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The Sleeper Stretch: Effects on Range of Motion and Injury in Baseball Players

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THE SLEEPER STRETCH: EFFECTS ON RANGE OF MOTION AND INJURY IN BASEBALL PLAYERS

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ABSTRACT

THE SLEEPER STRETCH: EFFECTS ON RANGE OF MOTION AND INJURY IN BASEBALL PLAYERS

by Kendall K Grow

The purpose of this study was to provide information concerning the effects of a posterior capsule stretching program on the internal range of motion (R-O-M) of overhead athletes as well as to determine if there was any impact on the number of players experiencing shoulder injuries. Thirty-five Division I collegiate baseball players had the degree of shoulder internal rotation (IROT) assessed in both their dominant and nondominant arms (pretest) and were subsequently divided into those who exhibited GIRD (glenohumeral internal rotation deficit; n=27) and those who did not (n=8). Then the Sleeper Stretch was taught to each player and utilized over the course of a 12-week period. Intermittent (every 4 weeks) as well as posttreatment reassessments were performed to determine changes in R-O-M across the length of the study. Parametric and nonparametric analyses indicated a significant gain of 9° of IROT over the course of the study, with the most prominent (6°) gain occurring between weeks 8 and 12. No differences between the GIRD and non-GIRD groups were noted. In addition, no shoulder injuries occurred during the 2010 season, although the comparison to the injury rates of the previous three seasons failed to be statistically significant. Clinically, an increase in R-O-M, coupled with the absence of shoulder injuries, suggests that the Sleeper Stretch could be a promising preventative measure for overhead athletes.

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Chapter 1

INTRODUCTION

Injuries may occur at any time during athletic participation and are common occurrences among athletes. The National Collegiate Athletic Association Injury Surveillance System (NCAA ISS) has reported that collegiate sports, particularly at the Division I level, have the highest incidence of injuries in season when compared to pre- and postseasons (Hootman, Dick, & Agel, 2007). Injuries may occur to the bone, muscle/tendon, ligament, nerve, cartilage, or skin (Arnheim & Prentice, 1997). One of the most common noncontact injuries occurs to muscles/tendons (Hootman et al., 2007). Woods, Bishops, and Jones (2007) reviewed athletic injuries and found that muscle injuries account for over 30% of the population seen in sports medicine clinics. They concluded that this possibly resulted from a condition that diminishes contractibility and ability of the muscle to absorb energy and, as a result, potentially made the muscle more susceptible to injury. Over a 16-year follow-up, the NCAA ISS documented that upper extremity and shoulder injuries accounted for approximately 20% of athletic injuries (Hootman et al., 2007).

The shoulder joint is comprised of three main bones: the clavicle, the humerus, and the scapula. These bones intimately work together to provide the motions seen at the shoulder (Arnheim & Prentice, 1997). The healthy shoulder is a very mobile joint that should present with 90° of internal rotation (IROT) and 90° of external rotation (EROT). Consequently, this mobility compromises stability, thus making the shoulder more susceptible to injury (Arnheim & Prentice, 1997). Repetitive overhead movements commonly lead to the overuse injuries seen in athletes (Arnheim & Prentice, 1997). Meister (2000) noted that the throwing motion, specifically, demands much resistance throughout its phases and puts the shoulder at risk. The throwing mechanism is divided into five phases: wind-up, cocking, acceleration, deceleration, and follow-through. The deceleration phase is most damaging because of the extreme forces placed on the shoulder (Park, Loebenberg, Rokito, & Zuckerman, 2003). These violent forces are repetitively placed on the shoulder joint, eventually causing osseous and soft tissue adaptations to its anatomy. The adaptations can lead to loss of range of motion (R-O-M); specifically, a loss of IROT. This condition is known as glenohumeral internal rotation deficit (GIRD) (Osbahr, Cannon, & Speer, 2002). This loss of IROT has been associated with rotator cuff injuries (i.e., impingement and tears), anterior instability, labral tears, and scapular dyskinesis (Burkhart, Morgan, & Kibler, 2003a; Meister, 2000; Ouellette et al., 2007; Sauers, August, & Snyder, 2007).

GIRD is a common problem among overhead athletes (Lorenz, 2005; Tokish, Curtin, Kim, Hawkins, & Torry, 2008), especially baseball players. GIRD is associated with a loss of shoulder IROT, and often an increase in EROT (Myers, Laudner, Pasquale, Bradley, & Lephart, 2006; Osbahr et al., 2002; Reagan et al., 2002). Investigators have attributed this change in motion to a stretching of the anterior capsule, and tightening of the posterior capsule (Burkhart, Morgan, & Kibler, 2003b; Myers et al., 2006; Sauers et al., 2007), however, recent research indicates that the posterior capsule does not tighten, but thickens (Thomas et al., 2009b). Researchers have suggested that, although an individual may be asymptomatic, there are potential problems with repetitive throwing, and that stretching the posterior capsule will help prevent injury (Lorenz, 2005; Sauers et al., 2007).

R-O-M, strength, and neuromuscular control are key factors in preventing injuries. The body must be able to go through its necessary R-O-M to perform properly. The surrounding musculature must also be strong enough to tolerate the forces demanded by the body's tasks. Trakis and colleagues (2008) suggested that proper stretching of the posterior capsule and strengthening of the posterior shoulder musculature may aid in preventing injury. Similarly, Lorenz (2005) and Sauers et al. (2007) suggested that stretching the posterior capsule will help prevent injury. Stretching the posterior shoulder is the common theme for preventing injuries.

Few investigators have looked at the stretching techniques for the posterior capsule such as the Cross-Body Stretch and the Sleeper Stretch (Laudner, Sipes, & Wilson, 2008; Lintner, Mayol, Uzodinma, Jones, & Labossiere, 2007; McClure et al., 2007). McClure and colleagues (2007) found that the Cross-Body Stretch and the Sleeper Stretch were both beneficial for reducing posterior shoulder tightness. Laudner et al. (2008) studied the immediate R-O-M effects of the Sleeper Stretch; however, they did not relate the data to functional activity. Lintner and colleagues (2007) examined the long-term (i.e., over months and years) stretching protocol utilized by the Houston Astros. Their findings were consistent with the conclusions of Woods et al. (2007) that long-term stretching programs are beneficial for increasing flexibility, subsequently, increasing R-O-M, because the amount of stretch determines the amount of permanent lengthening for tissue.

In summary, the shoulder is most commonly injured in overhead athletes. Repetitive movements can cause changes in the structures of the shoulder. Most often, overhead athletes experience a loss of IROT and a gain in EROT, causing a tightening/thickening of the posterior capsule, potentially leaving the athlete susceptible to injury. Strengthening and stretching the posterior shoulder may help prevent such injuries. There are various ways to stretch the posterior capsule, but few researchers (Laudner et al., 2008; Lintner et al., 2007; McClure et al., 2007) have compared these different techniques to find the most beneficial method. However, the majority of these researchers focused on the acute effects of stretching. No data exist on a stretching protocol lasting for as long as 12 weeks for collegiate baseball players. Further, there are no data on the effects of stretching protocols on injury rates in college baseball players.

Problem Statement

The purpose of this study was to examine the effects of the Sleeper Stretch on the IROT gains in Division I collegiate baseball players over the course of 3 months and, in turn, determine if there was also a decrease in the number of players experiencing shoulder injuries during the current (2010) season relative to the past three seasons.

Hypotheses

Due to the supporting evidence concerning the beneficial effects of the Sleeper Stretch, the following hypothesis was proposed for the study:

1. The Sleeper Stretch will produce significant gains on the internal rotation deficits present in the Division I collegiate baseball players.

Due to the absence of evidence concerning diminished injury rates after implementing stretching protocols, the following null hypothesis was proposed for this study:

2. There will be no difference in the number of players experiencing shoulder injuries during the current baseball season relative to the number who experienced such injuries during the previous three seasons.

Limitations

Some of the most significant limitations to this study are innate to the type of research design being utilized. While the one-group design has the advantage of the subjects serving as their own controls, which helps to reduce individual differences as a source of between group differences and/or reducing the sample size between conditions/groups, therefore allowing for the detection of differences in before and after scores, this approach is considered a "pseudo-experimental design" and leaves a large number of secondary variables uncontrolled (Huck, Cormier, & Bounds, 1974; Matheson, Bruce, & Beauchamp, 1978). A main concern is the possible effect of participant awareness of the study. That is, the participants may be affected by their interpretation of the purposes of the study or the motivation to provide treatment effects for the investigator. However, other factors that are beyond the investigator's control, but that can have significant impact on a longitudinal design such as this, include historical, maturation, and mortality issues. Basically, as the length of the study increases, so do the possible effects of the participants changing in some way that is not attributable to the experimental treatment effects, therefore causing difficulty in clear interpretation of results. For example, participants' R-O-M could be affected by accidents or extracurricular activities, such as getting hurt playing pick-up football or basketball, accidental falls, strains from moving furniture, and so forth. These were threats to the interpretability of the treatment effects. Also, as the length of the study increases, the potential for the number of participants "lost" to the study, for a variety of reasons, was an increasing threat. Of importance is the notion that the lost participants could somehow diminish the significance of the findings. However, while a longer study increases certain risks, the 12-week duration of this study is also a limitation. This length of time was not selected based upon any supporting literature, but due to the ability of the primary investigator (PI) to access the baseball team. A study of longer duration may be more sensitive in detecting long-term beneficial effects of a stretching regime on increasing R-O-M and reducing shoulder injuries. Further, the second part of the study, to investigate the effects of the Sleeper Stretch on the injury rate over the course of the season, when compared to the past three seasons, may also be susceptible to certain limitations. In particular, the past three seasons had many variables that were not controlled. Specifically, the PI could not control the players that started each game, those who played more than others, the weather/conditions, the team dynamics, warm up routines, and so on of past seasons. Each of these factors may indirectly contribute to the injuries incurred over the past three seasons; therefore, this was recognized as a critical limitation, exclusive to the second part of the study.

Delimitations

A principal delimitation of this study is the exclusive participation of college-age, male baseball players from the PI's university. These participants were selected due to the PI's direct and frequent access to them for the duration of the study. However, having such a narrow participant focus impacts the generalizability of this study. That is, using the accessible participant population does not guarantee similarity to other baseball players from other universities, to other geographic locations, to other age ranges, or even other overhead athletes (e.g., girls' high school volleyball). Another critical limiting factor is the restricted focus on the Sleeper Stretch. Improvements in R-O-M and reduced injuries may indicate beneficial effects of the Sleeper Stretch, but without a comparison stretch, it would be difficult to conclude that this is the only stretch to use, or even imply that it is superior to any other stretching regimen.

Assumptions

Once they were notified of the potential benefits, it was assumed that all participants properly performed the stretch each time it was executed. Also, no participant carried out the stretch without supervision by the PI or the investigator's assistant (Tester 2). Lastly, all participants honestly answered the questions regarding previous injury or Sleeper Stretch participation.

Definition of Terms

<u>Glenohumeral internal rotation deficit</u> (GIRD) - "the loss in degrees of glenohumeral internal rotation of the throwing shoulder compared with the non-throwing shoulder" (Burkhart et al., 2003a, p. 406).

<u>Posterior capsule tightness</u> - occurs when the posterior capsule and musculature of the shoulder tighten, usually due to "repeated overload in the eccentric portion of arm deceleration" (Lorenz, 2005, p. 60).

Range of motion (R-O-M) - "the distance, measured in degrees, that a limb moves in one plane" (Starkey, 2004, p. 404).

Recurrent injury - injury that occurs to a body part that has previously sustained the same type of injury, either in the current academic year or one academic year prior to the current (Swenson, Yard, Fields, & Comstock, 2009).

Sleeper Stretch - the Sleeper Stretch isolates the soft tissue of the posterior shoulder. It is performed by having the participant side-lying on his dominant side. The participant's shoulder and elbow are positioned to 90° of flexion, with the lateral border of the scapula against the ground. Pressure is applied to the distal forearm in the motion of IROT. This pressure is held constant at the end R-O-M (Laudner et al., 2008).

Time-loss Injury - injury, classified as moderate severity, requiring the removal from athletic participation for at least 8 days (Powell & Barber-Foss, 2000) or the equivalent of at least 4 games.

Importance of the Study

Most researchers who have studied posterior capsule tightness and its related injuries have only examined the acute effects of various stretching protocols. In addition, professional athletes have tended to be the focus of study. Laudner and colleagues (2008) examined the acute effects of the Sleeper Stretch and found no statistical significance in IROT gains between the pretests and posttests; however, they did not study the IROT gains in a functional manner. On the other hand, Lintner et al. (2007) examined a long-term stretching protocol designed for the Houston Astros. The participants were divided into two groups: those that had undergone the stretching program for 3 years or more and those that had not. Statistical significance of R-O-M increase was found for those involved in the stretching program for 3 years or more, suggesting a benefit of long-term stretching for professional baseball players.

This study examined the effects of the Sleeper Stretch on collegiate baseball players over the course of 12 weeks. No published studies have involved a stretching protocol of this duration for this particular population. Further, no data exist on injury rates as they relate to the increases of IROT such athletes obtain through their stretching protocols. Although baseball pitchers are the most common position studied, this study involved all position players. Results from this study provided information on the Sleeper Stretch in the prevention of overuse injuries. Identifying R-O-M deficits early in an athlete’s career may contribute to longer participation, since injuries and improper mechanics are carried beyond college.

Chapter 2

REVIEW OF LITERATURE

Injuries to those who participate in athletics are a common occurrence (Hootman et al., 2007). In particular, those who engage in overhead sports (e.g., baseball, volleyball) are prone to shoulder injuries. The shoulder is a complex joint that allows extreme mobility; however, this degree of mobility also compromises stability, particularly in regard to the types of repetitive demands commonly encountered in the overhead athlete (Woods et al., 2007). The shoulder joint is comprised of three main bones: the clavicle, the humerus, and the scapula, and these intimately work together to provide the motions seen at the shoulder (Arnheim & Prentice, 1997).

In overhead athletes, the motions of the shoulder are often functionally seen in the throwing mechanism, which is divided into five phases: wind-up, cocking, acceleration, deceleration, and follow-through (American Academy, 1991; Park et al., 2003). The deceleration phase is known as the most damaging phase because of the extreme forces placed on the shoulder (Park et al., 2003). These violent forces are repetitively placed on the shoulder joint, eventually causing osseous and soft tissue adaptations to its anatomy. The adaptations can lead to loss of R-O-M, specifically, a loss of IROT, a condition known as GIRD (Osbahr et al., 2002). Continuously damaging forces can lead to shoulder injuries such as rotator cuff pathologies, labral tears, anterior instability, and scapular dyskinesis (Burkhart et al., 2003a; Clabbers et al., 2007; Meister, 2000; Ouellette et al., 2007; Sauers et al., 2007). These injuries are entwined with each other, and sometimes are the culprit of further injury. Although bony adaptations are permanent, an effort can be made to correct the soft tissue alterations. However, these are postinjury procedures, and it is preferable to undertake preventive procedures to avoid such injuries. Many researchers suggest stretching protocols and physical training to prevent complications at the shoulder (Laudner et al., 2008; Lintner et al., 2007; Woods et al., 2007). Specifically, posterior capsule stretching is one approach that has been examined for the prevention of shoulder injuries in overhead athletes (e.g., Laudner et al., 2008; Lintner et al., 2007; McClure et al., 2007).

