SHOULDER STRENGTH AND CONDITIONING FOR INJURY PREVENTION IN BASEBALL PLAYERS

A Case Report

Presented to

The Faculty of the College of Health Professions and Social Work

Florida Gulf Coast University

In Partial Fulfillment

Of the Requirement of the Degree of

Doctor of Physical Therapy

By

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2014

Approval Page

This Case Report is submitted in partial fulfillment of

the requirements for the degree of

Doctor of Physical Therapy

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The final copy of this case report has been examined by the signatories, and we find that both the content and the form meet acceptable presentation standards of scholarly work in the above mentioned discipline.

Acknowledgement

I would like to thank the Florida Gulf Coast University Department of Physical Therapy and Human Performance faculty, in particular, my committee members Professor Thomas Bevins and Professor Kelley Henderson, for their assistance with my independent study. Their expertise and dedication to teaching has helped me expand my knowledge on the subject of shoulder strength and conditioning for baseball players. I would also like the thank the Gordon State College baseball coaching staff, head coach Travis McClanahan, and assistant coaches Tim Jones and Gary Sharpe for their participation in and feedback for the case report. Finally, I would like to thank the players on the Gordon State College baseball team for their hard work and participation in the shoulder strength and conditioning program.

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ABSTRACT

According to a survey completed by the National Federation of State High School Associations, baseball is the third most popular boys sport played. In the 2012-2013 year season, 15,632 schools played high school baseball across America. These schools' teams were comprised of 474,791 student athletes. A recent study reports that 63.3% of injuries in high school baseball are to the upper extremity. (Shanley, Rauh, Michener, & Ellenbecker, 2011). Bonza, Fields, Yard, and Comstock (2009) reported that 17.7% of high school baseball players injure their shoulders. This is a greatest percentage of injuries among baseball players. It is for this reason that shoulder injury prevention is of the upmost importance for baseball pitchers. This following scholarly paper provides a review of the phases of the baseball pitch including the structural and muscular requirements of each phase. The paper also reviews current literature used to produce an evidence based shoulder strength and conditioning program that may be implemented by institutions with limited financial resources, limited facilities, and without a qualified strength and conditioning professional. The case report describes how this program was implemented as part of the overall strength and conditioning program used during the fall baseball season at Gordon State College in Barnesville, GA. The development of the shoulder strength and condition program took into account current research as well as the financial and equipment limitations, availability of qualified strength and conditioning professionals, and training time allotted for the strength and conditioning of National Junior College Athletic Association student athletes.

Background

Shoulder Strength and Conditioning for Injury Prevention in Baseball Players

The activity of pitching a baseball places massive amounts of stress upon the upper extremity, particularly the shoulder, due to the extreme range of motion, high velocities and torques, and the repetitive motions required by overhead throwing (Park, Loebenberg, Rokito, & Zuckerman, 2003). These extreme stresses tax the stabilization of the glenohumeral joint, and lead to constant microtrauma to the shoulder musculature and the possibility of overuse injury. The dynamic stabilization of the shoulder is performed by the scapular muscles, the posterior rotator cuff, the supraspinatus, and the anterior wall structures such as the pectoralis major, latissimus dorsi, subscapularis, teres major, and long head of the biceps. The dynamic stabilizers compress and steer the humeral head in the glenoid fossa, and are most important at mid-range of motion. The abnormal translations of the humeral head are further controlled by the static stabilizers, such as the joint capsule, glenohumeral ligaments, and the glenoid labrum. The extreme range of motion along with the extreme forces needed to throw a baseball cause the static stabilizers of the shoulder to increase in laxity. The increased laxity can lead to improved performance, however once these static stabilizers are overstretched, an increased amount of stress is placed on the dynamic stabilizers and may lead to a pathological condition (Park et al., 2003).

Due to these factors, shoulder injuries are all too common in baseball players. A 2001 study performed by Conte, Requa, and Garrick reported that shoulder injuries account for 28% of injuries sustained by professional baseball pitchers. In a 1998 study, McFarland and Wasik reported that 75% of the time missed by collegiate baseball players was due to upper extremity issues, and pitchers accounted for 69% of these injuries. There is strong evidence that the current method of limiting the total amount of work a pitcher performs over the course of the year, particularly inning limits, is not effective in preventing injuries. Instead, between-game training and recovery techniques may explain why some pitchers can handle high cumulative loads and some cannot (Karakolis, Bhan, & Crotin, 2013). A proper strength and conditioning program will prepare a pitcher for the stresses of the upcoming season. In order to develop a proper strength and conditioning protocol for overhead throwing athletes to reduce the incidence of injury, it is important for physicians, physical therapists, athletic trainers, and coaches to have an understanding of how the different muscles in the shoulder are used during an overhead throwing activity (Escamilla &Andrews, 2009). Electromyographic (EMG) studies of muscle activation during the overhead pitching motion have been performed and have demonstrated that precise coordination of the upper extremity musculature is necessary to generate the velocity needed to improve performance while maintaining stabilization to prevent injuries. This information, as well as an in-depth knowledge of the biomechanics of pitching and the biomechanical sources of injuries, is important in order to develop proper strength and conditioning programs and rehabilitation regimens in an effort to prevent injuries and aid the injured athlete in their return to play (Park et al., 2003).

Shoulder injuries can be a career ending issue for baseball players, as well as provide a significant clinical challenge for health care professionals (Downar & Sauers, 2005). A baseball pitch can be broken up into six distinct phases. These phases are the wind-up, stride, arm cocking, arm acceleration, arm deceleration, and follow through. Each phase requires different shoulder musculature recruitment patterns (Escamilla & Andrews, 2009). During the wind-up and stride phases, muscular recruitment is low and therefore, injury rates related to stresses from these phases are also low. The next three stages: arm cocking, arm acceleration, and arm deceleration generate large forces and torques. It is during these three stages that a majority of the pitching injuries take place. The final two stages, arm deceleration and follow-though, allows the arm to slow down in order to reduce the amount of arm injuries (Park et al., 2003).

Muscle Recruitment Patterns during the Different Phases of Overhead Pitching

The first phase of the baseball pitch is the wind-up phase. This phase consists of the time from the initial movement made by the pitcher to the maximum knee lift (Escamilla & Andrews, 2009). For most pitchers, this phase consists of slow movements in which the shoulder activity is very low. The shoulder musculature most active during this phase is the upper trapezius, serratus anterior, and anterior deltoid. All of these muscles contract concentrically in order to upwardly rotate and elevate the scapula and to abduct the shoulder while the arm is brought overhead. These muscles then eccentrically contract to control downward rotation of the scapula and shoulder adduction as the hands are lowered back to chest level. During this phase, the rotator cuff muscles function as both compressors and rotators of the glenohumeral joint. Since the activity of the shoulder musculature is so low, movements are slow, and forces are low, very few shoulder injuries occur during this phase (Escamilla & Andrews, 2009).

