textit{FHRSP}

FHRSP can be measured and determined clinically by analyzing head and shoulder position in the sagittal plane. According to Thigpen et al. (2009), Cole et al. (2013), and Hibberd et al. (2016), forward head angle (FHA) is calculated by measuring the angle between a line drawn from the tragus to the C7 spinous process and a vertical plumb line through C7. Forward shoulder angle (FSA) is determined by measuring the angle between a line drawn from the tip of the acromion process to the C7 spinous process and a vertical plumb line through C7.\textsuperscript{6,22,43} Thigpen et al. (2009) reported intra-day reliability for FHA (ICC\textsubscript{2,1} = .92, SEM = 2° and FSA ICC\textsubscript{2,1} = .89, SEM = 5°\textsuperscript{6} and Hibberd et al (2016) reported
intrasession reliability for FHA ICC(2,1) = .98 SEM = .73°, and FSA ICC(2,1) = .99, SEM = .9.

**Diagnostic Ultrasound**

Ultrasound has been found to be a reliable measure of subacromial space. Diagnostic ultrasound distance has been found to be a valid assessment compared to standard x-ray measurements. Azzoni et al. (2004) found that ultrasound imaging had very similar measurement outcomes when compared to x-ray (p>.8). The authors showed that sonographic images can be successfully used for clinical purposes. Hibberd et al (2013) identified AHD measurements and reported intrasession reliability for ADH ICC(2,1)= .91 SEM = .04cm.

**Clinical significance**

A thorough screening examination is the first step to identifying underlying shoulder pathology. Burkhart et al. (2003) concluded that a scapular posture screening exam should include “a posture check for cervical and thoracic areas, scapular symmetry at rest and on ascending and descending arm motion in flexion and abduction, active scapular retraction and elevation, lateral slide measurements, and glenohumeral internal rotation measurements.” Posture is a critical component of assessment to analyze for both diagnosing pathologies and for treating them.

The literature concludes that alterations in scapular positioning can change the biomechanics of scapular movement, leading to potential shoulder pathology. Thus, if the scapula has altered orientation and improper movement patterns, there is risk of narrowing the subacromial space and increasing the risk and rate of
subacromial space pathologies and other concomitant upper extremity pathologies. Therefore, FHRSP could potentially lead to a narrowing of the subacromial space and subsequent increase in risk of injury.
CHAPTER III

Design

This study uses a longitudinal repeated measures design. Participants were measured prior to the start of the regular season (baseline) and within 10 days after the conclusion of the regular season. Data collected pre and post season included postural FHA and FSA and subacromial space measurements. Measurements for the volleyball participant group were obtained prior to the start of the regular season at the first testing session on August 22, 2016, and after the regular season at the second testing session from November 28th – December 5th, 2016. Measurements for club volleyball participants and comparison group were taken at the start of the fall semester from September 22nd – September 29th, 2016 and end of the fall semester from December 1st – December 7th, 2016. Subjects were retested at least 10 weeks after the first testing session.

Participants

Participants were recruited from a collegiate volleyball athlete group and a collegiate female comparison group. Participants in the collegiate volleyball athlete group were current student athletes on the varsity and club volleyball teams at the University of North Carolina at Chapel Hill (UNC). Participant subjects were excluded if they had an upper extremity surgery within the last 6 months or were unable to perform any of the movement tasks. The comparison group was included to account for changes in physical characteristics that occur due to the demands of
being a student in the collegiate setting. To be included for participation, comparison subjects must be current females in college. Comparison subjects were excluded if they are current student-athletes, if they had an upper extremity surgery within the last 6 months, were unable to perform any of the movement tasks, or if they participated in recreational volleyball activity at least 3 times per week. Comparison subjects were recruited from the Exercise and Sports Science department undergraduate student population and from Campus Recreation participants. Participants were matched based on age to ensure changes were not due to other influences such as skeletal maturity or hormonal changes. Recruitment targets for the participants and the comparison group were females between the ages of 18 and 25 years old. The dominant arm was used for testing in all subjects.