The purpose of this chapter is to provide a more detailed rationale for the use of posterior capsule stretching as a means of increasing shoulder R-O-M in overhead athletes in an effort to reduce the incidence of shoulder injuries.

Anatomy of the Shoulder

The shoulder is a complex ball and socket joint that allows extreme mobility and is comprised of three main bones: the clavicle, the humerus, and the scapula. The clavicle is an S-shaped bone that attaches at the manubrium of the sternum and the acromion of the scapula, forming the sternoclavicular joint and acromioclavicular joint, respectively (McKinley & Dean O' Loughlin, 2006). The humerus is the largest and longest bone of the upper limbs. The proximal end, or head, of the humerus articulates with the glenoid fossa of the scapula to create the glenohumeral joint (Crouch, 1985). The scapula is a flat, triangular bone that sits over the posterior wall of the thorax between the second and seventh ribs (Crouch, 1985). Main structures of the scapula for the shoulder joint are the acromion, glenoid fossa, and coracoid. The acromion connects with the clavicle via ligaments, the glenoid fossa articulates with the head of the humerus by means of the glenoid labrum (fibrocartilage) and many ligaments to create the shoulder capsule, and the coracoid attaches to the humerus, clavicle, and acromion via ligamentous structures (Crouch, 1985).

Due to the vast degree of movement of the shoulder joint, stability may be compromised (Arnheim & Prentice, 1997; Crouch, 1985). The movements of the shoulder are comprised of synchronized motions occurring from all three bones of the joint (Crouch, 1985). Independently, the humerus can move into flexion, extension, abduction, adduction, horizontal abduction, horizontal adduction, IROT, and EROT. The scapula can travel in retraction, protraction, elevation, depression, and upward and downward rotation. In contrast, the clavicle has no independent motion, and moves only slightly in congruence with the other bones (Magee, 2006; Myers, Laudner, Pasquale, Bradley, & Lephart, 2005). Importantly, the scapula and humerus move in an orchestrated manner known as scapulohumeral rhythm. This rhythm is seen when moving from about 60° of abduction toward 180° of abduction, where there is approximately a 2:1 ratio of humeral to scapular movement (that is, for every 2° of humeral movement, there is 1° of scapular movement). Scapulohumeral rhythm can be further broken down to describe the movements of each shoulder bone throughout the motion of abduction. In the first phase (0-30°), the humerus elevates into abduction up to 30°. There is little to no movement from the scapula or clavicle. However, in the second phase (30-90°), the humerus elevates 40°, while the scapula rotates approximately 20°, thus creating the 2:1 ratio. There is also little elevation seen from the clavicle due to this scapular movement. In the third phase (90-180°), the 2:1 ratio remains with the humerus moving at 60° of abduction, the scapula at 30° of rotation, and the clavicle rotates and elevates to allow the motion to occur smoothly (Magee, 2006). This rhythm is necessary to maintaining a healthy balance of movement throughout the shoulder.

Similar to healthy scapulohumeral rhythm, there are set ranges of normal motion that the shoulder should demonstrate. A healthy shoulder should exhibit 0-180° of flexion, 0-50° of extension, 0-180° of abduction, 0-40° of adduction, 0-90° of IROT, and 0-90° of EROT. Loss of motion from these normal ranges can lead to compensatory actions and adaptations that may leave an individual susceptible to injury (Arnheim & Prentice, 1997; Luttgens & Hamilton, 1997; Starkey & Ryan, 2003).

In summary, the structures comprising the shoulder (the clavicle, humerus, and scapula) must work together to allow the extreme motions characteristic of this joint. Healthy R-O-M, including scapulohumeral rhythm, is important to maintain full functional mobility, particularly in sports that place significant demands on the shoulder (such as baseball). Since the structures are so intimately related, injury to one may cause serious imbalance for the entire joint.

Phases of the Throwing Motion

Functional movement of the shoulder across the phases of the throwing motion is complex, but can be broken down into five distinct phases: wind-up, cocking (early and late), acceleration, deceleration, and follow-through. Throughout each phase, various structures are utilized to perform the high velocity task of throwing (American Academy, 1991).

The wind-up phase begins when the pitcher starts the motion and ends when the ball leaves the glove. The goal of this phase is simply to arrange the body's posture and balance to prepare for the next phase (Bailey, 2009). Most of the motion occurring in the body is in the lower trunk; the pitcher is "pushing off" with the hind leg and then brings it forward, causing the body to rotate toward the throwing target (Park et al., 2003). This rotation of the body is extremely important as it is estimated that approximately 50% of the velocity of the overhand throw results from the step and body rotation, and the remainder from the shoulder, elbow, wrist, and fingers (Toyoshima, Hoshikawa, Miyashita, and Oguri, 1974, as cited in Park et al., 2003).

The second step in the throwing action is the cocking phase, which is sometimes broken down into early and late cocking phases. In the early cocking phase, the stride leg, which is elevated and flexed from the wind-up, extends toward the target, while the trunk starts a slight forward movement. As soon as the stride foot hits the ground, this early phase is completed. Specifically, at the shoulder, the scapula is retracted and humerus horizontally abducted (Bailey, 2009; Myers et al., 2005). In this position, it is important for the trapezius, serratus anterior and, particularly, the supraspinatus, infraspinatus, and teres minor, to stabilize the glenoid (Johansen, Callis, Potts, & Shall, 1995); otherwise, abduction of the arm can cause instability and impingement (Park et al., 2003). During the late cocking phase, the trunk rotates forward, but the shoulder becomes the prime mover, as the forces from the lower trunk disperse into the shoulder. The scapula begins to protract, while the humerus abducts and externally rotates to its maximum capacity (Bailey, 2009). The EROT is due to activity from the infraspinatus and teres minor; these muscles produce this rapid movement while stabilizing the humeral head in the glenoid. This stability is important because, as the arm is maximally externally rotated, the rotator cuff tendons and labrum are pinched between the humeral head and glenoid, which can cause impingement (Park et al., 2003). Once the arm achieves maximum EROT, the late cocking phase is over.

Next is the acceleration phase—a very fast, explosive part of the throwing motion that accelerates a ball from a “stationary position to speeds up to 95 miles per hour in about 50 milliseconds” (Park et al., 2003, p. 76). During this phase, the scapula continues to protract, while the humerus is forcefully internally rotated (Bailey, 2009) approximately 7000+ degrees per second (Borsa, Laudner, & Sauers, 2008; Zheng, Fleisig, & Andrews, 1999). The latissimus dorsi and pectoralis major are the key muscles firing to contribute velocity to the ball. Concomitantly, all scapular stabilizing muscles are working to keep the scapula stable in this high force phase. Specifically, the subscapularis and teres minor fire to prevent subluxation of the humeral head during the rapid IROT (Johansen et al., 1995; Park et al., 2003). The acceleration phase is complete upon ball release.

In the deceleration phase, the ball has been released, and the muscles must act to slow down the throwing arm. Bailey (2009) states that the deceleration forces are almost double the acceleration forces. The shoulder is “abducted, horizontally adducted, and internally rotated” (Zheng et al., 1999, p. 10). The rotator cuff muscles are eccentrically firing to slow the arm while still stabilizing the glenohumeral joint. This eccentric maneuver of the rotator cuff causes the greatest strain in the musculature, leaving it susceptible to injury (American Academy, 1991). The deceleration phase is deemed over when the pitcher reaches 0° on IROT.

The final phase is the follow-through, where the throwing arm is adducted across the body while the body moves forward to aid in reducing the forces placed on the rotator cuff during deceleration. The planted leg remains fixed to the ground to maintain the body's balance (American Academy, 1991; Bailey, 2009; Park et al., 2003).

Across the five phases of the throwing motion tremendous forces are placed on the shoulder and its surrounding musculature to accelerate the ball, decelerate the arm, and stabilize the shoulder joint, all in a matter of seconds. However, the shoulder may be the most susceptible to injury during the late cocking, acceleration, and deceleration phases, as stabilizing demands are by far the greatest. Reflective of the magnitude of demands and stresses placed on this ball and socket joint, Bailey (2009) comments, "It's a wonder we can throw at all!"

Anatomical Adaptations in the Shoulder

Repetitive motions, such as the throwing motion, that demand much torque throughout its phases, can cause alterations in the structures of the body over time (Meister, 2000). In particular, it is believed that this repetitive, forceful action can cause bony and soft tissue changes at the shoulder (Huffman et al., 2006; Osbahr et al., 2002; Reagan et al., 2002); however, when these adaptations specifically start to occur is unknown. Studies have recently been undertaken to explore when adaptations to the shoulder may occur by examining the throwing mechanics of children.

Meister and colleagues (2005) examined the glenohumeral R-O-M in Little League baseball players. Over the course of 1 year, 294 players, ages 8-16, had shoulder flexion, IROT, and EROT measured in both arms. They found an overall significant change in all three shoulder motions between the 8-year olds and the 16-year olds. Specifically, there was a decrease in IROT from the 8-year olds (39.0°) to the 16-year olds (21.3°), a loss of 17.7°. Closer examination revealed that the significant decrease in IROT was most notable at the ages of 12 and 13. The Meister et al. (2005) study, however, did not examine how much repetitive throwing motion was required (e.g., 1 month, 6 months, 1 year, 2 years, and so on) in order for these changes to occur.

Thomas, Swanik, Swanik, and Huxel (2009a) examined glenohumeral adaptations after a single high school sports season (12 weeks) to determine the length of time necessary to detect adaptation changes in the shoulder. Thirty-six high school female overhead athletes underwent glenohumeral internal and external R-O-M measurements in both arms by one investigator, preseason and postseason. In addition, upward rotation and protraction of scapular positions were assessed at the same time. Results indicated a significant decrease in IROT after only 12 weeks ($r = 0.012$), and this decrease was more prevalent in the dominant arm than the nondominant. Also, an increase of EROT between the dominant and nondominant arms was evident. Additionally, scapular positioning (upward rotation and protraction) was significantly altered ($r = 0.003$-0.007) over the course of the 12-week season. While these outcomes indicated that adaptations causing R-O-M changes do occur within the course of 12 weeks, they did not indicate whether bony or soft tissue alterations occurred.

Bony Adaptations

It is well documented that repetitive throwing can cause osseous (bony) adaptations in the throwing shoulder (Crockett et al., 2002). Some believe that these osseous changes occur before the end of skeletal growth (Crockett et al., 2002; Meister et al., 2005). The bony adaptation seen in overhead athletes is the phenomenon of humeral head retroversion. Humeral retroversion is defined as “the acute angle, in a medial and posterior direction, between the axis of the elbow joint and the axis through the center of the humeral head” (Reagan et al., 2002, p. 354). Simply stated, the humeral head migrates in a medial and posterior direction in the glenoid fossa.

A widely cited study by Crockett and colleagues (2002) examined the osseous changes present in professional baseball pitchers. Twenty-five pitchers comprised the experimental group, while 25 males with no history of participation in overhead sports were used for the control group. All participants had their glenohumeral R-O-M, laxity, and retroversion assessed on both dominant and nondominant arms. Three examiners evaluated R-O-M and laxity, and retroversion was examined using a computed tomographic scan (CT scan). Results indicated no differences among R-O-M or laxity between arms, or between groups. However, for the pitchers, there was a significant increase of humeral retroversion of the dominant arm when compared to the nondominant arm (mean difference of 17°), as well as a significant increase of retroversion of the dominant arms of the pitchers when compared to the control group (mean difference of 22°). Crockett and associates (2002) concluded that the increase of humeral retroversion contributed to the loss of R-O-M found in the overhead athletes.

Similarly, Tokish and colleagues (2008) studied 23 professional pitchers to assess their humeral retroversion and its relationship to reductions in R-O-M. Glenohumeral R-O-M and laxity were assessed, and then radiographs (x-ray) were taken to examine humeral retroversion. Results revealed no significant difference for total R-O-M between dominant and nondominant arms; however, there was a significant increase of humeral retroversion of the dominant arm (difference = 11.2°). The investigators also reported a positive correlation between the degree of reduced R-O-M and humeral retroversion.

Similar to the aforementioned studies, an investigation by Reagan and colleagues (2002) found a significant difference in humeral retroversion between dominant and nondominant arms of collegiate baseball players. Fifty-four players had their glenohumeral R-O-M assessed in all directions and then underwent a standard radiograph (x-ray) to examine humeral retroversion. With regard to humeral retroversion, a significant difference of 10° between dominant and nondominant arms was found, though no significant difference for total R-O-M was noted. The researchers concluded that the significant difference of retroversion detected “clearly affects glenohumeral R-O-M” (p. 359). Osbahr and colleagues (2002) noted similar results when examining humeral retroversion in 19 college baseball pitchers. They performed R-O-M and tomographic (CT scan) assessments on both shoulders and found a significant difference of external and internal R-O-M between arms (12.3 ± 6.7° and -12.1 ± 8.6°, respectively), as well as a significant difference of humeral retroversion (10.1 ± 4.7°) between the dominant and nondominant side.

Collectively, these studies suggest that humeral retroversion, or osseous adaptations, in the shoulder of athletes who participate in overhead sports, such as baseball, plays an important role in reduced glenohumeral R-O-M. While all these investigators note the bony adaptations that are taking place in the shoulder, they do not discount the soft tissues adaptations that are simultaneously occurring.

Soft Tissue Adaptations

Prior to the more recent research on the adaptations of the bony structures of the shoulder, it was believed that soft tissue alterations were the main cause of the R-O-M changes seen at the shoulder (Sauers et al., 2007). However, current research suggests that soft tissue adaptations are the source of the bony adaptations occurring at the shoulder (Burkhart et al., 2003a; Laudner et al., 2008).

The soft tissue changes seen at the shoulder include both an increase in the laxity of the anterior capsule and a tightening of the posterior capsule (Lorenz, 2005; Crawford & Sauers, 2006), though recent research indicates that the posterior capsule thickens rather than tightens (Thomas et al., 2009b). Posterior capsule tightening/thickening occurs when the capsular tissue and musculature of the shoulder tighten, usually due to “repeated overload in the eccentric portion of arm deceleration” (Lorenz, 2005, p. 60), and subsequent reactive scarring due to the fatiguing forces imparted in this phase (Crawford & Sauers, 2006). At the same time, anterior capsular laxity occurs from the repetitive “microtrauma” of hyper-external rotation, producing anterior instability or laxity (Borsa et al., 2008; Burkhart et al., 2003a). However, assessing purely soft tissue alterations seen in the overhead athlete is rather difficult, as researchers may often simply look for glenohumeral R-O-M or laxity differences, and attribute those differences to soft tissue adaptations (Myers et al., 2009).

Crawford and Sauers (2006) examined the glenohumeral joint laxity of 22 high school baseball pitchers. Anterior and posterior laxity measurements were obtained on both arms by a commercial computerized stress device (device to measure joint laxity that can calculate between soft tissue and static restraints) in the neutral position and at 90° of abduction. No significant difference was found for laxity between throwing and nonthrowing shoulders, suggesting that capsular changes may not be seen in overhead athletes of this young age. This finding was consistent with the contention of Meister and colleagues (2005) that adults have tighter tissue traits than youth, thus making it difficult to determine significant laxities in children that have yet to anatomically mature. It also provided further support to the notion that, unlike the bony adaptations that occur in young populations, soft tissue adaptations are attributed to increases of joint laxity or decreases of R-O-M after the individual is skeletally mature (Myers et al., 2009).