The second phase of the baseball pitch is the stride phase (Escamilla & Andrews, 2009). This phase is also known as the early cocking phase (Park et al., 2003). This phase begins as the pitcher moves from a balanced single legged stance to when the lead foot of the stride makes contact with the ground. During this phase, the activity of the shoulder dramatically increases applying more stress to its musculature. As the pitcher strides out and his hands separate to prepare to throw, the scapula upwardly rotates, elevates, and retracts (Escamilla & Andrews, 2009). The throwing arm follows a “down-and-up-motion” which brings the throwing arm into a pattern of abduction, extension, and internal rotation during the stride phase in order to ensure that the throwing arm stays in proper sequence with the rest of the body (Park et al. 2003). When the ball reaches the lowest point of the stride phase the deltoid, supraspinatus, infraspinatus, serratus anterior, and upper trapezius continue to concentrically contract to abduct, and horizontally abduct the shoulder. The internal rotation moment changes over to an external rotation moment caused by a concentric external rotation from the infraspinatus (Escamilla & Andrews, 2009). The throwing arm will continue to abduct, externally rotate, and horizontally abduct until it reaches approximately 90 degrees of abduction, 30 degrees of horizontal abduction, and 50 degrees of external rotation as the pitcher’s front foot makes contact with the ground (Park et al., 2003). The supraspinatus is at its highest activity during this phase. This is because it works to abduct the shoulder as well as to stabilize the glenohumeral joint by offering a superior compressive force (Escamilla & Andrews, 2009; Park et al., 2003). The superior compressive force offered by the supraspinatus will bring the humeral head toward the glenoid fossa increasing the congruency of the joint. This added congruency and stabilization helps protect the shoulder joint from superior translation of the humeral head (Park et al., 2003). The deltoid is also highly active as it initiates and maintains the shoulder in an abducted position (Escamilla & Andrews, 2009). The deltoid provides most of the force for shoulder abduction, while the supraspinatus makes fine, delicate adjustments to the position of the humeral head on the glenoid fossa (Park et al., 2003). The trapezius and serratus anterior are moderately active during this phase. These muscles assist in stabilization of the scapula and to properly position the scapula into upward rotation and protraction in order to allow the supraspinatus and the middle deltoid to abduct the arm smoothly, minimizing the risk of impingement and instability from an abducted arm (Escamilla & Andrews, 2009; Park et al., 2003). The humerus is abducted to 90 degrees or more from the cocking phase through the deceleration phase. In this position, the inferior glenohumeral ligament is the main static stabilizer limiting anterior and posterior translation of the humeral head on the glenoid fossa (Park et al., 2003).

The third phase is the arm cocking phase which begins as the lead foot makes its initial contact with the ground and ends with the throwing shoulder in maximum external rotation. During this phase, the lower extremities and trunk generate a great amount of kinetic energy that is transferred to the arm as the trunk rotates to face the hitter (Escamilla & Andrews, 2009). High to very high muscular activity in the shoulder is necessary to keep the arm moving with the rotating trunk. Shoulder musculature must also become engaged to control shoulder external rotation (Escamilla & Andrews, 2009). The deltoid must be moderately engaged to keep the shoulder in approximately 90 degrees of abduction, however the activity of the deltoid diminishes as the activity of the rotator cuff musculature increases (Park et al., 2003). It is at this time that the pectoralis major and anterior deltoid are engaged to horizontally adduct the shoulder. The shoulder must move from approximately 20-30 degrees of horizontal abduction when the lead foot hits the ground to 15-20 degrees of horizontal adduction at maximum external rotation (Escamilla & Andrews, 2009; Park et al., 2003). The supraspinatus, infraspinatus, teres minor, and subscapularis are highly active during this phase as they resist glenohumeral distraction and work to increase the stability of the glenohumeral joint (Escamilla & Andrews, 2009). The supraspinatus is only highly active for a portion of the time. At maximum external rotation the supraspinatus has a reduced capacity for providing a stabilizing, superior compressive force. However, at this point the subscapularis is able to provide some compression and stabilization for the anterior capsule, which makes up for the diminished stabilization from the supraspinatus (Park et al., 2003).

During the cocking phase the shoulder musculature generates a compressive force on the arm of about 80% of the pitcher's bodyweight in order to resist the 'centrifugal' force generated as the arm rotates forward with the trunk. The posterior musculature is also important in resisting this motion. The infraspinatus, teres minor, and latissimus dorsi are all able to generate a posterior force on the head of the humerus to help resist its anterior translation due to their posterior position having a stabilizing effect (Escamilla & Andrews, 2009; Park et al., 2003). The rotator cuff musculature provides about 480 Newton (N) of compressive force to aid with this stabilization (Park et al., 2003). The infraspinatus and teres minor also contribute to the extreme range of external rotation of the shoulder (Escamilla & Andrews, 2009; Park et al., 2003). During this phase, the posterior rotator cuff may help to keep the anterior capsule, and anterior band of the inferior glenohumeral ligament unloaded by limiting anterior translation of the humeral head.

The shoulder internal rotators, such as the pectoralis major, latissimus dorsi, and subscapularis are eccentrically active during the cocking phase to control external rotation of the shoulder (Escamilla & Andrews, 2009). The shoulder internal rotators apply an anterior force of approximately 310 N and an internal rotation toque of about 67 Newton-meters (N- m) to help stabilize the humeral head (Park et al., 2003). During this external rotation the throwing arm is externally rotated about 125 degrees, starting from approximately 50 degrees of external rotation and ending at approximately 175 degrees of external rotation at maximum external rotation. Some studies have demonstrated external rotations from 160 to 185 degrees among professional pitchers (Pappas, Zawacki, & Sullivan, 1985; Dillman, Fleisig, & Andres, 1993; Werner, Fleisig, & Dillman, 1993; Feltner, & Depena, 1986). This extreme amount of external rotation allows the pitcher the greatest amount of range to allow for acceleration of the baseball (Park et al., 2003). At the same time as the pectoralis major and subscapularis are eccentrically contracting to control external rotation, they are also concentrically contracting to horizontally adduct the shoulder. With these muscles both lengthening and shortening an isometric contraction is essentially taking place as far as the length of the muscle is concerned. This simultaneous concentric and eccentric contraction helps maintain appropriate length-tension relationship.

The scapular protractors are also very important during the cocking phase. Early in the phase, the muscles eccentrically and isometrically contract to resist scapular retraction. Later in the phase, they contract concentrically to cause scapular protraction. The serratus anterior is one of the most important scapular protractors during this stage and is at its most active state (Escamilla & Andrews, 2009). The scapular retractors, such as the middle trapezius, rhomboids, and levator scapulae, are concentrically active in order to oppose scapula protraction. These opposing actions provide a stable surface for the external rotation of the humerus (Park et al., 2003).

The biceps brachii and long head of the triceps brachii both become moderately active to increase shoulder stability (Escamilla & Andrews, 2009). In addition to increasing anterior stability, the long head of the biceps brachii acts as a restraint against excessive external rotation, and alleviates some of the tension on the inferior glenohumeral ligament. Since the humerus is abducted to 90 degrees at this time, the long head of the biceps is able to produce a transverse shear force at the glenohumeral joint as external rotation of the humerus passes 60 degrees by compressing the humerus into the glenoid fossa. This transverse shear force helps prevent humeral head displacement in the transverse direction. The activity of the long head of the biceps brachii has been shown to be significantly increased in shoulders with anterior instability compared to the normal shoulder of the same person. The greatest activity of the long head of the biceps was shown to be at 90 and 120 degrees of external rotation (Park et al., 2003). The triceps brachii must contract eccentrically during the first 80% of this phase to control the rate of elbow flexion, and contracts concentrically during the last 20% to initiate and accelerate elbow extension as the shoulder continues to externally rotate (Escamilla & Andrews, 2009).