**Instrumentation**

Methods were adopted from Thigpen et al. (2009) and Hibberd (2016). Reflective markers were placed on the tragus, C7 vertebra, and anterior tip of the acromion on the dominant limb.\(^6\)\(^{22}\) A digital camera (Casio EX-F1, Dover, NJ, USA) was placed on a tripod shoulder high and 3.5 m from the wall. High resolution images were analyzed with Image J software (National Institute of Health, Bethesda, MD).\(^6\)

A portable brightness mode diagnostic ultrasound machine (LOGIQe, General Electric, Milwaukee, WI, USA) with a 4cm multi-linear array probe was used to obtain dominant arm measurements of the subacromial space. All images were taken at a frequency of 12 MHz, gain of 58 dB, and depth of 4.0 cm.
Procedure

After signing university approved informed consent forms, participants reported to a university laboratory on their designated testing dates. Participant’s age, height, weight, and handedness were recorded. After collecting demographics, participants began posture testing. Reflective markers were placed on the tragus, C7 vertebra, and anterior tip of the acromion on the dominant limb (Figure 1). The participants stood 40cm in front of a scaled backdrop on a horizontal reference line looking forward. Subjects were asked to stand in a relaxed posture and a flash photograph was taken in the sagittal plane. Subjects were then prompted to reach overhead and bent forward to “reset” the body position. This was repeated 3 times. These images were saved to a memory card to be reduced at a later time.

Subacromial space measurements were recorded using a portable B-mode diagnostic ultrasound machine (LOGIQe, General Electric, Milwaukee, WI, USA). The patient was seated in a chair and instructed to sit with their hands on their thighs in a natural relaxed posture. Ultrasound coupling gel was applied directly to the transducer and placed in the coronal plane of the shoulder. When the lateral tip of the acromion and humeral head was identified, the image was saved on a portable flash drive for future analysis (Figure 2). This was preformed 3 times on the dominant limb. A research assistant re-labeled the images to blind the primary investigator to prevent possible bias. Pilot testing was performed for each measure and intrasession reliability and precisions was demonstrated to be excellent (FHA (ICC) (2,1) = .95, SEM = 1.05°, FSA (ICC) (2,1) = .97, SEM = 1.57°, AHD (ICC) (2,1) = .89, SEM = 0.05 cm). Participants returned at their designated follow up times and
complete the identical testing session. Privacy has been considered and is explained in section A.6.2.

Posture assessment and subacromial space images were opened with ImageJ software (National Institute of Health, Bethesda, MD) to measure forward head angle, forward shoulder angle, and subacromial space measurements. Data reduction was adopted from Hibberd et al. (2016) by putting reflective markers on the tragus, C7, and anterior tip of acromion. A vertical line was drawn in reference to a leveled, gridded backdrop. FHA was measured from the vertical line connecting
the tragus and the C7 marker. FSA was measured from the vertical line connecting the C7 marker and the acromial marker. The primary investigator calculated forward head angle and forward shoulder angle. A scaled, vertical line was drawn to measure the subacromial space, which was the recorded as the shortest distance visualized between the inferior tip of the acromion and the humeral head. This was digitized and the primary investigator calculated subacromial space distance.

**Statistical Analysis**

Descriptive statistics were calculated for the means of age, height, and weight. To answer Research Questions 1 and 2, an independent t-test was used to assess the difference in forward head degree angle, forward shoulder degree angle, and subacromial space (cm) measurements between the two groups (collegiate volleyball players and comparison group subjects) over the course of a season. This analysis evaluated the differences in mean change scores pre- and post-regular season for forward head angle and forward shoulder angle for Research Question 1 and subacromial space measurements for Research Question 2.