In summary, the decreases in R-O-M are of particular importance to overhead athletes since the repetitive throwing motion can lead to such adaptations as posterior capsule tightening/thickening, anterior capsule stretching, and humeral head retroversion. These adaptations are the main cause of reduced R-O-M at the shoulder, particularly, a loss of IROT (Myers et al., 2006). A condition known as GIRD is associated with such a loss of IROT, and often a gain in EROT (Burkhart et al., 2003a).

GIRD

GIRD is defined as "a loss in degrees of glenohumeral internal rotation of the throwing shoulder compared with the non-throwing shoulder" (Burkhart et al., 2003a, p. 406). This is a common pathology among overhead athletes (Lorenz, 2005; Tokish et al., 2008), especially baseball players. The normal shoulder should present with 90° of IROT and 90° of EROT to account for the expected 180° of total R-O-M (Arnheim & Prentice, 1997; Gulick, 2005; Prentice, 2004). Those suffering from GIRD often have less than 90° of IROT, and make up for those lost degrees by gaining EROT, therefore maintaining the 180° of total motion (Arnheim & Prentice, 1997; Dwelly, Tripp, Tripp, Eberman, & Gorin, 2009).

GIRD Assessment: Procedures

R-O-M of a joint can be estimated visually, or different instruments (e.g., goniometer, inclinometer, radiographs) can be utilized for specific measurement (de Winter et al., 2004). Reliability and validity of these procedures and instruments are researched to determine which is the most effective. Reliability is "the degree to which a measurement yields the same results when taken on at least two different occasions (intra-tester) or by a minimum of two different examiners (inter-tester)" (Gogia, Braatz, Rose, & Norton, 1986, p. 192). On the other hand, validity is "the degree to which an instrument measures what it is purported to measure and the extent to which it fulfills its purpose" (Gogia et al., 1986, p. 193).

Visual Estimation. Visually estimating the angle of a joint is sometimes utilized in the fast-paced clinical setting; however, few studies have examined its reliability or validity (Rachkidi et al., 2009). Rachkidi and colleagues (2009) examined the reliability of visual estimation on the R-O-M of pediatric lower limbs (hips, knees, and ankles). Fifty children, 32 girls and 18 boys, with an average age of 8 years, had both of their lower limbs assessed in the initial session and a session 3 weeks later by both a pediatric orthopedic surgeon and a 5th year resident in orthopedic surgery. A 7th year medical student concurrently performed goniometric measurements as a comparative criterion. R-O-M assessments of the lower limbs included hip flexion, hip adduction, hip abduction, hip internal and external rotation, knee flexion, popliteal angle (instead of knee flexion), and ankle dorsiflexion and plantarflexion. Results were broken down by examiner to assess reliability with the goniometric measurements. The pediatric surgeon evidenced good reliability ($r \geq 0.7$) for hip flexion, hip rotations, hip abduction, popliteal angle, knee flexion, and ankle dorsi- and plantarflexions; mediocre reliability ($r = 0.5$) was found with hip adduction. The resident also demonstrated good reliability ($r \geq 0.7$) for hip flexion, hip rotations, knee flexion, and popliteal angle. All other motions (hip abduction and adduction, and ankle R-O-M) had poor reliability. These results suggested that there are possible differences in accuracy with the level of experience of the examiner, but visual estimation is somewhat reliable with most lower limb movements.

Watkins, Riddle, Lamb, and Personius (1991) examined the reliability of visual estimation of knee R-O-M on 43 patients from a physical therapy clinic (29 males and 14 females, ages 18-80). For each patient, the referring therapist would measure knee flexion and extension with a goniometer, while a recorder documented patient position and the degrees obtained. Then, from a list of 13 other physical therapists, the referring therapist randomly assigned the patient to a second examiner. The second examiner visually estimated the subject's knee flexion and extension, and then obtained goniometric measurements of the knee, again with the recorder documenting patient positioning and degrees obtained for both measurements. Intra-tester reliability for visual estimates and goniometric measurements were 0.93 for knee flexion and 0.94 for extension. Using both visual estimation and goniometric measurements, inter-tester reliability was quite similar to visual estimation alone (0.86 for knee flexion and 0.82 for knee extension, 0.83 for knee flexion and 0.82 for knee extension, respectively). These results suggested a high level of agreement between visual estimation and goniometric measurements for knee flexion and extension. However, interchanging goniometry for visual estimation may cause additional error in measurement, and it must be decided whether that error is clinically relevant.

Goniometer. The goniometer is a simple, yet widely used instrument to measure both passive and active joint motion (Prentice, 2004; Riddle, Rothstein, & Lamb, 1986; Rheault, Miller, Nothnagel, Straessle, & Urban, 1988). There are two types of goniometers, universal and fluid-based. The universal is a clear plastic device with two arms for measuring angles. The fluid-based goniometer uses a fluid-filled chamber, similar to a level, and can only assess straight-plane movement (Rheault et al., 1988). Because of the fluid-based goniometer's lack of ability to measure in multi-planar movements, the universal goniometer is utilized more commonly in the clinical setting (Rheault et al., 1988). Researchers examining its measurement characteristics have primarily focused on reliability, though a few have also examined its validity.

Investigations into the measurement reliability of the universal goniometer have typically found high reliability estimates. For example, Mitchell, Millar, and Sturrock (1975) had two testers, neither with any prior experience using the device, but who received brief training, take measurements of knee joint motion on 20 patients. They found a high level of agreement, or inter-tester reliability (r = 0.95), even with these inexperienced evaluators. Riddle and colleagues (1986) examined both the intra- and inter-rater reliability of goniometer measurements on shoulder joint motion. In their study, 16 physical therapists measured shoulder R-O-M on 100 patients using a universal goniometer. Results showed a high level of test-retest (or intra-tester) agreement for both EROT (r = 0.98) and IROT (r = 0.93). However, while inter-rater reliabilities for EROT were also found to be quite strong (r = 0.89), agreement levels regarding IROT were poor (r = 0.49). The authors did not extensively examine why IROT agreement was so weak, although they suggested that possible variability of therapists' control of scapular motion impacted measurement consistency. Therefore, while measurements taken by the same therapist were highly consistent, IROT measurements taken by different testers were not. Gogia and colleagues (1986) undertook an additional study examining universal goniometer measurement reliability. Two examiners independently measured knee R-O-M on 30 individuals with a goniometer and found inter-tester reliability coefficients to be very high (r = 0.98).

Petherick, Rheault, Kimble, Lechner, and Senear (1987) examined the comparative reliabilities of universal and fluid-based goniometers. Two testers took three measurements of elbow R-O-M on 30 participants using both instruments. The results showed a high inter-tester reliability for the fluid-based goniometer (r = 0.92) and adequate reliability for the universal goniometer (r = 0.53). Similarly, Rheault et al. (1988) conducted an examination of inter-rater reliability with both the universal and fluid-based goniometer. In their study, two examiners took measurements of knee motion on 20 participants using both devices. In contrast to the Petherick et al. (1987) findings, they obtained high inter-tester reliability for both goniometers, with the universal slightly higher (r = 0.87, fluid-based = 0.83).

Intimately related to reliability is validity, although few studies have examined the validity of the goniometer. Those that have been undertaken often examine criterion-related validity, or comparing the measurements from the goniometer to some standard, such as an x-ray, or to simultaneous administration of two measures at the same time (concurrent validity). In the first approach, the joint angles can be measured on the radiograph and compared directly to the measurements obtained by the goniometer (Clarkson, 2000). Gogia and colleagues (1986) undertook such a study where two therapists measured knee joint motion, followed by a radiology technician obtaining an x-ray of the knee at its end-point of R-O-M. The radiologist then measured the angle of motion on the x-ray and compared that to the therapists' measurements. The results indicated an extremely high level of agreement (validity coefficient = 0.98) between the two types of measurement. Petherick and colleagues (1987) examined validity by simultaneously administering two measures, the universal and the fluid-based goniometer, on elbow R-O-M. They obtained a strong 0.83 correlation between the two instruments, suggesting that both measured the same criterion similarly. Rheault and colleagues (1988) also found high validity coefficients for knee R-O-M for both the universal and fluid-based goniometers (0.8 range).

In summary, research on the reliability and validity characteristics of goniometers provides strong support for the utility of this device to measure joint motion. Studies show strong evidence that goniometer measurements, both universal and fluid-based, provide high levels of agreement between repeated measurements by the same tester, as well as between two evaluators, particularly when measuring knee and elbow R-O-M (fluid-based device was superior to the universal device, though the latter did appear to evidence adequate reliability). Importantly, with regard to shoulder R-O-M and agreement between evaluators, the Riddle et al. (1987) study suggested that EROT measurements seemed highly consistent, but to improve inter-rater agreement, considerations for controlling scapular motion may be necessary when examining IROT.

Inclinometer. An inclinometer is an easy-to-use, digital device that is gravity-dependent, measuring R-O-M on a 360° scale (de Winter et al., 2004). It is becoming more widely used in the clinical setting because it only requires one hand for placement; whereas, the goniometer requires the use of two hands to position both arms of the device (Green, Buchbinder, Forbes, & Bellamy, 1998).

In 1998, Green and colleagues investigated reliability of the inclinometer on shoulder R-O-M. Six patients (4 men and 2 women, ages 45-66) complaining of shoulder pain or stiffness had several shoulder R-O-M measurements taken by six physiotherapists once, and then again after a 1-hour break. The motions examined included total shoulder flexion, glenohumeral flexion, total shoulder abduction, glenohumeral abduction, EROT in neutral abduction, EROT in abduction, IROT in abduction, and IROT, as hand behind back. Results indicated high intra-observer agreement (r = 0.75-0.85) for EROT in neutral and abduction, and IROT in abduction and hand behind back, but poor agreement (r = 0.38-0.49) for the remaining motions. Inter-observer agreement was strong (r = 0.72-0.88) for total shoulder flexion, total shoulder abduction, EROT in neutral, and IROT in abduction and behind back measurements, and poor (r = 0.44-0.65) for the remaining measurements. These results suggested that examiner consistency in obtaining R-O-M measurements for shoulders from one time point to the next, as well as agreement between evaluators, may vary significantly with regard to the type of motion measured, and may be an important consideration when using such a device.

Likewise, de Winter and colleagues (2004) examined the inter-observer reliability of the inclinometer on shoulder R-O-M with 155 patients complaining of shoulder pain. Patients had their shoulder abduction and EROT measured bilaterally by two examiners. The observers demonstrated 0.8° difference for glenohumeral abduction and 4.6° difference for EROT. Associated reliability coefficients were 0.83 and 0.90, respectively, suggesting good inter-observer reliability for two specific shoulder motions.

With regard to validity of the inclinometer, Tousignant, Morissette, and Murphy (2002) examined the criterion validity of a goniometer and inclinometer when compared to the double inclinometer method of lumbar R-O-M (considered the “gold standard”). Forty subjects, 23 men and 17 women, with lower back pain had their lumbar flexion measured once with each device, goniometer, inclinometer, and double inclinometer. Results provided strong support for the validity of both the goniometer and inclinometer.

When compared to the double inclinometer, though, the inclinometer showed a stronger linear relationship with the "gold standard" (r = 0.88, goniometer = 0.78).

Imaging Techniques. Photographs and imaging procedures, such as radiographs (x-rays) or CT scans (computed tomography), can also be used to examine R-O-M (Fish & Wingate, 1985; Gogia et al., 1986). In fact, researchers sometimes use x-rays or CT scans as an ultimate criterion for joint measurements (Gogia et al., 1986). Diagnostic pictures of the joint of interest are taken and R-O-M can easily be measured, as the pictures can be taken at the terminus of motion, capturing the full movement available. Importantly, the measurements can also be made at a later time, not necessarily that instant.

Hayes, Walton, Szomor, and Murrell (2001) utilized still photography to assess the reliability of shoulder R-O-M measurements when compared to several other methods (e.g., visual estimation, goniometry, "stand and reach", and hand behind back). The investigators took a picture of the shoulder of 17 subjects at end R-O-M. Then, they compared the measurements with those obtained with the other four methods to assess intra- and inter-rater reliability using still photography. Intra-rater reliability was found to be fair, ranging from r = 0.56-0.61; however, inter-rater reliabilities were higher, ranging from r = 0.62-0.73. While the still photography used in this study was similar to the method utilized with x-rays and CT scans, the investigators noted that their approach was much less expensive, since a regular Polaroid picture was used. This study was consistent with Fish and Wingate (1985), who found that standard photography was more accurate in assessing elbow R-O-M than a goniometer. In this investigation, 46 physical therapy students participated as subjects and examiners by measuring elbow R-O-M, with a goniometer, on each other. Pictures were also taken to assess the joint motion obtained in the testing sessions. Results indicated measurement of joint angles with photography was more accurate (± 0.7-1.1°) than goniometric measurements (± 2.4-3.4°).

Boileau, Bicknell, Mazzoleni, Walch, and Urien (2008) examined different diagnostic procedures for assessing humeral retroversion in 65 cadaveric humeri with x-ray, CT scan, and computerized and direct methods as the criterion measures. X-ray and CT scan photographs were taken and then angle measurements were made on these pictures. They found that the x-ray method tended to overestimate retroversion, while the CT scan was very accurate when compared to the criterion measures.

In summary, there are several tools available to assess R-O-M. Photographs and imaging procedures, collectively, seem to be a reliable method to obtain these measurements because still images can be used to measure the joint angles, thus creating the “gold standard” of R-O-M measurement. However, there may be cost and time prohibitive factors in routinely using techniques such as x-rays and CT scans that would make them impractical for routine clinical use. Visual estimation has been found to display adequate reliability, but seems dependent on the level of experience of the examiner. Two instruments commonly found in clinical settings, the goniometer and inclinometer, have been shown to be reliable and valid methods of measuring R-O-M. Ultimately, one must select an appropriate approach for obtaining R-O-M measurements, and this may be influenced by access to, or availability of, the instrument.

GIRD Assessment: Positioning

As previously discussed, R-O-M of a joint can be estimated visually, or different instruments (e.g., goniometer, inclinometer, radiographs) can be utilized for specific measurement (de Winter et al., 2004). Importantly, R-O-M at the shoulder can be assessed in different patient positions, seated or supine (Spigelman, 2006). The seated position may be seen as more practical (Spigelman, 2006); however, the scapula is free to move, possibly allowing more motion to occur, when this motion is not strictly glenohumeral. On the other hand, supine assessment stabilizes the scapula (Spigelman, 2006), allowing a more exact measure of pure glenohumeral motion. Awan, Smith, and Boon (2002) investigated the reliability of IROT measurements with the scapula stabilized and not stabilized, and visual inspection of scapular movement. Their findings suggest that R-O-M measured with scapular stabilization "represents a more isolated measure of glenohumeral internal rotation" (p. 1232). Further, Myers and colleagues (2007) examined reliability and precision in measuring R-O-M at the shoulder and found that supine assessment had better inter-session and inter-tester reliability ($r = 0.75$, $r = 0.94$, respectively).

Shoulder Injuries

The NCAA ISS has reported that collegiate sports, particularly Division I, have the highest incidence of injuries in season when compared to pre- and postseasons (Hootman et al., 2007). Injuries may occur to the bone, muscle/tendon, ligament, nerve, cartilage, or skin (Arnheim & Prentice, 1997). One of the most common noncontact injuries occurs to muscles/tendons (Hootman et al., 2007). Woods et al. (2007) reviewed the literature concerning athletic injuries and found that muscle injuries occur in over 30% of the population seen in the sports medicine clinic. Muscle injury is believed to result from a condition that diminishes contractibility and the ability of the muscle to absorb energy, potentially making the muscle more susceptible to injury (Woods et al., 2007). Over a 16-year follow-up, the NCAA ISS documented that upper extremity injuries accounted for approximately 20% of athletic injuries (Hootman et al., 2007).