The fourth phase of baseball pitching is the arm acceleration phase which begins at maximum shoulder external rotation and ends with the release of the ball (Escamilla & Andrews, 2009). The baseball is accelerated from a near stationary position to speeds over 90 miles per hour in about 50 milliseconds. At maximum external rotation during the arm cocking phase there is an external rotary torque of almost 15,000 inch-lb on the humerus. Once the acceleration phase begins the torque reverses to internal rotary torque of 14,000 inch-lb on the humerus (Park et al., 2003). The shoulder internal rotation is the fastest human movement recorded and occurs in excess of 7250 degrees per second (Wilk et al., 2011).The peak angular velocity has been shown to occur 5 milliseconds before ball release (Pappas et al., 1985). During this phase, moderate activity from the deltoid maintains the shoulder in approximately 90- 100 degrees of abduction (Escamilla & Andrews, 2009; Park et al., 2003). This amount of shoulder abduction in relation to the head and trunk is consistent in all throwers, including “over the top” and “sidearm” pitchers. The positional change of the arm as compared to the vertical plane is caused by increased lateral flexion of the trunk more than it is by a change in shoulder abduction (Park et al., 2003). The shoulder’s internal rotators such as subscapularis, pectoralis major, and latissimus dorsi are performing at their highest level to concentrically contract to help generate the internal rotation angular velocity needed to accelerate the ball before release. The internal rotation usually occurs in a range of about 80 degrees from maximum external rotation around 175 degrees to approximately 90 to 100 degrees of external rotation at ball release (Escamilla & Andrews, 2009; Park et al., 2003). The subscapularis not only helps create internal rotation, but it also is needed to help maintain the humeral head in the glenoid fossa. The teres minor and infraspinatus are also vital to keeping the head of the humerus properly positioned in the glenoid fossa. The triceps brachii concentrically contracts to help extend the elbow and the long head aids in shoulder stabilization, however, the main force that extends the elbow is kinetic energy from the lower extremities and trunk. Throwing motions that involve the entire body produce almost twice the elbow extension angular velocity of a throwing motion that does not use any lower extremity, trunk, or shoulder movements. It is believed that the arm is swung open like a “whip” (Escamilla & Andrews, 2009). The arm is positioned at 0 degrees of horizontal abduction when the ball is released and the acceleration stage is finished (Park et al., 2003).

The fifth phase is the arm deceleration phase, which begins when the pitcher releases the ball and ends when the arm reaches maximal internal rotation (Escamilla & Andrews, 2009). The deceleration phase begins at ball release and lasts for approximately 50 milliseconds (Park et al., 2003). During this phase the posterior shoulder musculature is very active generating deceleration force close to -500,000 degrees per second. The main purpose of the phase and the following phase is to decelerate the throwing arm comfortably and safely, dissipate the excess kinetic energy not transferred to the ball, and stabilize the shoulder, thereby minimizing the risk of injury. The deceleration of the throwing arm produces a very large amount of stress on the posterior shoulder structures. These forces contribute to posterior instability and rotator cuff tears (Park et al., 2003). The infraspinatus, teres major, teres minor, posterior deltoid, and latissimus dorsi all contract eccentrically in order to decelerate the internal rotation and horizontal adduction of the arm and aid in the resistance of distraction and anterior subluxation of the humeral head (Escamilla & Andrews, 2009). The teres minor reaches 84% of its maximum voluntary contraction, the highest level of activation of all of the posterior musculature. This strong contraction allows the teres minor, along with the latissimus dorsi, subscapularis, and to some extent the pectoralis major, to provide posterior joint stabilization, limit humeral head translation, and protect against subluxation of the humeral head. Due to this high activation posterior cuff pain with deceleration can often be isolated to the teres minor (Park et al., 2003). The biceps brachii is at its most active during this phase. At first the biceps brachii eccentrically contracts to help decelerate elbow extension. The biceps brachii must also work synergistically with the posterior shoulder musculature to resist distraction and anterior subluxation of the humeral head (Escamilla & Andrews, 2009). Due to these forces of the posterior shoulder musculature along with the biceps brachii the shoulder internal rotation angular velocity decreases from its maximal speed at 5 milliseconds before ball release to zero. Following ball release the surrounding musculature places a posterior force of about 400 Newton, a compressive force of 1090 N, and a horizontal abduction torque of about 97 N-m onto the humerus to decelerate the arm. During this phase the shoulder travels from a position of neutral horizontal abduction at the time of ball release to horizontal adduction across the body. The shoulder quickly abducts from approximately 90 degrees to approximately 110 degrees following ball release. The fact that the arm stays in between 90-110 degrees of abduction throughout the pitching motion suggests this is a strong, dynamic position for the arm and shoulder. As the deceleration phase continues the humerus will drop below 90 degrees of elevation. It is at this point the pectoralis major loses its mechanical advantage causing the latissimus dorsi to be the more active than the pectoralis major in the deceleration of the arm. The deceleration phase ends when the humerus reaches 0 degrees of internal rotation. (Park et al., 2003).

The final phase of the baseball pitch is the follow through (Park et al., 2003). This is a mostly passive stage in regards to the shoulder musculature. Electromyography **(**EMG) analysis shows all musculature in the shoulder girdle and upper extremity to have low to moderate activity during this stage. It is during this stage that the body “catches up” with the throwing arm. The follow through is associated with shoulder adduction, horizontal adduction, and elbow flexion. Due to the shoulder adduction the anterior and superior portions of the joint capsule are the limiting factor in inferior and posterior motion of the humeral head (Park et al., 2003).

Relationship Between Upper Extremity Muscle Strength and Throwing Speed

Research performed by Toyoshima, Hoshikawa, Miyashita, and Oguri in 1974 suggested that only 53.1% of throwing velocity can be attributed to the upper extremity; however Bartlett, Storey, and Simons (1989) and Pedegena, Elsner, Roberts, Lang, and Farewell (1982) have both suggested that throwing velocity will be increased by increasing the strength of the upper extremity. Both studies have shown that concentric shoulder adduction, wrist extension, and elbow extension peak torque can be used to predict the throwing velocity in adult baseball players. Clements, Ginn, and Henley (2001) set out to determine if this same correlation between muscle strength and throwing velocity was present in adolescent athletes. Clements et al. (2001) found that in adolescent baseball players, isometric shoulder internal rotation torque-to-body weight ratio and concentric elbow extension torque-to-body weight ratio were most closely related to throwing velocity. This study found 71% of the variation in throwing velocity was caused by isometric shoulder internal rotation torque-to-body weight ratio and concentric elbow extension torque-to-body weight ratio in about equal parts. These results are in agreement with the study performed by Pedegana et al. (1982) which found the increase in concentric elbow extension explained 27% of the change in throwing velocity. The results of these studies suggested that the shoulder internal rotators and the elbow extensors are important to producing the force on the ball during the acceleration phase of pitching. Therefore, a program designed to increase throwing velocity should focus on concentric shoulder internal rotator and elbow extensor strength in order to increase the speed generated during the acceleration phase, as well as eccentric strength of shoulder external rotators and elbow flexors to help protect the shoulder during the deceleration phase (Clements et al., 2001).