To evaluate Research Questions 3 and 4, paired samples t-tests were used to assess the change from pre- to post-regular season in forward head angle, forward shoulder angle, and subacromial space measurements in the dominant limb of collegiate volleyball players. This analysis evaluated differences in mean change scores for FHA and FSA for Research Question 3 and subacromial space measurements for Research Question 4 from pre- to post-regular season in collegiate volleyball players.

In an exploratory analysis, paired samples t-tests were used to assess the
change from pre- to post-regular season in forward head angle, forward shoulder angle, and subacromial space measurements in the dominant limb of the comparison group and collapsed across the participant and comparison groups. In an additional exploratory analysis, the volleyball participant group was stratified into subgroups of the varsity participants and club participants. Paired samples t-tests were used to assess the change from pre- to post-regular season in forward head angle, forward shoulder angle, and subacromial space measurements in the dominant limb of each subgroup.

An alpha level of 0.05 was set for all comparisons for statistical significance, effect sizes (Cohen’s d), and 95% confidence intervals were calculated. Effect size quantifies the size of the difference between two groups to assess meaningful group differences and clinical relevance. Effect sizes will be interpreted as weak (<0.2), small (0.21<0.5), moderate (0.51<0.8), and large (>0.8). Although a finding may be statistically significant, the clinical meaningfulness may change depending on effect size. In regards to a clinically meaningful evaluation, Thigpen et al (2010) established that ideal posture is FHA <36 degrees and FSA <22 degrees, and poor posture FHA>46 degrees and FSA>52 degrees. Statistical analyses were run using SPSS version 23 software.

Based on power calculations, the required sample size for forward head angle was calculated to be 1,400 participants, forward shoulder angle was calculated to be 22 participants, and subacromial space was calculated to be 18 participants (Hibberd et al., 2016). Effect size of .5 was determined from the results of the dissertation of Hibberd et al. (2015) using percent change scores in swimming
athletes versus athletes over the 12 week training period. Because of this, there were 52 subjects in two groups: 26 collegiate volleyball players and 26 females, which will allow us to achieve sufficient power for forward shoulder angle and subacromial space. Despite a poor power analysis for forward head angle, it is an important measure to examine due to the differences between collegiate volleyball and club swimming athletes.
CHAPTER IV

Results

Twenty-six volleyball participants, 18 varsity and 8 club, (age: 19.62 ± 1.47, height: 181.42 ± 9.80, weight: 165.19 ± 20.38) and 26 female comparisons (age: 20.38 ± .90, height: 167.82 ± 7.99, weight: 142.96 ± 19.46) participated in the study. The volleyball participants had 25 right hand dominant subjects and 1 left hand dominant subject, and the comparison group had 24 right hand dominant subjects and 2 left hand dominant subjects.

For each dependent variable (forward head angle, forward shoulder angle, and acromiohumeral distance), independent samples t-tests were used to compare means between the change in dependent variables between collegiate volleyball subjects and comparison group subjects (Table 1). There was no significant difference between groups (volleyball versus comparison) over the course of a season for FHA ($t_{50} = 1.009, p=.318, d=.28$), FSA ($t_{50} = 1.120, p=.268, d=.31$), or AHD ($t_{50} = 1.041, p=.303, d=.29$).

Within the volleyball participation group, there was a significant increase in FHA ($t_{25} = -2.928, p=.007, d=.47$), no significant change in FSA ($t_{25} = .497, p=.623, d=.07$), and approaching a significant increase in AHD ($t_{25} = -1.800, p=.084, d=.27$) between the pre-testing and post-testing time points (Figure 3,4). Within the comparison group, there was a significant increase in FHA ($t_{25} = -2.598, p=.015, d=.30$), significant decrease in FSA ($t_{25} = 2.094, p=.047, d=.37$), and no significant
change in AHD ($t_{25} = -.065, p=.948, d=.01$) between the pre-testing time point and the post-testing time point (Figure 3,4).