The excessive mobility seen at the shoulder comprises its stability, thus making the shoulder more susceptible to injury (Arnheim & Prentice, 1997). There are a number of injuries that can occur to the shoulder, including bursitis, rotator cuff tears, impingement, instability, labral tears, neuropathy, fractures, dislocations, joint sprains, and tendonitis (Magee, 2006). Although some of the aforementioned injuries are of an acute nature, most occur over time and are considered overuse injuries. In athletes, repetitive overhead movements commonly lead to such overuse injuries (Arnheim & Prentice, 1997).

Shoulder Injuries in the Overhead Athlete

As discussed above, the throwing motion places significant stress on the shoulder, putting it at risk for injury (Meister, 2000). Specifically, the deceleration phase, with its repetitive eccentric loading, can place excessive strain on the joint. This can cause adaptations to occur which, in turn, create R-O-M losses. Loss of R-O-M at the shoulder, particularly GIRD, is associated with injuries such as rotator cuff pathologies (i.e., impingement and tears), anterior instability, labral tears, and scapular dyskinesis

(Burkhart et al., 2003a; Clabbers et al., 2007; Meister, 2000; Ouellette et al., 2007; Sauers et al., 2007).

Scapular dyskinesis, an "alteration in the normal position or motion of the scapula during coupled scapulohumeral movements" and alterations in scapular position and motion are seen in 68 to 100% of patients with shoulder injuries (Kibler & McMullen, 2003, p. 142). During the throwing phases, the scapula intimately moves with the arm to create the desired motions. In normal throwing mechanics, the scapula has three roles: retraction to facilitate cocking, elevation of the acromion during cocking and acceleration to clear the rotator cuff for its movement, and protraction during acceleration into deceleration to help dissipate some of the forces that occur in these stages (Kibler & McMullen, 2003; Myers et al., 2005). However, when scapular stabilizing muscles become fatigued from repetitive eccentric forces, the scapula will not move correctly with its counterpart, thus leading to the common glenohumeral pathologies, including instability, labral tears, and rotator cuff issues (Kibler & McMullen, 2003). Specifically, scapular dyskinesis may be found in 68% of patients with rotator cuff pathologies, 94% of patients with labral tears, and 100% of patients with glenohumeral instability (Kibler & McMullen, 2003).

Scapular dyskinesis and glenohumeral pathologies are foes of one another. Inflexibility of the shoulder muscles, as well as tightening of the shoulder capsule, can cause scapular malposition (Burkhart, Morgan, Kibler, 2003c). Additionally, GIRD can adversely affect scapular motion by causing excessive protraction and loss of elevation control. On the other hand, too much protraction will cause impingement as the scapula tries to compensate its movements (Kibler & McMullen, 2003). Further, loss of correct scapular protraction control will increase the stresses at the glenohumeral joint, increasing the risk of labral tears. Loss of elevation control may cause instability and rotator cuff tendonitis (Kibler & McMullen, 2003).

The scapula, then, plays an important role in the mechanics, subsequent injuries encountered in, and development of GIRD in the overhead athlete. Proper scapular positioning and motion are pertinent to maintaining a healthy shoulder complex. Minute alterations in the scapula can lead to significant shoulder pathologies that are all too common in overhead athletes, such as baseball players.

Although scapular dysfunction is the most likely culprit of rotator cuff pathologies, labral tears, and instability, these complications can arise even with proper scapular position and movement (Burkhart et al., 2003a; Clabbers et al., 2007), and they all seem to intertwine with each other (Meister, 2000). Rotator cuff pathologies may occur from the eccentric loading of the rotator cuff muscles during the deceleration phase of throwing, which causes fatigue of these muscles (Meister, 2000). Repetitive loading of these muscles may cause muscular imbalances and altered movement patterns which, in turn, can lead to impingement (Magee, 2006, Prentice, 2004). Primary impingement is an anatomical issue, where the subacromial arch (where the rotator cuff tendons run through and attach) is too small for the structures within it, and may lead to irritation and fibrosis of the cuff tendons (Ouellette et al., 2002; Prentice, 2004). Secondary impingement is due to glenohumeral anterior instability, where the anterior capsule fails, causing increased translation of the humeral head within the shoulder joint. Both forms of impingement cause compression forces on the cuff tendons, aggravating and inflaming these structures, and continuous irritation of the tendons will eventually cause the rotator cuff to rupture or tear (Ouellette et al., 2002; Prentice, 2004).

Anterior instability is often caused by a fatiguing and stretching of the capsuloligamentous structures of the anterior shoulder by the shear forces placed on the capsule during cocking and acceleration (Meister, 2000), and the humeral head translating anteriorly during the deceleration phase of throwing (Prentice, 2004). This increased laxity can cause impingement and labral fraying (Meister, 2000). Similarly, the translation of the humeral head, back and forth, during cocking and deceleration places high compressive forces on the labrum. It is this grinding that often causes fraying or tearing of the labrum (Ouellette et al., 2002). Further, the retroversion of the humeral head causes an alteration of the contact point of the humeral head in the glenoid, creating different grinding forces on the cartilaginous labrum (Ouellette et al., 2002).

Burkhart and colleagues (2003a) best summarized the “pathologic cascade” of shoulder injury, noting that the tightening/thickening of the posterior capsule initiates the cascade, and is provoked mostly during the cocking phase. Then, the humeral head starts to translate into retroversion, placing uncommon stresses on the labrum. As the humeral head shifts, new forces are placed on the anterior capsule, causing it to fatigue and become lax, and potentially fail. Additionally, the rotator cuff tendons become irritated due to the humeral head movement and capsular laxity. As a final blow, all of these alterations are worsened by scapular malposition and dysfunction.

Treatment of Shoulder Injuries

Overhead athletes experience common shoulder injuries such as rotator cuff injuries (i.e., impingement and tears), anterior instability, labral tears, and scapular dyskinesis (Burkhart et al., 2003a; Meister, 2000; Ouellette et al., 2007; Sauers et al., 2007). It is common practice to initially treat all injuries with RICE—Rest, Ice, Compression, and Elevation (Arnheim & Prentice, 1997). Modalities such as ice and electrical stimulation may also be used to aid these processes (Starkey, 2004). Once swelling and pain have subsided, R-O-M, strengthening, and neuromuscular control exercises may begin. Shoulder motion may be regained by moving the joint through the desired R-O-M and by stretching. Strengthening can be obtained by having the individual perform exercises using weights and specific motion to target precise muscles. Lastly, neuromuscular control (proprioception) exercises train the neural pathways to become as efficient as possible by training the body to act and react to the demands placed on it (Arnheim & Prentice, 1997).

The Impact of Stretching and Physical Training on Tissue and Structures

The process of stretching (and physical training) and its beneficial impact on the human body involve malleability and plasticity of tissue and structures. Skeletal muscle "demonstrates a remarkable malleability and can adjust its metabolic and contractile makeup in response to alteration in functional demands" (Fluck, 2006, p. 2239). This idea is based upon the Specific Adaptation to Imposed Demand (SAID) principle, which states, "when the body is subjected to stresses and overloads of varying intensities, it will gradually adapt, over time, to overcome whatever demands are placed on it" (Prentice, 2004, p. 695). Concurrently, Wolff's Law states that bone and soft tissue will adapt to the stresses placed on them and align in the direction of those forces (Prentice, 2004). The length of time it takes for these adaptations to occur varies. It is generally thought to take 3-8 weeks for bone and other connective tissue healing and adaptations and 6-8 weeks for muscle tissue. Some of these adaptations may become permanent, as the tissues demonstrate plasticity, and thus allow permanent changes or deformations (Prentice, 2004). Additionally, these training-induced adaptations have been found to be the product of repeated stimuli (Fluck, 2006).

Fluck (2006) reviewed a few of his own experiments examining adaptations at the cellular level, which provided evidence that cellular processes of plasticity involve both quantitative and qualitative changes to the cells and related structures. For example, training over the course of weeks or months causes an increase in mitochondria (energy producer) within the cells (quantitative change). Additionally, when these cellular changes occurred after 6 weeks of training, the tissue's response appeared to be modified to those adaptations (qualitative change). These findings suggest that structural and functional changes from training do occur, even at the cellular level, with repeated stimuli.

Blazevich, Cannavan, Coleman, and Horne (2007) studied muscle tissue adaptations to resistance training. Twenty-four subjects (16 men, average age 24 years, and 17 women, average age 21 years) were assigned to either a concentric (a contraction in which the muscle shortens) or eccentric (contraction in which the muscle lengthens) training group, while 9 subjects served as controls. Pretest muscle strength, size, and architecture or fascicle length (muscle makeup) were assessed on all participants. Repeat assessments were conducted at weeks 5, 10, and 24. The two training groups underwent a 10-week training protocol (determined by their assignment) followed by a 14-week detraining period. The control group did not train during this 24-week period. There was a significant improvement in muscle strength in both training groups at weeks 5 and 10, with the concentric group exhibiting slightly greater gains. After the 14 weeks of detraining, the concentric group did not evidence significant decreases, although the eccentric group did. Regarding muscle size measurements, both training groups exhibited relatively equal increases in the volume of the quadriceps muscle. Of importance, it was also found that both training groups significantly increased their muscle architecture (or fascicle length) by week 5, with no further changes noted at week 10. There was a small, residual increase of architecture after the 14-week detraining period, although it failed to be statistically significant. The investigators concluded that, although muscle strength and volume continued to increase over the course of 10 weeks before leveling off, muscle architecture adapted within the first 5 weeks with no further changes occurring. Therefore, it appears that 5-10 weeks may be enough time to allow adaptations to occur to muscle tissue. Furthermore, 14 weeks of detraining is not sufficient time to cause the muscle structures, strength, and volume to return to baseline.

With regard to stretching protocols and their impact on muscle elasticity, two studies examined the passive-elastic properties of the calf muscles in women. Gajdosik, Vander Linden, McNair, Williams, and Riggin (2005) investigated the effects of an 8-week stretching protocol on the calf muscles of older women, aged 65-89 years.

Nineteen women had their calf R-O-M assessed before the performance of three functional pretests: timed agility course, fast 10-meter walk, and a standing forward functional reach. They were then assigned to either a stretching or control group. The stretching group performed 10 repetitions of 15-second calf stretches, once daily, 3 times per week for 8 weeks (totaling 24 stretching sessions). The control group did not perform any activities over the course of the study. At the end of the 8-week period, all subjects' calf R-O-M was reassessed, and the subjects performed the three functional tests for posttreatment analysis. A significant increase in calf R-O-M occurred as a result of the 8-week stretching program for the treatment group. However, due to the pretest/posttest format with no intermittent R-O-M assessments within the 2-month period, the exact point of the onset of improvements could not be determined. There was no change in R-O-M for the control group. Analysis of the functional test data revealed that the stretching group also performed better on all three tasks, indicating that stretching the calf muscles over the course of 8 weeks causes significant adaptations to length and passive forces of this musculature in older women.

Similar to the 8-week Gajdosik et al. (2005) study, Gajdosik, Allred, Gabbert and Sonsteng (2007) examined a 6-week stretching protocol on the R-O-M of calf muscles of young women, aged 18-31 years. They randomly assigned 10 women to either a stretching or control group after their calf R-O-M was measured pretreatment. The stretching group performed 10 repetitions of calf stretches held for 15 seconds each. This procedure was performed once a day, five times a week for 6 weeks, resulting in 30 stretching sessions. At the conclusion of the 6 weeks, posttreatment calf R-O-M was reassessed. Results showed that the stretching group significantly increased the length and passive resistive properties of the calf muscle when compared to the control group, indicating that significant adaptations can occur after only 6 weeks of consistent stretching in younger women.

While the investigations have yet to identify the specific time it takes for tissue adaptations to occur, preliminary evidence suggests such changes are detectable in intervals as short as several weeks for both men and women. The Gadjosik et al. (2005, 2007) studies suggested that adaptations are evident in as short as 6 to 8 weeks, while Blazevich and colleagues (2007) found indications of adaptations as a result of 5 to 10 weeks of training. Fluck (2006) provided additional support for relatively rapid tissue adaptations, noting that 6 weeks of training caused a modified response within tissue.

Strengthening and Neuromuscular Control

Strengthening and neuromuscular control (proprioception) of the musculature surrounding the shoulder and scapula is important to regain or maintain proper mechanics. Scapular stabilizing muscles, specifically, the rotator cuff muscles, must be targeted to rehabilitate rotator cuff pathologies, scapular dyskinesis, and even labral tears (Burkhart et al., 2003a). Rehabilitation exercises for all such injuries should begin with focus on the scapula, since all motions involve, and most muscles of the shoulder attach, there. Exercises specific to the scapula often include rowing, scapular punches, shoulder shrugs, and shoulder depressions (Prentice, 2004). Once normal scapular motion is obtained, rotator cuff strengthening can begin (Burkhart et al., 2003a). Strengthening and proprioception exercises may include shoulder internal and external rotation with a

Theraband; flexion, extension, and abduction with free weights; and rhythmic stabilizations. A variety of these exercises can successfully be incorporated to target the rotator cuff, as long as they target the motions of the related muscles (Prentice, 2004).

Likewise, strengthening and proprioception of the shoulder musculature is very important to treat anterior instability. Anterior instability refers to a stretching of the anterior capsule (Ouellette et al., 2007); therefore, to correct this, the capsule must be strengthened, or tightened. Rehabilitation exercises should focus on the musculature of the anterior shoulder and may include flexion, abduction, adduction, horizontal adduction, IROT with free weights or Theraband, and rhythmic stabilizations (Prentice, 2004).

Stretching, strengthening, and neuromuscular control are key factors to successful rehabilitation programs. Since the muscles of the shoulder intimately act together to create the desired movements, the common shoulder injuries seen in overhead athletes can often be treated with similar exercises.

Shoulder Injury Prevention

While the treatment of shoulder injuries is important, it is even more critical that injury prevention procedures be undertaken to reduce the necessity for such treatments. R-O-M, strength, and neuromuscular control are key factors in shoulder injury preventive procedures. The shoulder must be able to go through its necessary R-O-M to perform properly. The surrounding musculature must also be strong enough to handle the forces imposed by the body. Lorenz (2005) and Sauers et al. (2007) suggested that stretching the posterior capsule helps prevent injury, and Claps (2003) indicated that continually stressing the shoulder with a reduced R-O-M could lead to severe injury. Supporting these notions, Trakis and colleagues (2008) examined 12 adolescent pitchers with throwing-related shoulder pain and 11 who did not have pain. They found that the pitchers with pain had a loss of internal R-O-M and weakened posterior shoulder muscles, thereby reinforcing the idea that proper stretching of the posterior capsule and strengthening of the posterior shoulder musculature may aid in preventing injury.