Throwing Related Muscular Fatigue and Related Injuries

Some of the main injuries sustained by baseball players are tears in the rotator cuff. The rotator cuff must stabilize the humeral head in the glenoid fossa, while also moving the glenohumeral joint (Yanagisawa, Niitsu, Takahashi, & Itai, 2003). The researchers believed the prevention of rotator cuff injury depends on a coach's or athletic trainer's understanding of the rotator cuff musculature and how it is affected by throwing activities. In a 2003 study, Yanagisawa et al. compared the effects of a predetermined pitching protocol and concentric shoulder external rotator strengthening with a Thera-band®. T2-weighted MRI imaging was used to detect an increase in intramuscular water. This increase can partially reflect the amount of muscle damage caused by the throwing or exercise protocol on the rotator cuff. Yanagisawa et al. (2003) found that the supraspinatus and external rotator muscle group had a significant increase in T2 signal, which occurred over 96 hours after pitching, compared to the baseline. The subscapularis showed a significant increase in T2 signal over the first 48 hours, and then returned toward baseline over the next 96 hours. However, immediately after pitching there was no significant difference between the supraspinatus, external rotators, and subscapularis as far as T2 signaling. As for shoulder external rotation exercise, the T2 signal was significantly increased, even more so than the pitching group, over 60 minutes post exercise but returned toward baseline over the next 24 hours.

One important note on this study is the participants were instructed to refrain from other physical activity or performing physical therapy modalities such as icing or stretching post throwing or exercise protocol. The increase in T2 signal due to increased intramuscular water immediately after exercise is most likely due to cellular accumulation of metabolites such as lactic acid. Therefore, the change in T2 signal immediately after exercise is related to the mean forces generated by the muscles. The amount of lactic acid influencing the signal is probably why the signal was more intense immediately post exercise than it was post throwing. A rest period was given to the participants within the throwing protocol, which would allow the shoulder musculature to clear some of the lactic acid. The T2 signaling in the throwing shoulder stayed significantly elevated for a few days post throwing protocol. The authors believed this increase was mainly due to edema and swelling resulting from damage to the skeletal muscles caused by eccentric contractions. This also explains why the subscapularis muscle recovered before the supraspinatus and the external rotators of the shoulder. The supraspinatus and external rotators must perform a greater eccentric contraction than the subscapularis. This study shows the importance of proper training protocols to replicate the stress of throwing as much as possible, as well as the need to understand the time required for tissue healing associated with different types of muscular contractions (Yanagisawa et al., 2003).

Another study on work-fatigue in a thrower's shoulder suggested muscles which were forced to eccentrically contract showed greater work-fatigue than those which concentrically contracted following a throwing bout (Dale, Kovaleski, Ogletree, Heitman, & Norrell, 2007). Dale et al. (2007) also found that repeated eccentric internal rotation activity of the shoulder musculature during the cocking phase diminished the thrower's capacity to maintain the same level of work output over time. Dale et al. (2007) suggested that increased fatigue can lead to a lack of coordination and control of the humeral head by the rotator cuff during throwing. This can add stress to the stabilizing structures of the anterior shoulder. A reduction of the rotator cuff's ability to control the humeral head, along with muscle fatigue that decreases the ability of the scapula to remain positioned properly, can also lead to impingement syndromes and other glenohumeral injuries (Dale et al., 2007).

Weak or overly fatigued posterior rotator cuff muscles are associated with many injuries, such as tensile overload undersurface rotator cuff tears, labral and bicep tendon pathologies, capsular injuries, and internal impingement of the infraspinatus and/or supraspinatus tendons on the posterosuperior glenoid labrum (Gowan, Jobe, Tibone, Perry, & Moynes, 1987). Also, conditions such as chronic anterior shoulder, instability can cause adjustments to the musculature used during the throwing motion (Glousman, Jobe, Tibone, Moynes, Antonelli, & Perry, 1988). When pitchers with chronic anterior shoulder instability are compared to pitchers who are healthy, they show less activation of the pectoralis major, latissimus dorsi, subscapularis, and serratus anterior. Conversely, pitchers with chronic anterior shoulder instability show greater involvement of the biceps brachii, infraspinatus, and supraspinatus. The increased activity of the biceps brachii can increase the stress that the insertion point of the long head of the biceps brachii has on labrum and may cause labral pathology (Glousman et al., 1988).

While pitching, some sensorimotor deficits may become apparent. The sensorimotor system is responsible for maintaining throwing form and dynamic stability of the upper extremity. These deficits can lead to improper positioning of the scapula and injury (Tripp, Yochem, & Timothy, 2007). Through motion analysis, Tripp et al. (2007) tested 16 NCAA baseball player's ability to reproduce their arm-cocked and ball-release positions before and after completion of a functional fatigue protocol. The researchers found sensorimotor system deficits recover after 7 minutes in most joints in the upper extremity, however, the ability to replicate the same glenohumeral arm-cocked positioning with precision did not recover within 10 minutes of rest. This is important because this information offers insight to further our understanding of capsular and labral pathology of overhead throwers by showing that the pitcher loses the sensorimotor control with fatigue, which can then change the biomechanics of scapular positioning. It is possible that this change in positioning, particularly in the arm-cocked position may lead to injury. Other researchers have implicated the arm-cocked position as a critical factor in the cause of shoulder injuries such as subacromial and posterior, and labral tears (Jobe, Kvitne, & Giangarra, 1989; Meister, 2000; Jobe, 1995; Kuhn, Lindholm, Huston, Soslowsky, & Blasier, 2003). This information is crucial during the prescription of recovery intervals during intense overhead activity. In order to help prevent injury, a minimum of 4 to 7 minutes should be given to allow for sufficient recovery between fatiguing bouts of throwing in order to avoid the accumulated sensorimotor deficits. Due to the fact that the glenohumeral joint does not recover as fast as other joints in the upper extremity, it is necessary to emphasize sensorimotor system acuity and endurance training of shoulder abduction and external rotation (Tripp, Yochem, & Timothy, 2007).

Another variable that must be taken into account to help ensure the safety of a pitcher is how much recovery time is needed between pitching appearances. A study performed by Potteiger Blessing, & Wilson (1992) examined how different recovery times between games affect the serum creatine kinase, serum lactate dehydrogenase, muscle soreness, and pitch velocity in baseball pitchers. Creatine kinase and lactate dehydrogenase serum levels are used as physiological markers for skeletal muscle damage following strenuous exercise. It is also been reported that eccentric muscle contractions, like the ones present with pitching, result in greater creatine kinase and lactate dehydrogenase levels (Komi & Buskirk, 1972; Newham, McPhail, Mills, & Edward, 1983; Newham, Mills, Quigley,& Edwards, 1983; Talag, 1973). Potteiger et al. (1992) compared the differences in these factors following 4-day and 2-day rest periods. These rest periods were chosen because a 4-day rest period is typical for regular season play, while pitching on a 2-day rest period often occurs as a post-season strategy. To do this, the researchers asked 10 pitchers to throw three simulated games, with 4 rest days between games A and B and 2 rest days between games B and C. All of the pitchers in the study participated in an 18 day throwing program to prepare for this study. Following all three simulated games, the pitchers showed a significant increase in creatine kinase levels. The peak value of creatine kinase was at 24 hours post games A and B, but at 6 hours following game C. In each case, the creatine kinase levels decreased following the peak and reached near baseline levels at 72 hours. Lactate dehydrogenase serum levels also showed a significant increase following each game, with their peak values coming 6 hours after each game. One difference between the creatine kinase levels and lactate dehydrogenase levels was that the former appeared to change in response to repeated games. The lactate dehydrogenase levels were greatest after game A and lowest following game C. This effect of repeated games was the opposite for muscle soreness. The pitchers reported the greatest amount of muscle soreness directly following each simulated game, with the least amount reported following game A and the most amount of soreness reported following game C. There was no significant decrease in velocity due to the changes in rest; however, the general trend was a slightly decreased velocity in game C. There was no significant change in velocity by inning within each game. This study suggests that there is a release of creatine kinase and lactate dehydrogenase following pitching. There was not a significant decrease in either depending on a 4 or 2 days of rest; however, there was an increase in muscle soreness, and an insignificant reduction in velocity after only 2 days of rest (Potteiger et al., 1992). This study helps strength and conditioning professionals understand the need to train starting pitchers, who throw roughly every 4 days, and relief pitchers, who throw on 1 to 2 days of rest differently. This study can also help explain the reduction in velocity that often takes place throughout a season due to the buildup of muscle fatigue.