Since there was limited significant change within groups, we collapsed the groups together to assess overall changes from preseason to post season. There was a significant increase in FHA ($t_{51} = -3.875, p<.001, d=.37$), approaching significance in FSA ($t_{51} = 1.822, p=.074, d=.21$), and no significant change in AHD ($t_{51} = -1.145, p=.258, d=.13$) (Figure 5,6). We also ran additional analyses that divided varsity and club volleyball athletes into subgroups due to the differences in overall load and volume (Table 2). Within the varsity subgroup there was no significant change in FHA ($t_{17} = -1.971, p=.065$), significant decrease in FSA ($t_{17} = 2.819, p=.012$) and a significant increase in AHD ($t_{17} = -2.502, p=.023$).

### Table 1. Descriptive Statistics of FHA(degrees), FSA(degrees) and AHD(cm) for Volleyball and Comparison Participants

<table>
<thead>
<tr>
<th></th>
<th>PRE</th>
<th>POST</th>
<th>CHANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volleyball</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FHA</td>
<td>36.82 ± 5.33</td>
<td>39.63 ± 6.44</td>
<td>2.80 ± 4.88*</td>
</tr>
<tr>
<td>FSA</td>
<td>53.35 ± 10.53</td>
<td>52.55 ± 11.45</td>
<td>-0.80 ± 8.18</td>
</tr>
<tr>
<td>AHD</td>
<td>1.47 ± 0.27</td>
<td>1.54 ± 0.25</td>
<td>0.07 ± 0.20</td>
</tr>
<tr>
<td>Comparison</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FHA</td>
<td>41.35 ± 5.18</td>
<td>43.00 ± 5.90</td>
<td>1.65 ± 3.23*</td>
</tr>
<tr>
<td>FSA</td>
<td>54.54 ± 8.31</td>
<td>51.22 ± 9.67</td>
<td>-3.33 ± 8.1*</td>
</tr>
<tr>
<td>AHD</td>
<td>1.40 ± 0.30</td>
<td>1.40 ± 0.30</td>
<td>0.00 ± 0.26</td>
</tr>
<tr>
<td>All Participants</td>
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<td></td>
</tr>
<tr>
<td>FHA</td>
<td>39.09 ± 5.68</td>
<td>41.31 ± 6.35</td>
<td>2.23 ± 4.14*</td>
</tr>
<tr>
<td>FSA</td>
<td>53.95 ± 9.41</td>
<td>51.88 ± 10.51</td>
<td>-2.06 ± 8.16</td>
</tr>
<tr>
<td>AHD</td>
<td>1.44 ± 0.28</td>
<td>1.47 ± 0.26</td>
<td>0.04 ± 0.23</td>
</tr>
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</table>

* Indicates a significant change between time points at the 0.05 level (2-tailed).

Note: Ideal posture is FHA <36 degrees and FSA <22 degrees, and poor posture FHA>46 degrees and FSA>52 degrees.⁶
Table 2. Descriptive Statistics of FHA(degrees), FSA(degrees) and AHD(cm) for Varsity Volleyball and Club Volleyball Participants

<table>
<thead>
<tr>
<th></th>
<th>PRE</th>
<th>POST</th>
<th>CHANGE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>FHA</td>
<td>FSA</td>
<td>AHD</td>
</tr>
<tr>
<td>Varsity</td>
<td>35.51 ± 5.46</td>
<td>38.13 ± 6.89</td>
<td>2.62 ± 5.46</td>
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<tr>
<td></td>
<td>53.81 ± 9.11</td>
<td>49.73 ± 11.21</td>
<td>-4.08 ± 5.97*</td>
</tr>
<tr>
<td></td>
<td>1.49 ± 0.26</td>
<td>1.59 ± 0.26</td>
<td>0.10 ± 0.17*</td>
</tr>
<tr>
<td>Club</td>
<td>39.76 ± 3.87</td>
<td>43.01 ± 3.71</td>
<td>3.25 ± 2.88</td>
</tr>
<tr>
<td></td>
<td>52.33 ± 13.90</td>
<td>58.90 ± 9.82</td>
<td>6.59 ± 7.58</td>
</tr>
<tr>
<td></td>
<td>1.43 ± 0.30</td>
<td>1.42 ± 0.18</td>
<td>0.01 ± 0.22</td>
</tr>
</tbody>
</table>

* Indicates a significant change between time points at the 0.05 level (2-tailed).