Posterior Capsule Stretching

Limited data exist on the stretching techniques for the posterior capsule, although a few investigators have examined the Cross-Body Stretch and the Sleeper Stretch (Laudner et al., 2008; Lintner et al., 2007; McClure et al., 2007). For example, McClure and colleagues (2007) examined 54 asymptomatic college students; 24 were assigned to the control group, while both the Cross-Body and Sleeper Stretch groups were composed of 15 participants each. Shoulder internal and external R-O-M was measured. The two intervention groups were instructed on how to perform each of their respective stretches and sent home with compliance logs. Individuals were to stretch every day through a 4 week period. After the completion of the stretching protocol, each subject's R-O-M was reassessed. As a group, the Cross-Body Stretch participants demonstrated statistically significant improvement in R-O-M relative to the control group, though the Sleeper Stretch group did not. The investigators postulated that the lack of improvement utilizing the Sleeper Stretch was due to diminished compliance among the participants in that group. Differences in R-O-M between the Cross-Body Stretch and the Sleeper Stretch groups were not significant. While not demonstrating clear support of the Sleeper

Stretch, the researchers concluded that both the Cross-Body and Sleeper Stretch would be beneficial for increasing an athlete's R-O-M.

Shoulder stretches are routine preventative activities for Major League Baseball (MLB) teams such as the Houston Astros, San Francisco Giants, Los Angeles Dodgers, and the California Angels (Lintner et al., 2007; Zomar, Kurland, & Brewster, 1980). Unless recently updated (it is not published), stretching programs for the Giants, Dodgers and Angels incorporate only the Cross-body Stretch (Zomar et al., 1980); however, the Astros utilize both the Cross-body and Sleeper Stretches. Lintner and colleagues (2007) examined the stretching protocol administered to the Houston Astros. In their study, 85 pitchers were divided into two groups: those who had gone through the Astros stretching program for 3 years or more and those who had not. Internal and external R-O-M were measured, and the group that had stretched for 3 or more years demonstrated significantly greater R-O-M, suggesting that long-term stretching is beneficial for improving R-O-M in professional pitchers. This finding was consistent with Woods and colleagues (2007) who concluded that long-term stretching programs are beneficial for increasing flexibility and, in turn, increasing R-O-M, because the duration of stretch determines the amount of permanent lengthening for tissue.

While it has been shown that long-term use of the Cross-Body Stretch and Sleeper Stretch is beneficial, Laudner and colleagues (2008) recently examined the acute effects of the Sleeper Stretch. The investigators chose that stretch specifically because it is a newly adopted stretch with little supporting evidence to date. Baseline internal and external R-O-M measurements were taken on 33 collegiate baseball players and 33 active college men with no overhead activity. The baseball players performed the Sleeper Stretch 3 times for 30 seconds while the other group was instructed not to perform any activity. Immediately following the baseball group's stretching, R-O-M was reassessed on both groups. Statistical significance was found only between pre- and posttest measures of the baseball players; however, the investigators did not observe if these gains had any benefit on athletic performance.

Conclusion

Injuries are a common occurrence in athletes, and, for overhead athletes in particular, the shoulder is most commonly injured. Repetitive overhead movements, such as throwing a baseball, can cause changes in the structures of the shoulder, leading to a loss of IROT and a gain in EROT. This, in turn, can cause a tightening/thickening of the posterior capsule, potentially leaving the athlete susceptible to injury. Specifically, GIRD, a frequent condition seen in overhead athletes, is the gateway to overuse injuries. Strengthening and stretching the posterior shoulder may help to prevent these injuries. Stretching has an impact on both the plasticity and elasticity of tissue. Studies have suggested that such adaptations can occur in as short as 5 weeks of consistent stretching. There are various ways to stretch the posterior capsule, including the Cross Body Stretch and the Sleeper Stretch. However, there is limited research comparing the different techniques to find the most beneficial method. No data presently exist on stretching protocols lasting as long as 3 months for collegiate baseball players. Further, there are no data on injury rates due to the increase of IROT these athletes obtain through their stretching protocols.

Chapter 3

METHODS

The purpose of this chapter is to introduce the procedures of this investigation. The participant population, along with information regarding the PI and testers, are identified. Information on the instrumentation required is also provided. Further, the procedures executed are outlined in detail; specifically, R-O-M measurement procedures, along with proper Sleeper Stretch instructions. As a second part of this study, data on injury occurrence was recorded, and instructions for this measure are supplied. Finally, the statistical analyses that were used to evaluate the data obtained in this study are presented.

Participants

Baseball Players

The participants in this study were male collegiate baseball players with an average age of 19.0 years (ranging from 17-22), average height of 181.6 cm (± 6.4), and average mass of 85.3 kg (±13.1). Importantly, there was found to be no statistically significant differences between the participants' age, height, or mass (see Results). The participants were verbally recruited by the PI from the 35-member baseball team at the PI's NCAA Division I university. Upon approval by the university's Institutional Review Board (IRB) but prior to testing, all players who volunteered reviewed and signed an informed consent form (Appendix A), and answered a brief questionnaire relating to their history of shoulder injuries (Appendix B). Every participant completed all measurement phases of the study and utilized the Sleeper Stretch procedures.

It was anticipated that all participants would make gains in shoulder IROT, though to what extent was unclear. It was believed that the risk to subjects due to participating in the Sleeper Stretch, a recognized and advocated stretch (Laudner et al., 2008), was minimal, as the probability of harm was no greater than would be encountered in typical athletic participation. Importantly, confidentiality was maintained by coding the participant data, and the PI was the only individual who had access to the code key (Appendix C). Upon completion of the data analysis, this key was destroyed.

Testers

Two certified athletic trainers familiar with the use of a goniometer conducted the IROT measurements on all participants during all testing phases. The PI served as one of the testers. The second tester (Tester 2) was a certified athletic trainer who volunteered to assist. This tester was required to perform IROT measurements on three practice participants and at a 95% agreement level with the PI prior to each assessment phase. Mayerson and Milano (1984) found that "…regardless of whether difference of scores are derived from within or between observers, repeated measurements under controlled conditions can confidently be expected to fall within approximately four angular degrees of each other" (p. 93).

Tester Assistants

Two additional certified athletic trainers aided in each measurement session. Each assistant was trained to the same criterion level of agreement as the testers (as described above). One assistant helped each tester by using the measuring device and recording the value obtained for each trial.

Instrumentation

The only instrumentation required for conducting this study was a universal goniometer (manufactured by Baseline, Irvington, NY). It is a clear plastic instrument with arms 12 inches in length and individual marks for each of the 360 degrees.

Procedures

After agreeing to participate by signing the consent form and completing the injury history questionnaire addressing previous shoulder injuries participants had their R-O-M assessed. It was determined prior to the start of the study that any participant with recurrent or persisting shoulder injuries would be excluded from the study, but this proved to be unnecessary. The definition of GIRD that was used in this study was "the loss in degrees of glenohumeral internal rotation of the throwing shoulder compared with the non-throwing shoulder" (Burkhart et al., 2003a, p. 406). Therefore, all participants had their pretreatment dominant and nondominant shoulder IROT measured by both testers, as opposed to IROT and EROT measurements. The participants were then shown how to perform the Sleeper Stretch on the dominant arm only, utilized it across the entire course of the study, and underwent intermittent and end-of-treatment measurements.

R-O-M Measurement Procedures

Two testers independently measured R-O-M on all participants to ensure inter-tester reliability or measurement agreement. A participant was first assessed by one tester, then immediately moved to the next tester for a repeat measurement. To increase precision of measurement during all testing sessions, each tester took three measurements of the participant's dominant arm, then nondominant arm (see Appendix D). The mean of the three scores was used as the measure for comparison over time and for intra- and inter-tester reliability estimates (Garvin, 1981; Phillips, 1982). All R-O-M testing occurred before practice on the assigned measurement day to ensure that the measurements were not affected by any practice activities.

Due to the consideration offered by Riddle et al. (1986) regarding the need to control scapular motion to increase inter-rater reliability, and the Myers et al. (2007) finding that measurements taken supine provide a significantly higher inter-session reliability when compared to seated measuring, participants were instructed to lie supine on the table, thus allowing for scapular stabilization. The participant’s throwing shoulder was placed at 90° of abduction and 90° of elbow flexion by the tester. Then, the tester placed a circular sticker on the participant’s styloid process of the ulna and the olecranon process of the elbow. These landmarks were used to align the goniometer each time. Proper initial alignment of the goniometer is having the axis at the olecranon process, with both movement and stationary arms of the goniometer pointing up, aligned with the styloid process (Norkin & White, 2009). The tester’s assistant properly aligned the goniometer. Then, the tester placed one hand over the acromion of the shoulder and the other hand on the distal wrist/hand, preparing for movement. The tester then passively moved the participant’s dominant arm into IROT, as the assistant simultaneously guided the arm of the goniometer to stay aligned with the participant’s landmarks, but keeping the stationary arm of the goniometer aligned with the initial spot. As soon as the slightest movement was felt under the tester’s hand at the acromion, the motion was terminated, and the tester’s assistant read the measurement obtained for that trial. (The moment the acromion starts to move signifies the initial motion of scapular movement; therefore, to measure pure glenohumeral R-O-M, the movement is to be ended when the scapula starts to budge; Awan et al., 2002.) Once the motion was complete, the tester's assistant read and recorded the number on the goniometer, keeping the tester blind to the measurement. Measurements were reported in degrees, as conveyed by Spigelman (2006), "measurement reported in degrees represents absolute motion" (p. 23). The tester then returned the participant's arm to the starting point, and the same procedure was used for the remaining two trials. Each trial took about 20 seconds to complete, while there was <10 seconds between trials. Once the goniometer was realigned, the tester cued the start of a new measurement, and moved the participant's arm into IROT. After three trials were completed, the same procedure was used for the participant's nondominant arm for another three trials (see Appendices D, E, F, and G). The stickers were removed and the participant moved to the next tester for the exact same procedure. The order of which tester evaluated a player first was counterbalanced across the course of the study to control for any potential assessment sequence effects.

At weeks 4 and 8, as well as at the conclusion of the 12-week stretching period, the participant's R-O-M was reassessed. The procedure for all measurements followed exactly those of the baseline measurement. All participants also completed a postintervention questionnaire (Appendix H) designed to assess how frequently they utilized the Sleeper Stretch and if they followed the stretching steps correctly.

Measurement integrity, or ensuring the testers and assistants properly completed R-O-M measurements during each phase of the study, was addressed by having each tester/assistant observe the other conducting assessments on 7 of the participants and completing a procedural checklist (Appendix I) outlining the basic measurement steps.

Sleeper Stretch Instructions

After all baseline measurements were obtained, the PI explained and modeled for all participants a standardized set of instructions on how to perform the Sleeper Stretch properly. This stretch is appropriately performed with the participant side-lying, with the dominant arm against the ground. The humerus is abducted to 90° and elbow flexed to 90°. This side-lying position stabilizes the scapula, allowing for a truer stretch of the posterior capsule (Lorenz, 2005; McClure et al., 2007). The participant then provides a force at the wrist, with the opposite hand, in the direction of IROT. According to Sullivan, Dejulia, and Worrell (1992), the stretch should be held where there is “tightness without pain” (p.1385). Participants held the Sleeper Stretch for 30 seconds, and performed it a total of three times, as this was found to be the time needed to elongate tissue (de Weijer, Gorniak, & Shamus, 2003). Therefore, when each participant demonstrated the successful completion of the stretch on three consecutive trials, he was considered to have “mastered” the Sleeper Stretch. This stretch was performed every day of university-related athletic participation on the baseball field, and was supervised by the PI or Tester 2 each session. The Sleeper Stretch was conducted throughout the entire 12-week time period.

Current and Existing Injury Data

Secondary to R-O-M measurements, the number of players who experienced a shoulder injury was recorded throughout the season and compared to the number that occurred during each of the previous three seasons. For the purpose of this study, shoulder injuries included nontraumatic rotator cuff injuries (i.e., impingement and tears), anterior instability, and labral tears (Meister, 2000; Ouellette et al., 2007; Sauers et al., 2007) significant enough to require removal from practice or competition, also known as a time-loss injury. Previous injury reports were obtained through the university's medical records with permission of the Director of Sports Medicine at the university. The PI tabulated only the number of players having shoulder injuries over the last three baseball seasons, and no personally identifiable information was known by the PI (Appendix J). Current team members who had participated on the baseball team during the 2007, 2008, and/or 2009 seasons who experienced shoulder injuries were only counted up to, and including, the first season they experienced a shoulder injury to avoid artificially inflating the number of injuries counted (since the same individual could have repeat injuries across multiple years). Likewise, previous players who participated in more than one season during the 2007-2009 seasons were only counted up to their first shoulder injury.

Design

Because the Sleeper Stretch is considered a beneficial approach to reduce athletic injuries and, arguably, should not be withheld from any baseball player, and there were only a limited number of participants available, no participants were assigned to a control (i.e., no treatment) group. Therefore, each participant's dominant arm was the focus of intervention, while the nondominant arm served as the control. The present study utilized a one-group, repeated measures design to address the potential increases in R-O-M experienced by the participants. A second comparison was also made to examine the potential benefits of stretching to reduce shoulder injuries, examining the number of players experiencing shoulder injuries during the present season relative to the previous three seasons. Therefore, this study incorporated two separate dependent variables, shoulder IROT and the number of players experiencing shoulder injuries. R-O-M was measured in degrees of motion, and scores over time were compared to determine the effects of the Sleeper Stretch. The number of players experiencing shoulder injuries during the 2010 baseball season was compared to the number of players experiencing such injuries during the 2007, 2008, and 2009 seasons.

Analysis of Data

Both parametric and nonparametric procedures were required to address the two research questions. Additional assessments (i.e., GIRD versus non-GIRD and position comparisons) were made after the main analyses to better understand the effects of the Sleeper Stretch on the participants' R-O-M changes.

R-O-M Analysis

The PI's mean R-O-M measurements during each testing session were used to examine changes in IROT across the duration of the study. Although a second tester also took measurements, their data was used merely as a reliability check. A repeated measures analysis of variance (ANOVA) was undertaken (Garvin, 1981) using the data analysis tool on The Statistical Package for the Social Sciences Inc., 17th Edition (SPSS, Chicago, IL, 2008). When a significant omnibus F was obtained, paired T-tests were undertaken to determine when the significance occurred.

Injury Occurrence Analysis

The examination of the frequency of players experiencing shoulder injuries during the 2010 season, in comparison to the three previous seasons, required the use of a nonparametric procedure. The Fisher Exact Test (FET) (e.g., Garson, 2008; Huck et al., 1974; Langsrud, 2004) was used to analyze the injury rates. This test calculates the probabilities that could be generated from the data and gives an “exact,” not estimated probability such as that utilized by Chi Square.

Accuracy Estimates

Intra- and inter-tester agreement of reliability during the four testing sessions was examined using the mean score each tester obtained for each participant. The lowest measurement was divided by the highest, and then multiplied by 100% to determine percent agreement for each individual participant (Araujo & Born, 1985; Huck et al., 1974). The percent agreement scores were totaled and divided by the number of participants to determine the average agreement between the two testers for the assessment sessions.

Procedural Integrity

During all assessment phases, both testers and assistants observed the other conducting measurements on 7 of the athletes and completed a procedural integrity form (Appendix I) to ensure proper procedural protocol. Percent of steps correctly performed for each athlete, averaged across the 7 athletes, resulted in the percent of procedural compliance estimate.

Chapter 4

RESULTS

Analyses were undertaken to determine the effects of the Sleeper Stretch on R-O-M gains and injury occurrence with the participating overhead athletes. In addition, intra- and inter-tester reliability, and degree of measurement agreement were examined. The dominant arm was the focus of the analyses; following the baseline session, the 35 participants had their dominant arm reassessed every 4 weeks to examine the effects of the Sleeper Stretch on R-O-M. During this baseline phase, R-O-M of the nondominant arm was also measured to assess the degree of difference between arms to identify participants experiencing GIRD. Finally, total time-loss shoulder injuries were recorded for the present season, and were compared to time-loss injuries of the previous three seasons.