Conditioning to Reduce Injury and Maximize Performance

Studies completed by Dale et al. (2007), Yanagisawa et al. (2003), and Page, Lamberth, Abadie, Boling, Collins, and Lintin (1993) show the importance of the posterior rotator cuff eccentrically contracting to decelerate the arm and prevent injury. Dale et al. (2007) suggested that due to this factor, eccentric exercise of the posterior rotator cuff musculature is a vital part of a conditioning or rehabilitation protocol in overhead throwing athletes. In 1993, Page et al. showed that performing a Thera-band® routine using the D2-diagnonal pattern of proprioceptive neuromuscular facilitation (PNF) patterns increased eccentric strength of the posterior rotator cuff musculature. The issue Page et al. (1993) discovered with this type of eccentric strength training was the strength gain by the subjects was only significant at a test speed of 60 degrees per second. This is much slower than a pitcher's arm during throwing, which can reach 7250degrees per second (Wilk, et al. 2011). Therefore, although the eccentric strength gained through this Thera-band® routine may help improve strength of the shoulder musculature, it may not have as big of an impact at the speed the thrower's arm is moving as it does at a slower rate (Page, et al. 1993). This type of training has become mainstay in many strengthening and rehabilitation programs to prevent shoulder injury.

To build on this information, researchers began to investigate how to train the shoulder musculature at higher speeds. In an effort to do this, more recent research has focused on the use of upper extremity plyometric training to increase performance (Carter, Kaminsk, Douex Jr, Knight, & Richards, 2007). Carter et al. (2007) also suggested a strong eccentric contraction of the external rotators in the shoulder is vital for reducing injury. Although the vast amount of literature on plyometric training involves the lower extremities, stretch-shortening cycle activation is similar in the upper and lower extremities due to principles of neurophysiological adaptation. In this study, Carter et al. (2007) added a high volume upper extremity plyometric training protocol of six exercises, the "Ballistic Six", to the baseball player's current off-season strength and conditioning program. The control group continued their normal off-season strength and conditioning program. The Ballistic Six was performed two times a week for eight weeks by the athletes in the plyometric group. This study concluded that the athletes who also performed the Ballistic Six protocol significantly increased their throwing velocity, although no statistically significant differences in any isokinetic strength measurements were shown between groups. This study showed that to increase performance, a conditioning program must be sport specific and mimic the actual activity of the sport as much as possible. When compared to traditional strength training, plyometric training more closely mimics the stresses and speeds required of a thrower's shoulder (Carter et al. 2007).

A staple exercise for many strength and conditioning programs for overhead throwers is the full or empty can exercise used to strengthen the supraspinatus muscle. There is much debate over which exercise is superior for the overhead thrower. The goal of these exercises is to improve the strength and endurance of the supraspinatus muscle in order to provide increased stability of the humeral head, while minimizing the chance for impingement (Tino & Hillis, 2010). Researchers have stated that the empty can exercise effectively activates the supraspinatus muscle to a greater extent than other commonly used exercises, however improper performance of the empty can exercise can place the athlete in danger of shoulder injury (Kolber& Beekhuizen, 2009). The empty can exercise is to be performed in standing or sitting, with arm internally rotated so that the thumb is pointed toward the ground. The humerus is internally rotated in order to increase tension and maximize activation of the supraspinatus. The arm is then elevated in the plane of the scapula to approximately 60 degrees, and then lowered. At approximately 60 degrees of scaption, the humerus must externally rotate to prevent impingement of the supraspinatus tendon between the greater tuberosity and the acromion process. Since this does not occur during the empty can exercise, the exercise must be terminated at 60 degrees of scaption for safety (Kolber & Beekhuizen, 2009). Another reason the empty can exercise places the athlete at greater risk of shoulder impingement is due to the excess amount of middle deltoid activation causing superior humeral head migration and a decrease in subacromial space. Also, during the empty can exercise, the scapula is protracted, which causes internal rotation and anterior tipping, leading to a decrease in subacromial space (Tino &Hillis, 2010). In order to perform the full can exercise, the athlete is instructed to retract the scapula and externally rotate the humerus so the thumb is pointed up (Tino & Hillis, 2010). The retraction of the scapula and the external rotation of the humerus both help maintain optimal subacromial space. The arms are then elevated to 90 degrees in the scapular plane, before being lowered again. When the scapula is maintained in retraction during the elevation process, more force is produced. This fact helps support the importance of having strong scapular stabilizers to provide a stable platform for the arm. The internal rotation of the shoulder during the empty can exercise is thought to maximize the supraspinatus activity by increasing the tension on the muscles; however, the full can exercise has shown similar supraspinatus activity in EMG testing and MRI (Tino & Hillis, 2010). In conclusion, the full can exercise has been shown to offer similar supraspinatus activation while decreasing the opportunity for impingements, and therefore should be recommended over the empty can exercise for strengthening the supraspinatus in baseball players.

One final aspect of the throwing motion to take into account when developing strength and conditioning program is the stretch shortening cycle (SCC) contraction present in a throwers arm (Grezios, Gissis, Sotiropoulos, Nikolaidis, & Souglis, 2006). The 2006 study performed by Grezios et al. demonstrated that the SSC is in fact the type of muscle contraction associated with the overhead throw, and the amount of force developed before the concentric contraction ultimately determines the velocity of the throw. Grezios et al. (2006) demonstrated this by measuring the impulse and speed parameters during the first 50 milliseconds of the concentric phase of the overhead movement performed. Since voluntary muscle contractions are all but impossible in this short of a time, the influence of stored elastic energy on the concentric contraction can be shown. The efficiency of this type of contraction depends on neural factors in the arm. In a throwing motion, the musculature is pre-stretched before the arm acceleration phase. The stretch of the shoulder musculature can be caused by the deceleration of the initial external rotation movement and also by the effects of the forces of inertia. The effects of inertia can reach relatively high values, particularly on the distal segment of the kinetic chain, in this case, the hand. This stretch is related to the production of the initial strength. As seen in a plyometric jump, this SSC in pitching can be thought of as an increase in muscle recruitment before the initial movement of the acceleration phase. It is important to note that in order to take advantage of the SSC, the muscle being stretched must have elastic characteristics, which passive muscles do not. This means pre-activation and muscle stiffness, as determined by the central nervous system, are important in the overall throwing motion. Pre-activation also increases the sensitivity of the muscle spindles, which are an integral part of the SSC. In a research study written by Grezios et al. (2006), the researchers reference a study written in German, Gollhoffer (1987) which observed that trained people demonstrate a higher level of pre-activation EMG potentials. This allows for the assumption that increased pre-activation can be accomplished by a training program, and an increased amount of pre-activation will allow for the compensation of larger stretch loads and the storage of more elastic energy to be used through the SSC. Knowing this, it can be extrapolated that increasing the initial speed of contraction will increase the loading phase of the tissue and increase the elastic capacity of the tissue, allowing for greater velocity of a thrown baseball (Grezios et al., 2006).