Note: Ideal posture is FHA <36 degrees and FSA <22 degrees, and poor posture FHA>46 degrees and FSA>52 degrees.6

Figure 3. Posture Measurements of Volleyball and Comparison Participants

* Indicates a significant change between time points at the 0.05 level (2-tailed).
Figure 4. AHD Measurement of Volleyball and Comparison Participants

* Indicates a significant change between time points at the 0.05 level (2-tailed).

Figure 5. Posture Measurements of Collapsed Group

* Indicates a significant change between time points at the 0.05 level (2-tailed).
Figure 6. AHD Measurement of Collapsed Group

* Indicates a significant change between time points at the 0.05 level (2-tailed).
CHAPTER V

Discussion

The primary purpose of this study was to compare postural assessments and potential subacromial space changes between collegiate volleyball players and the general female college population over the course of a season. Based on the results of the study, we cannot conclude that there is a significant change in FHA, FSA, or AHD when comparing collegiate volleyball athletes to a general female college population. These findings do not support our hypothesis that there would be a significant difference between the groups.

Overall, we observed that there was a significant increase in FHA in both collegiate volleyball players from pre- to post-season and the collegiate female comparison group from pre- to post-semester. Time had a small effect size on FHA for the volleyball players (d=.47) and the comparison group (d=.30), which may indicate that time did not have as large effect as we had proposed. What is interesting to note is that the study was powered based on FSA and AHD measurements. We had expected time to have a minimal effect on FHA, but instead it was a main finding of this study. Although the effect size indicates that the change in FHA is low, further research should investigate this relationship with the volleyball population, due to the differences in volleyball and swimming athletes.

In a cross sectional study, Hibberd et al. (2016) analyzed FHA, FSA, and AHD between competitive adolescent swimmers and non-overhead athletes during a
pre-season examination. They found no significant changes in FHA (p=.22), FSA (p=.60), or AHD (p=.10) when comparing both groups at pre-season.\textsuperscript{22} The difference in sport demands between volleyball and swimming may have attributed to the different findings between the swimming and volleyball athletes. The swimming athletes compete in the horizontal position and must properly activate the cervical extensors in order to maintain proper head posture when pulling their head out from the water. Alternatively, the volleyball athletes consistently flex their head forward during the hitting motion, which may increase forward head posture.

It is possible that the increase in FHA may be attributed to the everyday demands of being a college student, including long term sitting,\textsuperscript{2} computer use,\textsuperscript{47} texting,\textsuperscript{46} and backpack use.\textsuperscript{48} Smart phone and computer use increases forward head and forward shoulder angle with use, and the small screens of smart phones cause further forward head posture toward a line of vision below eye level.\textsuperscript{57,58} College students also spend a large amount of time sitting at desks in class, which is not ergonomically advantageous due to the forward posture needed to read documents on a flat desk.\textsuperscript{59} Either individually or collectively, long term sitting, computer use, smart phone use, back pack use, and other potential factors may contribute to an increased predisposal to poor posture and shoulder pathology in female college students. Clearly this is an important area for future study.

An increase in FHA can ultimately lead to a change in scapular stabilizing muscle activation. This change in muscle activation could lead to dysfunction and ultimately pain. Prolonged forward head posture puts increased stress on normal spinal curvature and makes it difficult to maintain proper head posture. Over time,
the high levels of stress on the surrounding musculature and skeletal tissue can lead to a degradation of the natural cervical spine curvature and result in chronic pain and dysfunction.\textsuperscript{58} If there is not an intervention to correct the faulty postures that develop with smart phone and computer use during the college years it is possible that associated conditions could progressively worsen over time. Future research could identify if a relationship exists between years of school and head posture, as the change in FHA may be cumulative and continue to cause pain and dysfunction within the cervical spine.