SPSS version 17 (Chicago, IL, 2008) was used to conduct all ANOVA's, paired samples or dependent T-tests, and correlations. FET computations were conducted using an internet-based FET calculator *(www.langsrud.com/fisher.htm).* Inter-tester agreement was calculated utilizing Microsoft Excel 2007 (Microsoft Corporation, Redmond, WA). Since this study was considered an exploratory study examining the effects of this specific posterior capsule stretching program, adjustments for multiple comparisons were not undertaken, and alpha remained at .05 for all comparisons.

Results of Injury History Questionnaire

The participants completed an injury history questionnaire (Appendix B) prior to any shoulder measurements. Responses from these surveys were reviewed in order to identify and eliminate any participant with a present or recurring shoulder injury. Of the 35 participants in the sample, only 8 had a history of previous shoulder pathology and 27 participants were injury-free. Furthermore, none of the participants had ever undergone surgery on their dominant shoulder. Of the 8 participants with a history of injury, 7 had performed rehabilitation to correct the problem, while 1 had not. However, all 35 participants were asymptomatic for a shoulder injury at the start of the study; therefore, of those that had a history of injury, their symptoms had resolved prior to the current baseball season. Likewise, no participants were presently performing rehabilitation exercises on their throwing shoulder. Although no participant was currently suffering from symptoms, 20 reported utilizing preventative measures, including basic stretches and icing. Due to the fact that either the participants had no history of shoulder injury, or those that had a history were no longer suffering from any symptoms, no participants were eliminated from the study.

Measurement Procedural Integrity

A novel 7-step Procedural Integrity Checklist (see Appendix I) was completed during each of the four measurement sessions to ensure that all steps of the measurement process were completed properly. Each test team (tester and tester's assistant) was observed by the other tester while completing measurements for 7 of the 35 participants (20%) each session. Procedural integrity was determined by counting the number of steps correctly performed, divided by the number of possible steps (7), and then multiplying by 100. During all procedural checks, both test teams performed each of the seven steps correctly for all observed measurements (i.e., 100% procedural compliance).

Measurement Accuracy

Both intra- and inter-tester reliability and level of measurement agreement were examined using both correlation and accuracy agreement procedures.

Intra-Tester Reliability and Agreement

Intra-tester reliability was obtained for both the PI and Tester 2. Intraclass Correlation Coefficients (ICCs) were calculated for the three scores each tester obtained for each participant within the measurement session. Reliability estimates remained strong across the study for both testers as shown in Table 1.

Table 1

Intra-Tester Reliability Estimates

Session	**Primary Investigator**	**Tester 2**
Baseline	.898	.916
Week 4	.932	.870
Week 8	.967	.914
Week 12	.962	.931
Mean Total	.940	.908

While intra-tester reliability correlation coefficients establish whether one measure is linearly related to another measure (Garvin, 1981), additional information concerning the degree of relatedness of two scores can be obtained by also examining the degree to which the two scores are similar. By using intra-tester agreement calculation procedures (House, House & Campbell, 1981) specifically, dividing the lower of two scores by the higher, one can depict the level of agreement and degree they vary (e.g., 95% agreement denotes the two scores varied by 5%, so for a measure that averages 50°, they would vary by roughly 2-3° on average). Therefore, additional intra-tester comparisons were conducted using agreement calculation procedures, taking the minimum of the participant's three trial scores and dividing that by the maximum of the three (and multiplying by 100) to determine a percent agreement score. As seen in Table 2, these scores also tended to reflect an adequate level of agreement.

Table 2

Intra-Tester Percent Agreement Estimates

	Principal Investigator			Tester 2		
Session	**Mean**	**SD**	**Range**	**Mean**	**SD**	**Range**
Baseline	88.66	7.64	64.00-97.66	92.32	5.07	79.17-100.00
Week 4	93.90	3.83	83.33-100.00	91.29	7.01	76.09-100.00
Week 8	95.59	3.27	85.00-100.00	93.61	4.49	84.44-100.00
Week 12	95.56	2.28	91.07-100.00	95.12	4.03	85.11-100.00
Mean Total	93.43	4.26		93.08	5.15	

Inter-Tester Reliability and Agreement

Although intra-tester reliability appeared fairly strong, inter-tester reliability was weak (r = .562). This was determined by correlating each tester's mean score for every participant during the four measurement phases. This indicated that there was not a strong linear relationship between how one tester scored a participant's R-O-M compared to the other tester (i.e., PI might have scored a participant's R-O-M well below Tester 2, but for another participant, well above Tester 2's estimate, resulting in unpredictable differences in scoring). Again, while this relationship was not strong, and to further examine the degree to which the scores were similar, agreement between the two testers' mean scores for participants was also computed (see Table 3). In general, these agreement levels also were not strong, varying from approximately 11-17% on average.

Table 3

Inter-Tester Accuracy: Percent Agreement

Session	**Mean**	**SD**	**Range**
Baseline	87.43	9.92	59.62-100.00
Week 4	89.36	9.19	69.92-99.27
Week 8	89.07	6.53	70.39-97.94
Week 12	83.56	9.62	67.88-99.44
Mean Total	87.36	8.82	

Inter-tester agreement appeared "strong" (arbitrarily defined in the current study as ≥95%) for only 9 of the 35 (26%) comparisons at baseline, slightly increased to 12 (34%) at week 4, then dropped to 6 (17%) at week 8, and was only 5 (14%) during the final measurement session. Agreement levels inclusive of the 90-94% range (or "good" agreement), resulted in acceptable agreement for the following: 17 of the 35 comparisons (49%) at baseline; 22 of the 35 (63%) at week 4; 16 of the 35 (46%) at week 8; and 12 of 35 (34%) at week 12. Collectively, these comparisons suggested fairly good consistency between scores on occasion, but not nearly as often as would be desired. Oddly, the number of "moderate" (80-89%) or "fair" (<80%) agreement comparisons increased over the course of the study.

R-O-M Analyses

For the purposes of this study, the PI's data were used for all R-O-M analyses and in the determination of which participants displayed GIRD. R-O-M was assessed at both group and individual participant levels. Descriptive and parametric procedures were undertaken to examine the effect of the Sleeper Stretch on the study participants.

Descriptive Analysis

For the dominant arm, the participants exhibited IROT ranging from 16° - 74° with a group average of 46.78° at baseline (see Figure 1). In comparison, nondominant arm IROT measurements ranged from 21° - 70°, and averaged 51.68° for the group during this initial phase. Therefore, as a group, the participants began with approximately 5° less IROT in their dominant arms relative to their nondominant. By week 4 (or session 2), the group R-O-M average had increased to 48.64°, a gain of approximately 2° of IROT. By the third session (week 8), the participant average increased to 49.18°, less than a 1° increase. At the final measurement session (week 12), the group average was 55.23° of IROT, culminating in a total increase of approximately 9° from baseline.

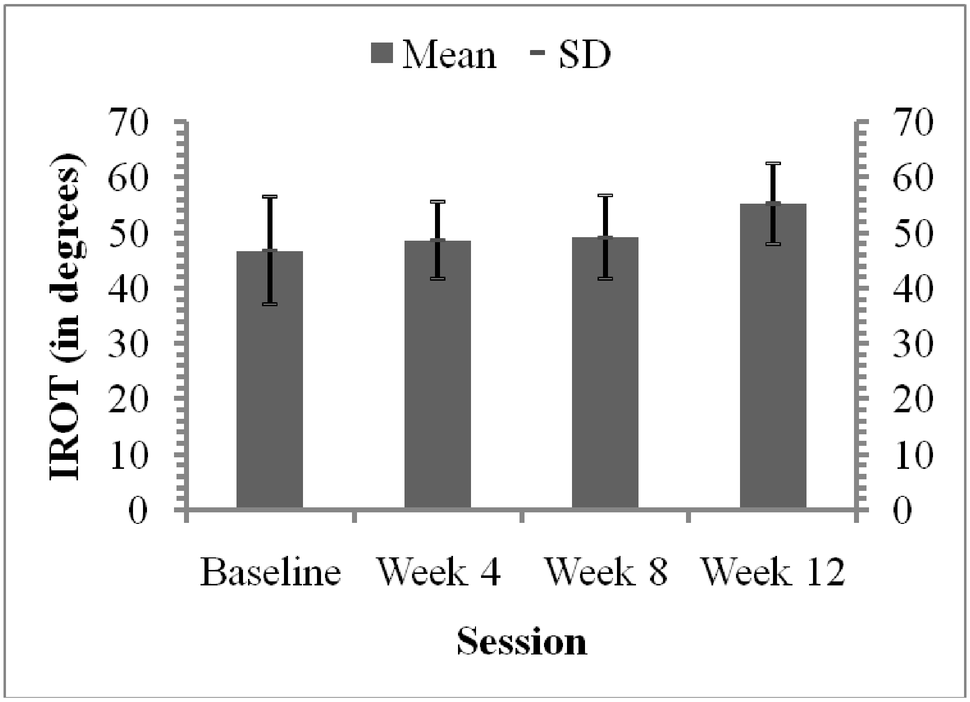

Figure 1

Dominant Arm Mean Range of Motion

To further assess R-O-M differences, the participants were broken down into GIRD and non-GIRD groups. GIRD was defined in this study as “the loss in degrees of glenohumeral internal rotation of the throwing shoulder compared with the non-throwing shoulder” (Burkhart et al., 2003a, p. 406); therefore, any participant with less IROT in their dominant arm (even 1° less) was placed in the GIRD group. Review of baseline data identified 27 participants suffering from GIRD, while the remaining 8 did not. Table 4 depicts the dominant arm data broken down by participant grouping.

Table 4

Dominant Arm Mean Range of Motion for the GIRD/Non-GIRD Groups

	GIRD			Non-GIRD		
Session	**Mean**	**SD**	**Range**	**Mean**	**SD**	**Range**
Baseline	45.86	8.32	20.00-57.00	49.88	13.43	37.33-71.00
Week 4	47.65	6.19	36.67-59.33	51.96	8.97	34.67-65.00
Week 8	48.47	7.11	31.67-60.67	51.71	8.74	42.33-69.33
Week 12	55.16	7.57	40.33-70.00	55.34	6.39	44.67-64.00

Parametric Analyses

A one-way ANOVA was undertaken to compare GIRD and non-GIRD groups across the variables of age, height, and mass. It was determined that no significant differences existed (age, F = .065, p = .800; height, F = .632, p = .432; mass, F = .078, p = .782), suggesting homogeneity across the participants.

A two-way repeated measures ANOVA (2x4; between groups, repeated across sessions) was used to assess the changes in R-O-M for the two groups across the four measurement sessions. During each session, every participant's R-O-M was measured three times by the PI, and the average of the three trials was used as the participant's "score" for that session. Therefore, each individual obtained a total of four scores across the study, and these were the values used in the repeated measures ANOVA. Results from the ANOVA indicated a statistically significant "session" (F = 11.082, p = .001) and "trial" effect (F = 13.530, p = .001), while the interaction comparison was not significant (F = 1.442, p = .200).

Since the global F statistic indicated some differences between session performances, post hoc dependent T-tests were used for further examination. The paired T-tests examined every session combination (e.g., session 1 vs. 2, session 1 vs. 3, session 2 vs. 3, etc.), collapsing the GIRD/non-GIRD grouping, resulting in six comparisons (see Table 5). The results indicated that there was no statistical significance between participant performances during the baseline phase versus the second (week 4) or third (week 8) sessions (t = -.986, p = .331 and t = -1.223, p = .230, respectively). No significant difference was found between the session 2 and session 3 comparison as well (t = -.518, p = .608). However, all comparisons to the final measurement session (week 12) rested at the .001 probability level, suggesting significant changes from the baseline phase to the end of the study; week 4 to 12; and, interestingly, from week 8 to 12. As depicted in Table 5, from the beginning to the end of the study (baseline-week 12), the players gained an average of 8-9° R-O-M, over 6.5° R-O-M during the 8-week interval between week 4 and 12, and 6° during the final month of the study (week 8-12).

Table 5

Post Hoc Analysis: Paired T-Tests

Session Comparison	**Mean Comparison**	**Mean Change**	**p**
1 vs. 2	46.78 vs. 48.64	1.86	.331
1 vs. 3	46.78 vs. 49.18	2.40	.230
1 vs. 4	46.78 vs. 55.23	8.45	.001
2 vs. 3	48.64 vs. 49.18	0.54	.608
2 vs. 4	48.64 vs. 55.23	6.59	.001
3 vs. 4	49.18 vs. 55.23	6.05	.001

Individual Participant Analysis

Examining each individual's performance across the 12 weeks of the study revealed much variability across sessions (see Appendix K). Importantly, 29 of the 35 participants (83%) demonstrated an overall increase in IROT in their dominant arm by the end of the 12-week study, though 6 failed to show any increase and, in fact, data suggested a decrease in IROT. Only 6 participants showed consistent gains across each session from baseline to week 12 and, 1 actually showed steady decreases in R-O-M across each session. The remaining 28 participants displayed varying patterns of gains and losses in R-O-M from session to session; for example, the two most common patterns (11 of 35 and 10 of 35 participants, respectively) were loss of IROT from baseline levels to week 4, then showing gains at week 8, and gains again at week 12 (summarized "loss-gain-gain") and a "gain-loss-gain" pattern.

The individuals were then divided into GIRD (n = 27) and non-GIRD groups (n = 8). Of the 27 participants in the GIRD group, 23 exhibited gains from baseline to week 12, while 4 displayed decreases in R-O-M. Of the 23 participants who gained motion, 11 had an increase of >10° in IROT, 6 gained 5-10°, and the remaining 6 gained <5°. For the 4 participants who lost R-O-M, 3 lost <5°, and 1 lost 7°. Reviewing the 8-member non-GIRD group, 6 demonstrated gains in IROT (4 gained >10°, 2 gained 5-10°), and 2 participants lost R-O-M by the end of the study (1 lost over 13° and 1 over 23°). A FET comparing the number that gained and that lost R-O-M for both groups revealed no differences ($p = .303$), concurring with the ANOVA for group differences.

Additional Exploratory Analyses

Following the primary analyses, unplanned comparisons were employed to examine the effects of the Sleeper Stretch between the varying baseball positions. An ANOVA was performed to examine the effects of "general position" (i.e., pitcher versus nonpitcher). The results indicated no significant difference in R-O-M between the group of 13 pitchers and 22 non-pitchers (group F =. 198, p = .898), while the “session” effect remained significant (F = 10.305, p = .001). Then, "specific position" was examined after grouping the players according to pitcher/infielder/outfielder designation (13 pitchers, 14 infielders, and 8 outfielders) and conducting an ANOVA. Again, the results suggested no difference in IROT between the varying positions (group F =.211, p = .973), or session (F = 2.484, p = .065).

The general position effect was also examined for differences between the following: athlete gains in R-O-M at the end of study (t = .325, p = .747); how many athletes showed gains and losses (11 pitchers demonstrated gains, 2 had losses, 18 nonpitchers gained, 4 exhibited reduced IROT) by the end of the study (FET p = .999); and number of athletes that displayed "good" gains (arbitrarily defined as ≥10° in IROT, pitchers = 7 of 13, nonpitchers = 8 of 22) (FET p = .481). Collectively, all analyses indicated that there were no notable differences between the R-O-M scores between these two player groupings.