Mobility and Strength Changes in Baseball Players and Related Injury Risk

In order to attain maximum performance, baseball players must achieve a delicate balance between shoulder mobility and shoulder stability, often referred to as the “thrower’s paradox” (Downar & Sauers, 2005). A 2005 study by Downar and Sauers compared the mobility of the throwing and non-throwing shoulders in 27 professional baseball players and found significant differences in scapular and glenohumeral mobility when compared to the non-throwing shoulder. The researchers found that scapular upward rotation was significantly greater in the throwing shoulder versus the non-throwing shoulder at 90 degrees of humeral elevation. The researchers also found increased posterior tightness in the throwing shoulder versus the non-throwing shoulder; however this is not necessarily statistically or clinically significant. Downar & Sauers, 2005). A 2000 study by Tyler, Nicholas, Roy, and Gleim found side to side differences in posterior shoulder tightness in non-overhead athletes with shoulder impingement as well. Posterior capsule tightness has previously been attributed to reactive scarring due to the repetitive trauma caused by overhead throwing (Pappas et al., 1985). During the follow through phase of the baseball pitch, the humerus internally rotates, possibly placing the posterior inferior capsule in the primary location to resist the deceleration forces and become the direct restraint against these loads. It is possible that the accumulation of these forces results in posterior capsule and posterior musculature tightness, causing the altered range of motion (Launder, Sipes, & Wilson, 2008). Even with these noted changes in throwing shoulder mobility, no cause and effect relationship between posterior shoulder tightness and injury has been established. Clinically, it is extremely difficult to differentiate between posterior capsule and posterior rotator cuff tightness. In this study, the posterior shoulder of the throwing arm was shown to be tighter at 90 degrees of abduction and maximum horizontal adduction. Due to this posterior tightness, it can be assumed that both the posterior capsule and the posterior rotator cuff are active in the limitation of cross-body humeral motion. Additionally, Downar and Sauers (2005) showed the throwing shoulder to have a statistically significant decrease in isolated glenohumeral internal rotation of 12 degrees, compared to the non-throwing shoulder, as well as an increase in isolated glenohumeral external rotation of 7 degrees, compared to the non-throwing shoulder. Isolated glenohumeral joint motion was used because it is more reflective of capsular mobility than shoulder complex range of motion. Overall, no statistically significant difference in overall arc of motion was found between throwing and non-throwing sides. Wilk, Meister, and Andrews (2002) and Morgan (2000) have shown similar results to Downar and Sauers (2005). Wilk et al. (2002) suggests that the total motion of the throwing shoulder and non-throwing shoulder should be within 5 degrees of each other. Morgan (2000) referred to a similar principle as “the 180 degree rule”, in which each degree of internal rotation that is lost must be made up by a degree of external rotation. It has been suggested that when the loss of glenohumeral internal rotation exceeds the gain of glenohumeral external rotation, the athlete is predisposed to a type II SLAP lesion. Downar et al. (2005) found similar results as did Wilk et al. (2002) in that the healthy athletes had slightly less than a 5 degree difference in total shoulder mobility between the throwing and non-throwing shoulder. Although all of these studies found slightly different numbers, it is important to note that the overall range of motion of the throwing shoulder being within 5 degrees of the non-throwing shoulder may help prevent injury in overhead throwing athletes. Several studies have also noted that the loss of internal glenohumeral rotation and the gain of glenohumeral external rotation in the throwing shoulder versus the non-throwing shoulder is often caused by humeral retroversion as well as soft tissue adaptations (Reagan, Miester, Horodyski, Werner, Carruthers, & Wilk, 2002; Downar & Sauers, 2005; Launders et al., 2008). These adaptations are a result from the large rotational and distractive forces that take place at the shoulder during the throwing motion (Launder et al., 2008). This increased humeral retroversion may enhance performance and velocity by allowing more external rotation, while reducing the stress on the anterior static stabilizers of the shoulder (Downar & Sauers, 2005). Other kinematic alterations that have been described due to posterior capsule tightness are decreased horizontal shoulder adduction, shoulder abduction, and flexion (Launder et al., 2008).

As previously stated, Wilk et al. (2002) and Launder et al. (2008) reported that healthy athletes demonstrate a loss of internal rotation, gain of external rotation, and have a total range of motion (internal plus external rotation) that is comparable (within 5 degrees) to the non-throwing shoulder. Reinold et al. (2008) reported that pitchers lose 9.5 degrees of internal rotation and 10.7 degrees of total motion immediately following pitching. This loss of motion is still present 24 hours following a pitching performance. In a 2011 study, Wilk et al. followed up this research by attempting to correlate glenohumeral internal rotation deficit (GIRD) and total rotational motion of a pitcher's throwing shoulder to injuries. Prior to this study, Burkhart, Storey, and Simons (2003) defined GIRD as a 20 degree or more loss of internal rotation in the throwing shoulder versus the non-throwing shoulder. It is possible that GIRD is due to posterior capsular tightness (Burkhart et al., 2003). Wilk et al. (2011) found that pitchers in their study averaged 136.1 degrees of external rotation, while in 90 degrees of abduction, in the throwing shoulder compared to 128.6 degrees in the non-throwing shoulder. The average internal rotation found in the throwing arm was 47.5 degrees versus 59.1 degrees in the non-throwing hand. The average total range of rotational motion was 183.7 degrees in the throwing shoulder and 187.7 degrees in the non-throwing shoulder. Wilk et al. (2011) found a correlation between certain patterns of mobility and injury. Pitchers with GIRD were shown to have twice the risk of shoulder injury as compared to pitchers without GIRD. Fortunately, 11 of the 13 pitchers in this study with GIRD were able to be successfully treated by the athletic training staff, with an effective stretching program to be at the forefront of the treatment. Similar to GIRD, total rotational range of motion was also shown to be correlated with injury rates. Pitchers who had a 5 degree or more difference in total rotational range of motion in the throwing shoulder versus the non-throwing shoulder were 2.5 times more likely to have a shoulder injury. The final measurement that showed correlation to injury is the total rotational range of motion in the throwing arm being greater than 176 degrees. Of all of the pitchers who sustained injuries in the study, 78% of the pitchers had a total rotational range of motion of over 176 degrees, while 16% of the injuries took place in pitchers with total rotational range of motion under 176 degrees and 5% of injured pitchers had exactly 176 degrees of total rotational range of motion. This finding can be troubling because the average total rotational range of motion for this study was 187 degrees in the throwing shoulder, well above 176 degrees. Also, if stretching is used to prevent GIRD, it may cause the athlete to surpass the recommended 176 degrees of total rotational range of motion. The increase in injury rates after 176 degrees of total rotational range of motion is thought to be due to the increased demands the extra range places on the dynamic and static stabilizers of the shoulder complex (Wilk et al., 2011).