Greater scapular internal rotation, greater anterior tipping of the scapula and less serratus anterior activity during humeral flexion and overhead reaching has been shown to be associated with poor posture.\textsuperscript{6,60,61} Lack of serratus anterior muscle activity can negatively affect the upward/downward and anterior/posterior tipping of the scapula, which can contribute to changes in scapular kinematics.\textsuperscript{6,62} There can also be changes in the timing of muscle activity between the upper and lower trapezius\textsuperscript{62} and increased upper trapezius activity contributing to increased forward head posture.\textsuperscript{63} Individuals may demonstrate FHRSP and associated muscle imbalances, but they may not experience pain. This may be due compensating for postural deviation with other muscle activity over a relatively short period of time. However, over a college career there may be a worsening of posture, and thus a predisposition to pain and dysfunction if corrective postural exercises are not addressed.

Although there was a significant increase in FHA for both groups, there was a smaller increase in FHA in the volleyball participation group. This suggests that the
volleyball participation group had better posture when compared to the comparison groups at both pre- and post-measures. This may possibly be attributed to a combination of the postural exercises, preventative arm care, strengthening exercises, and overall demands of the sport that the athletes routinely integrate into their daily training and conditioning regimen, which is essential for optimal performance in sport activity. Collectively, these factors may function to open the subacromial space during activity and improve posture.\textsuperscript{58,62,64,65} Varsity athletes have been exposed to postural evaluation screenings, which is less likely for non-athletes. Previous feedback from these postural evaluations may have influenced their posture while the measurements were taken.

The increase in AHD for the volleyball participants was approaching a significant increase, while there was virtually no change at all in the comparison group. When the participant group was divided into subgroups of varsity and club participants, there was a significant increase in AHD in the varsity participants. Clearly, this does not support our hypothesis that there would be a significant decrease in volleyball participant’s AHD due to hitting mechanics and the volume of overhead activity. Although no injury diagnoses were documented, there were anecdotal reports of anterior shoulder pain in the volleyball participants. Reeser et al. (2010) found that 60\% of collegiate club volleyball athletes have experienced a shoulder problem, with 42\% reporting a current shoulder problem during the current season.\textsuperscript{20} Subjects were screened for anterior impingement and anterior instability and 29\% reported anterior shoulder pain with glenohumeral flexion in the scapular plane. 29\% had apprehension at external rotation end range of motion with 82.5\% of
those subjects having relief with humeral head relocation, indicative of glenohumeral instability.20

This leads us to speculate that a symptomatic patient may not have a structural change that leads to a decrease in AHD and subsequent impingement, but rather secondary external impingement due to glenohumeral instability. Microtrauma from repetitive stress causes pathology to the static and dynamic stabilizers of the shoulder. During repeated overhead motions, the glenohumeral ligaments and capsule are under a substantial amount of stress, which can eventually lead to attenuation. If the static structures are compromised there will be increased demand on the dynamic structures.28 The rotator cuff muscles and long head of biceps brachii are the primary dynamic stabilizers that are weakened or fatigued around the glenohumeral joint. These impairments in the rotator cuff alter the supraspinatus and deltoid force couple. This alteration results in muscular imbalances that do not allow the supraspinatus to center and stabilize the humeral head while the deltoid forces that humeral head superiorly, leading to compression of the subacromial space structures and rotator cuff degeneration.26,28,31 Additionally, impairments of the long head of the biceps brachii decrease the superior and anterior stability of the glenohumeral joint.31 Secondary external impingement can also be due to weak serratus anterior, middle trapezius, lower trapezius, and overactive upper trapezius14,31,33 and a malposition of the scapula from overuse muscular fatigue (SICK scapula).5,34,35