PostIntervention Questionnaire Results

Each participant completed a 3-item questionnaire (see Appendix H) at the final measurement session to determine the degree of compliance to the Sleeper Stretch protocol. Answers were broken down and calculated in percentages, as can be viewed in Table 6. According to their responses, approximately one-third of the participants utilized the Sleeper Stretch on a daily basis and, with the exception of 1 player who performed it 3-4 times per week, the remaining players (63%) utilized the stretch at least 5-6 times per week. Most players (71%) reported that they performed the stretch for the minimum required 30 second interval each time, and 20% held the stretch for the appropriate length most of the time (i.e., 5-6 times per week). Question 3 addressed whether the participants completed the stretch the required three repetitions. Again, the majority (85%) did execute the stretch most of the time (i.e., daily or 5-6 times per week), but 2 players reported only performing the stretch the required number of repetitions approximately half the time (3-4 times per week), and 3 players reported rarely (1-2 times per week) doing it.

Table 6

Collective Participant Responses: PostIntervention Survey

Question	Daily	5-6 Times per Week	3-4 Times per Week	1-2 Times per Week	Never/ Rarely
How often did you utilize the Sleeper Stretch?	12 (34%)	22 (63%)	1 (3%)	0 (-)	0 (-)
Stretched for the minimum of 30 seconds?	25 (71%)	7 (20%)	2 (6%)	1 (3%)	0 (-)
Stretched the minimum 3 times?	11 (31%)	19 (54%)	2 (6%)	3 (9%)	0 (-)

(Total N = 35 participants per question)

Injury Occurrence Analyses

To provide additional information concerning the effects of the Sleeper Stretch on injury rates, the number of time-loss shoulder injuries occurring during the 12-week interval of this study was compared to the same interval of time during the previous three seasons. The FET was used to initially determine if any differences in injury occurrence rates were evident amongst the three previous seasons and the present season. There were four injuries in 2007, three injuries in 2008, one injury in 2009, and no injuries in 2010. First, the previous three seasons were compared to one another to determine any differences among them (2007 vs. 2008, 2007 vs. 2009, and 2008 vs. 2009). None of these results approached significance ($p = .286$, $p = .151$, and $p = .230$, respectively). Then, each previous season was compared to the present (2007 vs. 2010, 2008 vs. 2010, and 2009 vs. 2010). Again, no comparison proved statistically significant, though the difference between four injuries in 2007 and zero in 2010 approached significance ($p = .057$, $p = .120$, and $p = .500$, respectively).

Chapter 5

DISCUSSION

The present study was conducted to provide information regarding the effects of a posterior capsule stretch on R-O-M in the overhead athlete. Specifically, this study examined the effects of the Sleeper Stretch on: (1) the shoulder R-O-M of collegiate baseball players, and (2) injury occurrences of the present season compared to the previous three seasons. The results of this study suggest that the participants demonstrated significant gains in IROT, as a group, from the beginning to the end of the intervention. In particular, most significant gains appeared to occur between weeks 8 and 12 of the intervention. Therefore, overhead athletes, regardless of the presence or absence of GIRD, made significant gains in R-O-M, suggesting a universal, beneficial effect of the Sleeper Stretch. Also, there were no time-loss injuries in the present season, but when compared to the injury rates of the previous seasons, the differences in occurrence rates failed to be statistically significant. Additional exploratory analyses raised questions about inter-tester reliability of the measurement technique used in this study, as well as how GIRD should be defined in the clinical setting.

These general findings, how they compare to previous research, and their implications for clinical application will be discussed below. This discussion will end with a review of the limitations of the study and suggestions for future research.

Procedural Integrity

Assessment of R-O-M utilized seven specific steps that were created by the PI. Each tester was observed completing four specific steps of the measurement procedure during each assessment phase. Testers were required to: (1) properly mark the landmarks used to align the goniometer, (2) properly align the participant's arm to the starting position, (3) correctly move the participant's arm passively into IROT, and (4) correctly "feel" for movement from the acromion to terminate motion. The remaining three procedural steps were completed by the tester's assistant: (5) properly aligning the goniometer with the previously marked landmarks, (6) properly realigning goniometer with landmarks after motion, and (7) reading the measurement from the goniomter accurately. Both test teams were observed completing these steps with the first 7 participants measured during each assessment session. All investigators performed each step accurately during every trial, denoting procedural uniformity across all measurement sessions. Therefore, it appeared that procedural fidelity was easily obtained in the current study with only brief practice experiences for both the testers and tester assistants, suggesting that the actual steps to using the goniometer and taking R-O-M measurements are relatively easy. Similarly, Fish and Wingate (1985) and Mayerson et al. (1984) concluded that testers with little clinical practice should be able to obtain accurate measurements with the goniometer if a standardized method is followed.

Measurement Accuracy

Intra-tester reliability remained relatively strong for both testers throughout all measurement sessions, remaining in the r = .9 range. Similarly, intra-tester agreement also generally fell in the 90^{th} percentile range across the four sessions. Both estimation procedures suggested that intra-tester measurements were relatively consistent across all sessions. On the other hand, inter-tester agreement on average was "moderate" (.83-.89), but the inter-tester reliability coefficient fell in comparison (r = .562). At times, the two testers produced almost identical measurements, while at other times the testers could be 20° or more dissimilar, thus resulting in large fluctuations in scores with no consistent pattern of one tester obtaining higher measurement scores than the other.

One factor that could have had a significant negative effect on inter-tester reliability scores was "stretching" or loosening that occurred as participants repeatedly had their R-O-M measured (each participant was measured a total of six times each session, thrice by each tester). Preliminary analysis of the R-O-M data at the end of the first session suggested that the tester who measured IROT second tended to obtain higher scores than the first tester, suggesting a "tester sequence" effect. In order to control for this effect, a novel tester sequence chart (see Appendix L) was developed to randomly assign which tester the participants started with for the remaining three sessions and was strictly followed. As a result, all participants were evaluated first by each tester during two of the four measurement sessions. As can be seen in Appendix L, most of the participants during the initial assessment session were measured first by the one tester, due to one tester completing measurements more quickly than the other, but this was better controlled across the remainder of the study by strict adherence to the tester sequence chart.

Collectively, these findings suggest that the same tester should take measurements each time for shoulder IROT, as opposed to using several testers for accurate measurement. However, it must be noted that these less than acceptable levels of reliability cannot be attributed to flaws with the mechanical precision of the goniometer, per se, but with the precision associated with determining where to set the goniometer. That is, the disagreement seen between testers is more likely due to the subjectivity of the tester to “feel” for movement from the acromion, thus to terminate IROT motion. According to Awan and colleagues (2002), as soon as the acromion starts to rise, the scapula has begun to move. To ensure pure glenohumeral movement and to eliminate added scapular motion, IROT can be stopped at the first sign of movement and a measurement can be obtained. This “feel” became easier with practice for both testers. While in the current study practice sessions did occur prior to each measurement session to try to ensure tester agreement, this finding suggests that more practice may be needed to obtain better inter-tester agreement/reliability—more practice before each session and, perhaps, additional practice sessions prior to the start of the study.

While inter-tester reliability is a concept regarding the soundness and utility of a measurement device between testers (House et al., 1981; Mitchell, 1979), it is imperative to note that, clinically, there is almost never a time that two independent testers concurrently gather R-O-M measurements on an athlete. The clinician in charge of the athlete would be the sole person responsible for measurement; therefore, the strong intra-tester reliability in this study may bear greater relevance to actual clinical practice.

Participant Compliance in Utilizing the Sleeper Stretch

Overall, participant compliance was quite good throughout the course of the intervention with 97% of participants reporting utilization of the Sleeper Stretch at least 5-6 times per week, 91% holding the stretch for the minimum of 30 seconds, and 85% performing the stretch for a minimum of 3 times per week. The Sleeper Stretch was incorporated into the baseball team's warm up routine; therefore, Tester 2 was able to observe the stretch being performed on the days of athletic participation. The head coach fully supported the intervention because of its potential benefit, and conveyed this message to his team, possibly increasing the participants' desire to comply. These compliance results are similar to those of Lintner and colleagues (2007), but quite different from those of McClure et al. (2007). Lintner and colleagues (2007) found very strong compliance among their professional pitchers, but this was due to the fact that the pitchers were required to stretch with the athletic trainer every day prior to taking the field. On the other hand, McClure et al. (2007) sent their participants home with a home-based stretching program. Self-reported compliance for using the Sleeper Stretch from these participants showed a rate of approximately 81%. In order to increase levels of compliance, Chan, Lonsdale, Ho, Yung, and Chan (2009) suggested that medical care providers offer several sources of motivation, as simple as social support, to keep the participants inspired. This was achieved in the current study by encouragement from the PI at each measurement session, and by support of Tester 2 and the coaching staff throughout the season.

Though the frequency of Sleeper Stretch utilization was high for this study, no data exist on how often it should be performed in order to obtain good gains. It appeared that those who stretched quite frequently exhibited good increases in R-O-M, though even those that did not perform the stretch as consistently still appeared to make gains. It must be noted, however, that since this study used historical data (i.e., self-reported after the fact), which is subject to participant inaccuracies and unreliability due to the retrospective nature of the self-report (Edwards, 1953), and not a direct measurement of behavior (e.g., how many times they actually stretched or held the stretch), there are inherent weaknesses with the accuracy of these conclusions.

Sleeper Stretch and R-O-M

The examination of the effects of the Sleeper Stretch for the group as a whole suggested a significant gain in dominant shoulder IROT (approximately 9°) by the end of the 12-week study. However, at the individual level, not all participants exhibited gains; 29 of the 35 participants (83%) demonstrated overall gains, but 6 showed a decrease in IROT, and 2 of those 6 showed reductions of over 10°. Of those who exhibited gains, 15 demonstrated gains of 10° or more, while 8 fell in the 5-10° range, and 6 showed gains of up to 5°. Examining session-by-session changes, individual scores varied significantly, while group gains were minimal from baseline to session 2 (a gain of about 2°), and by the third session overall increase in R-O-M from initial measurements was only 2-2.5°. However, there was a significant increase of 6 ° from week 8 to week 12, resulting in the total gain of approximately 9° for the study. This would suggest that gains in R-O-M over time associated with use of the Sleeper Stretch are best viewed in a curvilinear sense, versus a simple linear relationship. That is to say, the beneficial effects of the Sleeper Stretch may occur at different rates across time versus steady gains and, therefore, 1 week of stretching early in the program may not result in the same level of gains observed at a later point in time. For example, the first few weeks may have little to no notable changes, but after periods of stretching there is a more rapid increase in R-O-M gains followed by a potential plateau effect, refuting the simple linear relationship.

The current findings support those of Lintner et al. (2007), who noted that long-term stretching is beneficial for increasing R-O-M. In their study, they examined professional pitchers who had undergone a 3-year stretching program compared to those that had not. The pitchers in the stretching program evidenced significantly more R-O-M than their counterparts (approximately19°). Interestingly, in comparison to the present study, the professional pitchers exhibited only about twice the R-O-M gains in 3 years as seen in this 12-week intervention. This may be explained by Lintner and colleagues' (2007) observation of a plateau effect occurring after 3 years of stretching. The pitchers made strides in R-O-M gains for 3 years, but even with continuous stretching beyond that time period, failed to improve their shoulder R-O-M. Further, the current study would seem to lend empirical support to the contention that long-term stretching is beneficial for increasing flexibility, and in turn, increasing R-O-M (Woods et al., 2007).

An important question remains: What is considered "long-term stretching"? The current study found prominent gains after 12 weeks, but relatively minimal improvements during the first 2-month interval, which leads to questions regarding why such little changes seemed to occur in the first 8 weeks of the intervention. There are at least two possible explanations to consider. One possibility is that, because the first 6 weeks of this intervention fell mostly during preseason practice and into the beginning of the regular season, all participants were practicing equally and frequently. Possibly, consistent practice (i.e., 20 hours per week) resulted in a tightening in shoulder musculature due to the repetition. Then, after 6 weeks the baseball team began their regular season and the participants were not throwing as frequently or for as long when they did throw. During the regular season, the baseball team typically played four games every weekend; therefore, most pitchers would generally only throw on practice days and then pitch in one game per week. Likewise, position players would be throwing during practice days, but then only throwing in games during the course of a play in which they were involved. In each instance, the participants would seem to have dramatically decreased the number of times they were throwing each week. It is possible that this transition into the regular season and change in throwing demands contributed to the notable increase in R-O-M between the 3rd and 4th sessions.

A second possible explanation to account for why there was such an increase in R-O-M after 2 months relates to plastic changes that became prominent after 8 weeks of consistent stretching. This interval of time was a little longer than previous research has noted and, importantly, the previous research focused only on lower extremity musculature, not the shoulder. Fluck (2006) found that plastic adaptations occurred at the cellular level after 6 weeks of repeated stimuli. Similarly, Blazevich et al. (2007) evidenced significant mechanical adaptations after only 5 weeks of training, and Gajdosik and colleagues (2007) found significant lengthening and increases in passive resistive properties of muscles after 6 weeks of stretching. More relative to the results from this study, Gajdosik et al. (2005) indicated a significant increase in calf R-O-M after 8 weeks of routine stretching. These authors found evidence of plastic changes to muscles in as little as 5 weeks; however, the current study sought to examine the adaptations occurring primarily to the capsular tissue of the shoulder joint. The tissue “make-up” is different for these two structures (Martini, Timmons, & McKinley, 2000), perhaps explaining this necessary length of time (8 weeks) to observe change.

In summary, the Sleeper Stretch increased the participant's dominant arm R-O-M by about 9°, with the most noteworthy gain (approximately 6°) between weeks 8 and 12. The improvement in IROT may have occurred as a result of an uncontrolled factor, namely, the baseball teams' schedule change from preseason practicing to regular season play, or because of plastic changes that occurred within the structures of the shoulder, or a combination of the two. Though previous research proposes that R-O-M changes of the lower extremity musculature can occur within 5-6 weeks, this study suggests that more dramatic changes to the shoulder may take at least 8 weeks.

Additional Exploratory Analyses

During R-O-M analyses, participants were assigned into GIRD and non-GIRD groups to examine for differences. In this study, the definition of GIRD was "the loss in degrees of glenohumeral internal rotation of the throwing shoulder compared with the non-throwing shoulder" (Burkhart et al., 2003a, p. 406). These authors also proposed a scale of GIRD, starting out with varying degrees of "asymptomatic GIRD" and becoming "symptomatic GIRD" at ≥ 25° lack of IROT when compared to the nondominant arm (Burkhart et al., 2003a). Therefore, many overhead athletes experience GIRD, but it is only considered problematic when there is at least 25° of difference. Twenty-seven participants in this study met criteria for asymptomatic GIRD, none for symptomatic GIRD, and 8 did not exhibit GIRD. However, most of the players with GIRD (23 of 27), as well as most of the non-GIRD players (6 of 8), improved R-O-M in their dominant arm, suggesting that the Sleeper Stretch is not just beneficial for those suffering from GIRD, but for most overhead athletes.

To further explore factors influencing R-O-M gains, additional analyses were undertaken by dividing the participants according to the position they played. First, pitchers were compared to all nonpitching positions and no significance in the gain of IROT was found between these two groups. Then, the positions were further broken down into pitchers, infielders, and outfielders. Again, no statistical significance was detected between these groups. These findings suggested that the Sleeper Stretch had a homogeneous effect across all participants.