With the loss of internal rotation being due to osseous adaptation, as well as muscular tightness, a posterior rotator cuff stretching exercise may be the most appropriate way to treat GIRD (Wilk et al., 2011). One proposed solution to this problem is to perform static stretches to the posterior shoulder structures in order to regain the lost internal rotation. One such stretch that has been developed is the “sleeper stretch” (Laudner et al., 2008). In order to perform the sleeper stretch, the participant takes a side lying position with their shoulders and elbows at 90 degrees of flexion and the lateral border of the scapula stabilized against the treatment table. Side lying helps to stabilize the scapula so that the posterior soft tissue restraints in the glenohumeral joint are isolated with internal rotation. The stabilization of the scapula is what makes the sleeper stretch superior to the cross-body adduction stretch for isolating the glenohumeral joint, however both stretches are recommended by Laudner et al. (2008). In a 2008 study performed by Laudner et al., the primary investigator passively internally rotated each participants shoulder by grasping the forearm and moving it to the treatment table. The stretch was held at the end of the range of motion for 30 seconds. The stretch was repeated two times with 30 seconds of rest in between stretching episodes. The stretch was performed by the investigator in order to ensure similar forces were applied to each participant; however the sleeper stretch can be performed without assistance which makes the sleeper stretch a more viable option in some cases than other proposed stretches that require a partner. This study compared the acute effects of the sleeper stretch on shoulder range of motion in both NCAA Division I baseball players and physically active college students who have not participated in overhead throwing athletics in the past five years. The study found an increase of 2.3 degrees in posterior shoulder motion and 3.1 degree increase in internal rotation following the sleeper stretches by the baseball group. The study found no difference in the external rotation of the baseball group following the stretch. The sleeper stretch provided no difference in any measurements for the non-throwing group. The results of this study suggest the sleeper stretch results in a statistically significant acute increase in shoulder range of motion, particularly the glenohumeral internal rotation and posterior shoulder motion, in the throwing arm of baseball players. The sleeper stretch may prevent or limit the posterior shoulder tightness, which is commonplace with overhead throwing due to the large forces and repetitive stresses places on the tissue. This study did not demonstrate if the results are clinically significant (Laudner et al., 2008).

Due to the extreme demands placed on the upper extremity during the throwing motion, pitchers without a proper strength and conditioning program may be at a higher risk for injury (Byram et al., 2010). A combination of the repetitive nature of throwing, inherent instability of the glenohumeral joint, and the large amount of muscle activation by the rotator cuff, particularly during the deceleration phase, places a significant amount of stress on the soft tissue surrounding the joint. The repetitive eccentric loading of the posterior shoulder musculature may result in a cycle of intramuscular connective tissue tearing, inflammation, and weakness. Unlike the external rotators, which are required to decelerate the throwing arm, the internal rotators which accelerate the arm undergo plyometric strengthening during the throwing motion, with the stretch during the late cocking phase and the concentric contraction to provide acceleration. If this plyometric internal rotation strengthening is not reciprocated by external rotation strengthening, the rotator cuff will become imbalanced. The median kilograms of external rotation strength to kilograms of internal rotation strength ratio demonstrated by Byram et al. (2010) were 1.05. Byram et al. (2010) showed a statistically significant association between preseason external rotation weakness and throwing related injuries which require surgical resolution. The same study showed a statistically significant association between supraspinatus strength and shoulder injury, including both injuries requiring surgery and those that do not. Finally, Byram et al. (2010) provided some evidence linking the ratio of external to internal rotation to the overall likelihood to sustain a throwing related injury. Players with a prone external rotation to internal rotation strength ratio in the 5^{th} percentile of players tested had an estimated 39% likelihood of injury, while players with a ratio in the 95^{th} percentile had a 17.5% likelihood of injury. The evidence was stronger when using prone external rotation strength, than it was when using seated external rotation strength or combining the two into one group. This is clinically relevant because it can help strength and conditioning professionals prescribe specific external rotation exercises.

Summary

In order to develop and implement a proper training or rehabilitation program, it is first and foremost important to understand the biomechanics and muscle recruitment pattern of the shoulder in a throwing motion. Once this is learned, a coach, physical therapist, or athletic trainer may implement the core principles of strength and conditioning, such as sport specific motions, sport specific types of muscle contractions, and proper program design to develop an appropriate strength and conditioning program for the athletes. Interestingly, the future of baseball strength and conditioning programs may be more related to injury prevention, and less toward optimizing performance (Ebben, Hintz, & Simenz, 2005). Ebben et al. 2005 noted marked differences when comparing the result of their survey on the practices of 21 of 30

Major League Baseball (MLB) strength and conditioning coaches to previously reported studies on the practices of strength and conditioning coaches in both the National Football League (NFL) and the National Hockey League (NHL) (Ebben & Blackard, 2001; Ebben, Carroll, & Simenz, 2004) Some of the major differences are the number of parameters used in exercise testing, emphasis on repetition maximum testing for program design, less variety in speed development, and less use of weightlifting and variations. It is possible this is due to the emphasis on injury prevention as well as some other factors. MLB strength and conditioning coaches reported a common theme of program design being geared more toward pre-habilitation and injury prevention rather than an increase or maintenance of strength. Another belief among at least one MLB strength and conditioning coach is that more dual certified athletic trainer/certified strength and conditioning specialists will be hired in order to adapt to the current needs to the baseball player (Ebben, Hintz, & Simenz, 2005). This paradigm shift will allow for medical staff, such as athletic trainers and physical therapists, to have a larger influence on the way that all of the athletes, injured and non-injured, train.

Case Report Purpose

The purpose of this case report is to illustrate how an evidenced based approach to the development of a shoulder strength and conditioning program helped increase performance and reduce the incidence of injury in a National Junior College Athletic Association (NJCAA) baseball pitching staff. Although individualized fitness testing, exercise prescription, and program design are the gold standard for any strength and conditioning program, the individualization of the proposed program was beyond the scope and purpose of this case study. Instead, the purpose was the observation of an evidence based strength and conditioning program for the shoulder that can be performed safely at institutions with limited resources and without the oversight of a qualified strength and conditioning professional. After an at length discussion about the current “arm care” program and current literature on shoulder strength and conditioning for baseball players, the Gordon State College, Barnesville, GA, coaching staff decided to make adjustments to their current program. These changes and reported outcomes are described in the following sections.

Case Description

The individuals on the pitching staff described in this case report are scholarship athletes at Gordon State College in Barnesville, GA. The pitching staff includes twelve pitchers. Two pitchers are sophomores; ten are freshmen. The average height of the pitching staff is 72.83 inches (184.99 cm). The average weight is 178.5 pounds (80.9 kg). Seven of the pitchers throw right handed, while five pitchers throw left handed. The entire pitching staff participated in the fall baseball season and arm care program from August 2013 to January 2014. None of the pitchers have reported previous injuries to their throwing arm.