Hebert et al. (2003) found that AHD significantly decreased during shoulder elevation in subjects with impingement compared to subjects with healthy shoulders,
but there was no significant change between the two conditions with the shoulder in a resting position.\textsuperscript{66} Additionally, Graichen et al. (1999) used an open MR system to evaluate the shoulders of 10 healthy subjects and 10 subjects with impingement syndrome. In all patients with impingement syndrome, there was a significant reduction in AHD during active glenohumeral abduction and an increase in AHD during relaxation.\textsuperscript{67} The upward migration of the humeral head and narrowing of the subacromial space was evident during muscle activity, but not relaxation.\textsuperscript{67} These studies suggest that there may not be a structural narrowing of the subacromial space in overhead athletes and patient populations with chronic subacromial impingement syndrome. Instead, the chronic forces around the shoulder may weaken the structural integrity of the glenohumeral joint and subsequently increase the AHD due to an inability to keep the humeral head stable and centered on the glenoid. The volleyball participants did not have any significant decrease in AHD in the resting position; however, there is a high prevalence of shoulder injuries primarily due to excessive overhead hitting\textsuperscript{10} Our findings suggest that subacromial impingement likely occurs during faulty dynamic overhead activity, rather than a structural change between the acromion and humeral head that would decrease the resting AHD position.

\textbf{Limitations}

There are several limitations to our study that warrant acknowledgement. Testing sessions were performed at different times due to the start of the varsity volleyball season prior to the start of the fall semester. We were unable to control for the activity performed by all of the subjects, including weight training and possible
postural stability exercises. We were also unable to control for the volume
differences between players based on their demand and position. Changes in the
subacromical space may not have been observed due to testing in a resting position,
compared to a functional movement task throughout various ranges of motion.
Additionally, the collegiate volleyball participants were made up of both club and
varsity level athletes, which require a different level of time, workload, and intensity.
The overall load of the volleyball athletes may not have been sufficient enough to
cause change from positional demands and total time spent performing overhead
activity during participation. Further studies could examine a larger population size
that is tested over a longer period of time to evaluate if the changes remain
consistent, worsen, or improve. Studies could also look at male overhead athletes
compared to a general male collegiate population. AHD measurements can also be
recorded throughout various glenohumeral ranges of motion more specific to the
necessary dynamic tasks specific to sport in association with shoulder pain and
dysfunction.

**Clinical Significance**

This research can be used for both the athletic population and general
population. Postural measurements are quick and valid clinical assessment tools
that can be used to generate a baseline and follow up assessment of posture
following activity or interventions. This study revealed that both groups, regardless of
activity participation, have an increase in FHA over the course of a season. Based
on the study results, it is recommended that all collegiate students to have an
understanding of posture and the available cervical and arm care interventions.
This research also gives insight on potential changes in subacromial space of collegiate volleyball athletes, specifically at the varsity level. Although there was not sufficient power for the varsity participant subgroup, there was a significant increase in AHD over the course of the season. An increase in resting AHD and altered shoulder kinematics with subsequent shoulder pain has been seen in subjects with subacromial impingement. Volleyball athletes may have shoulder dysfunction that is related to an increase in AHD. Thus, it is recommended that volleyball and overhead athletes integrate an arm care program that focuses on eccentric exercise for rotator cuff and scapular function, strength, and endurance.\textsuperscript{68,69}

**Conclusions**

There was not a significant change in posture or subacromial space between collegiate volleyball athletes and college female students from pre- to post-season. However, there was a change in FHA in both groups, which is likely due to the factors associated with being a college student. We understand that there is an increase in FHA over the course of a semester in the female college students in this study, regardless of activity, due to the demands of being a college student. An increase in FHA and subsequent worsening of posture can lead to altered scapular kinematics and altered length tension relationships, which in turn may result in pain and dysfunction. This is especially important for the overhead student athlete that needs to have proper biomechanics for success in sports while enduring the everyday physical stress of being a college student. This warrants proactive maintenance exercises for all students to help prevent the development of poor posture.
REFERENCES