Sleeper Stretch and Injury Prevalence

Examination of the injury occurrence of the corresponding 12-week interval during the previous three seasons revealed a relatively low number of time-loss injuries (four, three, and one). During the present season, no time-loss injuries occurred. Nonparametric comparisons revealed no statistical significance between the injury rates for the years 2007, 2008, and 2009, and also when these three years were compared to the zero occurrence rate for the 2010 season. While this does not lend statistical support to the beneficial effects of the Sleeper Stretch, two things are important to highlight. First, even with the small number of injuries available for comparison, the difference between four injuries in 2007 and zero in 2010 approached statistical significance ($p = .057$). Secondly, during the present (2010) season, it seems important to reiterate that not a single time-loss injury occurred. While this may not be statistically significant when compared to the previous seasons, it does support the idea of "clinical significance." The goal of every athletic season is to keep the players healthy and prevent injuries from occurring. Although it cannot be proven that the Sleeper Stretch is the sole cause of the absence of shoulder injury this season, these results do suggest that the Sleeper Stretch may be a preventative measure that overhead athletes can undertake to diminish or, possibly, eliminate shoulder injury.

Clinical Application

This study elucidated significant gains in R-O-M for these specific overhead athletes; however, the clinical implications of these gains need to be addressed. One aim of this study was to examine R-O-M gains in a more practical, functional manner in comparison to previous studies. For example, Laudner and colleagues (2008) found significant gains in R-O-M after using the Sleeper Stretch. They took baseline IROT measurements, had the participants stretch, but then immediately took posttreatment measurements. They found evidence of significant gains in R-O-M, but failed to examine any real functional effects of these gains (i.e., what can the gains in R-O-M do for the participants, athletically?). Unlike Laudner et al. (2008), the present study assessed the changes of R-O-M over the course of the baseball season, while the participants continued to compete. The rate of shoulder injuries was recorded during the intervention to assess what effect the increase in IROT would have on injury occurrence, thus evaluating the practical effects of these gains. Since no time-loss injuries were incurred, it could be argued that the gains in IROT due to the Sleeper Stretch may have diminished the number of injuries obtained over the course of a baseball season. At the conclusion of 12-week Sleeper Stretch intervention, the participants, when pooled, increased IROT by approximately 9°. In the clinical setting, 9° of motion can be quite significant. Although no published studies suggest what is considered “good” gains in R-O-M, when one focuses on pre- or postsurgical cases, 9° of R-O-M is considered a substantial motion gain. Many surgeons encourage full R-O-M prior to any invasive procedure to aid in postsurgical rehabilitation (Sanders, 2010); therefore, one lacking 9° may have their surgery postponed until full motion is achieved. As noted earlier, whether this reduced number of injuries was due to the use of the Sleeper Stretch remains to be proven, yet from a clinical standpoint, a large increase in motion coupled with a lack of shoulder injury across the season suggests promise.

Limitations and Implications for Future Research

While this study provides evidence that the Sleeper Stretch is beneficial for the Division I collegiate baseball players who participated, the study is not without its limitations. First and foremost, the length of time the intervention was implemented was selected due to the access of the PI to the baseball team, and not because of previous evidence. Though no previous research examined a stretching protocol of this length (12 weeks) on this particular sample, an intervention of longer duration would have been advantageous to further examine the course and beneficial effects of continued stretching. Again, significant gains did not appear to occur until after several weeks, and when the study was discontinued after 12 weeks, this left open the question as to the ongoing rate of improvement or gains that would occur with an additional month or two of continued stretching.

The number of participants in this study was adequate for an exploratory study, but still relatively small, and contained only those on the baseball team at the PI's university. A larger sample size, with participants from different geographic areas, and even other overhead sports and gender, would greatly increase the generalizability of the findings.

Another possible limitation to the current study was that the participants became aware of the purpose of the study, and this could have caused them to try to unknowingly inflate their IROT scores. To manage this, each tester passively moved the participant's arm at each measurement session, therefore, possibly controlling any participant's "urge" to increase his IROT scores. Additionally, the PI was unable to control factors such as the number of innings played by each participant, the weather/conditions the team played in, and so forth, that could have a critical effect on how the intervention affected the results.

While this study attempted to provide new information concerning the effects of the Sleeper Stretch, much more information is needed. Improvements, as well as ideas for future research, relate directly to many of the limitations discussed above. In order to provide more solid evidence on the effects of the Sleeper Stretch on R-O-M and injury occurrence, additional research could utilize a much larger sample size. Also, while the participants were broken down into GIRD and non-GIRD groups, the non-GIRD sample consisted of only 8 participants in comparison to 27 in the GIRD group, significantly compromising any conclusions that could be drawn. Future researchers could examine GIRD and non-GIRD participants in more equal (and larger) numbers. This may provide more definitive information on the beneficial effects of the stretch on those athletes lacking R-O-M or to all overhead athletes, in general. Similarly, a mixed population of overhead athletes (e.g. baseball, volleyball, tennis) could be utilized to understand the benefits of this stretch across varied sports and gender. Future studies could also examine the frequency the stretch is used to examine gains in motion. For example, participants could be grouped into High (e.g., daily to 5-6 times per week), Moderate (e.g., 3-4 times per week), Low (1-2 times per week), and a Control group to examine relative gains. This would provide better information to coaches and staff on how frequently their team needs to stretch.

The frequency of R-O-M measurements (e.g., weekly, twice a week) could also be increased to better determine exactly when gains in IROT seem to occur, and whether these gains are similar to all or very individual. Further, this study only utilized the intervention for 12 weeks. While this is considered long-term, a study of longer duration would provide additional information on the course and effects of the Sleeper Stretch, again, providing more information on the relationship of time and rate of R-O-M gains. Similarly, maintaining the Sleeper Stretch as a routine stretch in the baseball team's warm up across future seasons may also provide further information on injury occurrence rates and the impact of the Sleeper Stretch. Perhaps, data on whether or not the Sleeper Stretch really can alleviate injury rates will become prominent after observation across several athletic seasons.

Researchers should also look to provide information on how to increase inter-tester reliability using the technique in this study. The subjectivity of the tester to "feel" the acromion's movement is something that should be practiced, as this method became much easier as the sessions went on, and is most likely the reason inter-tester reliability was so low. Studies could address how to improve or implement practice sessions prior to the initiation of the actual study to encourage similarity between testers. This would enhance procedural integrity, as well as ensure uniformity in methodology between all investigators.

Summary

In conclusion, the results of this study suggest that significant gains in IROT can be obtained in overhead athletes in 8-12 weeks with the use of the Sleeper Stretch. It would appear that this requires that the stretch be utilized on a frequent basis, be properly performed, and be held for the required amount of time. Baseball players, no matter what position they play or whether they suffer from GIRD, seem to benefit from the use of this stretch to gain IROT. Likewise, although statistical significance of this stretch as a way to diminish or eliminate a time-loss injury was not evidenced in this study, no injuries were incurred in the present season, and relative to the 2007 season, this change approached significance, leading one to feel optimistic about the beneficial effects of this stretching protocol.

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APPENDICES

APPENDIX A: Letter of Informed Consent

Responsible Investigator: Kendall Grow, ATC, SJSU Graduate Student
Title of Protocol: The Sleeper Stretch: Effects on Range of Motion and Injury in Baseball Players

Dear SJSU Baseball Player:

1. You have been asked to participate in a research study investigating the beneficial effects of a stretching protocol to prevent shoulder injuries.
2. You will be asked to perform the designated stretch every day of athletic participation and be involved in several measurement sessions.
3. The Sleeper Stretch is a recognized and advocated stretch. The probability of harm is no greater than would be encountered in typical athletic participation.
4. It is anticipated that participation in this study will have the benefits of increasing a participant's shoulder range of motion and reduce occurrence of injuries.
5. Although the results of this study may be published, no information that could identify you will be included.
6. There will be no compensation for participation in this study.
7. Questions about this research may be addressed to: Kendall Grow. Complaints about the research may be directed to: Mr. Al Douex Jr., MA, ATC, Interim Program Director, Graduate Athletic Training Education Program. Questions about a research subjects' rights, or research-related injury may be presented to: Pamela Stacks, Ph.D., Associate Vice President, Graduate Studies and Research.
8. No service of any kind, to which you are otherwise entitled, will be lost or jeopardized if you choose not to participate in the study.
9. Your consent is being given voluntarily. You may refuse to participate in the entire study or in any part of the study. If you decide to participate in this study, you are free to withdraw at any time without any negative effect on your relations with San José State University.
10. At the time you sign this consent form, you will receive a copy of it for your records, signed and dated by the investigator.
    - The signature of a subject on this document indicates agreement to participate in the study.
    - The signature of a researcher on this document indicates agreement to include the above named subject in the research and attestation that the subject has been fully informed of his/her rights.

Participant's Name Printed	Participant's Signature	Date
Investigator's Name Printed	Investigator's Signature	Date

APPENDIX B: Injury History Questionnaire

San José State University
Division I Baseball
Demographic Questionnaire

Thank you for agreeing to participate in this project. Please answer the following questions concerning shoulder injuries you may have experienced.

1. Have you ever injured your throwing shoulder? YES NO
   (If NO, go to question 2. If YES:)
   a. What was the month & year of the injury? ____________
   b. What was your diagnosis? ____________

   ____

2. Have you ever had surgery on your throwing shoulder? YES NO
   (If NO, go to question 4. If YES:)
   a. What was the month and year of the surgery? ____________

3. If you answered YES to either Question 1 or 2, did you perform rehabilitative exercises for your injury? YES NO
   (If NO, go to question 4. If YES:)
   a. How long did you do the exercises? ____________

4. Are you currently experiencing any symptoms from a shoulder injury? YES NO

5. Do you currently undertake any preventative measures for a shoulder injury (e.g., stretching, heating, icing, electrical stimulation, ultrasound, etc.)? If YES: YES NO
   a. Please describe your preventative strategies

   ____

   ____

6. Are you currently doing any rehabilitation for your throwing shoulder? YES NO

APPENDIX C: Participant Code Key

CODE KEY

P #	Participant Name
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P #	Participant Name
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APPENDIX D: Data Collection Form – Tester Baseline

TESTER # ____: BASELINE

Date: ____________________

	DOMINANT			NON-DOMINANT			
S	Trial 1	Trial 2	Trial 3	Trial 1	Trial 2	Trial 3	
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APPENDIX E: Data Collection Form – Tester Week 4

TESTER # ____: Week 4

Date: ____________________

	DOMINANT			NON-DOMINANT			
S	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 1**	**Trial 2**	**Trial 3**	
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APPENDIX F: Data Collection Form – Tester Week 8

TESTER # ____: Week 8

Date: ____________________

	DOMINANT			NON-DOMINANT			
S	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 1**	**Trial 2**	**Trial 3**	
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APPENDIX G: Data Collection Form – Tester Posttest

TESTER # ____: POSTTEST

Date: ____________________

	DOMINANT			NON-DOMINANT			
S	**Trial 1**	**Trial 2**	**Trial 3**	**Trial 1**	**Trial 2**	**Trial 3**	
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APPENDIX H: Participant PostIntervention Survey

Participant PostIntervention Survey

Thank you for participating in the Sleeper Stretch study. In order to assess any beneficial effects from this stretching protocol it is important to categorize all participants by their level of involvement, so please objectively rate yourself on the following items:

1. How often did you utilize the Sleeper Stretch?				
Daily	5-6 times/wk	3-4 times/wk	1-2 times/wk	Never/Rarely

2. Stretched for the minimum 30 seconds?				
All of the time	Most of the time	Half of the time	Some of the time	Never/Rarely

3. Stretched the minimum 3 times?				
All of the time	Most of the time	Half of the time	Some of the time	Never/Rarely

APPENDIX I: Procedural Integrity Checklist

CHECKLIST

Tester Initials: ___________ Observer Initials: ___________ Date: ___________

Assistant Initials: ___________ Observer Initials: ___________ Date: ___________

Procedural Step	**Obs. 1**	**Obs. 2**	**Obs. 3**	**Obs. 4**	**Obs. 5**	**Obs. 6**	**Obs. 7**
Tester: Mark proper landmarks (styloid process of ulna & olecranon process of elbow)							
Tester: Correctly move participant's arm to starting position							
Assistant: Properly align goniometer with landmarks							
Tester: Correctly move participant's arm passively into internal rotation							
Tester: Correctly feel for acromion movement & terminate motion							
Assistant: Properly realign goniometer to the landmarks							
Assistant: Read measurement accurately							

Total Correct Steps	/7	/7	/7	/7	/7	/7	/7

% Correct Steps	%	%	%	%	%	%	%

APPENDIX J: Extant Data Form

Extant Data Form

Instructions: A player's name can only appear one time on this form.

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Key:	—— = Was not on the team that season √ = Participated, no games or practices missed due to a shoulder injury X = Missed practices and/or games due to diagnosed shoulder injury

Examples:

#	2007	2008	2009	2010	
121	——	√	√	√	Was not on team in 2007, then played the next 3 years with no shoulder injuries.
122	X	——	——	——	Had a shoulder injury during 2007 season, did not play in '08, '09, or 2010.
123	√	X	——	——	No injury in 2007, but shoulder injury in 2008; not on team on '09 and 2010.

APPENDIX K: Individual Growth Across the Measurement Sessions

Participant #	**Session 1 - 2**	**Session 2 – 3**	**Session 3 - 4**	**Total (1-4)**
1	10.00	-11.33	17.33	16.00
2	1.00	-5.00	8.67	4.67
3	-14.00	8.00	4.00	-2.00
4	-14.67	-4.33	5.67	-13.33
5	-25.33	0.67	1.00	-23.67
6	2.33	1.33	7.67	11.33
7	24.33	7.00	2.33	33.67
8	-14.67	4.67	8.33	-1.67
9	-4.33	-1.67	-1.00	-7.00
10	-1.67	3.00	15.00	16.33
11	-10.67	3.33	15.67	8.33
12	2.67	-3.33	9.33	8.67
13	12.67	-12.00	3.33	4.00
14	-11.67	3.67	12.67	4.67
15	-7.00	5.00	10.33	8.33
16	-1.67	0.33	6.00	4.67
17	9.67	9.67	9.33	28.67
18	-4.67	7.67	2.33	5.33
19	5.67	-9.67	9.00	5.00
20	3.33	-9.33	3.00	-3.00
21	6.33	-0.67	12.00	17.67
22	18.00	-9.33	11.00	19.67
23	22.33	4.33	-9.67	17.00
24	12.00	-1.33	-3.00	7.67
25	-3.67	1.00	8.67	6.00
26	-9.33	0.00	11.67	2.33
27	5.00	3.33	5.67	14.00
28	13.33	-0.33	6.33	19.33
29	3.00	-3.33	10.00	9.67
30	6.67	6.00	1.00	13.67
31	11.67	2.00	-0.67	13.00
32	-4.33	15.00	1.67	12.33
33	10.00	-3.67	12.67	19.00
34	10.00	7.00	-4.67	12.33
35	2.67	1.33	-1.00	3.00

APPENDIX L: Tester Sequence Chart

Assignment of Participants to Testers Each Session (to control Tester Sequence effects)
[White = 1st Tester; Gray = 2nd Tester]

Subject #	**Session 1**	**Session 2**	**Session 3**	**Session 4**
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