Two key concepts were employed in the development of this program. The first is that dynamic stability is essential for pain free arm function and prevention of shoulder injury in the overhead-throwing athlete (Carter et al., 2007; Wilk, 2013). The second is that the major stress placed on the musculature during overhead-throwing is centered on the muscle’s ability to exert its maximum amount of force output in a minimal amount of time (Carter et al., 2007).

Impression

All players on the Gordon State College baseball team completed a physical examination prior to participation in the first practice in accordance with Section 9 of the eligibility rules of the National Junior College Athletic Association which states : “All student-athletes participating in any one of the NJCAA certified sports must have passed a physical examination administered by a qualified health care professional licensed to administer physical examinations, prior to the first practice for each calendar year in which they compete.” Further individual evaluation of the player’s throwing arms and exercise prescription is beyond the scope of this case study. The pre-existing shoulder strength and conditioning program at Gordon State College was examined and compared to current literature, as well as expert opinion, in the field.

Initial examination of the pre-existing shoulder strength and conditioning program at Gordon State College found the program to be relatively comprehensive. The program included band exercises, traditional “Jobe” shoulder exercises, and medicine ball throws. The specific exercises are presented in the Appendix, Tables 1 A-D. Due to time constraints, the team is broken up into groups of three. Each group is assigned to a station in which specific exercises are performed. Once complete, they move onto the next station. Rest breaks are based on the time needed for fellow teammates to perform their exercise, rather than a prescribed rest period. The team also performed “Six Backs” exercises. These are stabilization exercises for the shoulder and back musculature. The exercises are presented in the Appendix, Table 2. These exercises are prescribed to be held for 30 seconds in weeks 1-3 and for 45 seconds in weeks four and on. These exercises are performed in sequence without rest in between. The purpose of these exercises is to build endurance of shoulder and scapular musculature. The upper extremity stretching program is outlined in the Appendix, Table 3. These stretches are performed prior to practice and games. Each stretch is held for 30 seconds. The purpose of these stretches is to increase tissue length and upper extremity range of motion.

Actions

The intervention in this case report included changes to the existing shoulder strength and conditioning program at Gordon State College. Gordon State College had a relatively comprehensive shoulder strength and conditioning program prior to this case report; however, some changes were made in exercise selection, technique, and prescription. All proposed changes were presented to the Gordon State College coaching staff in a meeting prior to the 2013 fall baseball season.

Modifications to the Gordon State College stretching program were made based on current literature and expert opinion. All stretches previously performed are listed in the Appendix, Table 3. Players were instructed to perform 4 repetitions for 30 seconds before and at the end of exercise in order to improve shoulder range of motion and flexibility (Laudner et al., 2008) Two stretches, the “Arms Back and Up” and “Arms Back and Together” partner stretches, were eliminated from the stretching protocol. This is because both stretches required the pitcher’s throwing shoulder to be forced into humeral extension. Glenohumeral extension occurs about a coronal axis passing through the center of the humeral head (Levangie & Norkin, 2011). In theory, this motion shoulder should be a “spin”, however based on muscle activation and timing an anterior translation may also take place. This places a stretch on the anterior capsule, glenohumeral ligaments, and the glenoid labrum. These structures already have increased laxity due to the extreme range of motion along with the extreme forces needed to throw a baseball. The increased laxity can lead to improved performance; however, once these static stabilizers are overstretched, an increased amount of stress is placed on the dynamic stabilizers and may lead to a pathological condition (Park et al., 2003).

The “Arm Across” stretch was changed from a standing stretch to a modified side-lying cross body stretch. The player is positioned side-lying with throwing shoulder down. The player then rolls posteriorly 20 to 30 degrees. This quarter turn allows for stabilization of the scapula. The second modification to this stretch is to align the forearms together with the opposite forearm on top. This modification prevents external rotation of the humerus during the stretch. These modifications help isolate the targeted tissue of the posterior shoulder region (Wilk, Hooks, & Macrina, 2013).

The “Sleeper Stretch” is performed with the goal to treat posterior tightness and to combat the loss of internal rotation that is often associated with overhead throwing. The suggested modification of the sleeper stretch was to have the player in a side-lying position with his trunk posteriorly rolled 20 to 30 degrees and shoulder elevated to 90 degrees. This modification was made to minimize symptoms associated with the shoulder being at a 90 degrees flexed position. The trunk position aligns the humerus in the scapular plane, which has been shown to increase strain on the posterior capsule allowing for a more targeted stretch. The final modification to the sleeper stretch was to place a towel roll under the player’s humerus. This causes horizontal adduction which helps to better isolate the stretch of the infraspinatus, which is often the target tissue (Wilk, Hooks, & Macrina, 2013).

The existing shoulder strength and conditioning exercises and prescription are noted in the Appendix, Table 1 A-D. This list of exercises was found to be relatively comprehensive. The first major modification to the program was the change from elastic tubing resistance to free weights. The purpose of this change was to increase the demand for dynamic stabilization required when performing exercises. Another change was in the exercise prescription. Previously, Gordon State College was performing 1 set of 10 repetitions for each exercise. The main reasoning behind this was time constraints. The exercise prescription was changed to 3 sets at various repetitions, depending on the week. The accommodation for time was made by eliminating exercises that were deemed less important, such as the prone shoulder exercises, and were replaced with the low row exercise after the first two weeks.

One strength exercise that was added to the program was supine eccentric internal rotation. This exercise is performed with the player supine, knees bent, and feet flat on the ground. The upper arm is positioned with the shoulder in approximately 80^{o} of abduction and the elbow in 90^{o} of flexion with his knuckles facing up. A partner assists by stabilizing the scapula and by returning the weight to the starting position. The stabilization of the scapula focuses the eccentric rotator cuff and internal rotator activation, while lowering the weight. The repetition begins from the starting position with the forearm perpendicular to the ground and ends when the weight touches the ground at approximately 90^{o} of external rotation. Tissue elasticity may be augmented by eccentrically training the internal rotators. In theory, the augmented tissue elasticity may reduce pitching effort and decrease the required concentric effort at the maximal external shoulder rotation moment and the maximal internal shoulder rotation moment. (Crotin & Ramsey, 2012).

Three plyometric exercises were recommended to be added to the plyometric training program already in place. These exercises were the “baseball throw”, the “90/90 side throw”, and the “deceleration catch”. The “baseball throw” and “90/90 side throw” were incorporated into the Gordon State College program. The deceleration catch was not implemented due to reservations from the coaching staff about the exercise possibly causing injury. These new plyometric drills were prescribed at greater volume than the existing plyometric exercise. They were prescribed to be completed twice a week for eight weeks. The first two weeks included 3 sets of 10 repetitions. Weeks three to five required 3 sets of 15 repetitions. Final weeks six to eight required 3 sets of 20 repetitions. Carter et al. (2007) demonstrated that these exercises, along with several exercises already existing in the Gordon State College plyometric program, could lead to significant improvements in baseball throwing velocities in college baseball players.

The final change to the Gordon State College shoulder strength and conditioning program was the replacement of the “empty can” exercise with the “full can” exercise. The purpose of this change is to decrease the risk of shoulder injury. Research has shown that the “empty can” exercise effectively activates the supraspinatus muscle to a greater extent than other commonly used exercises, however, improper performance of the “empty can” exercise can place the athlete in danger of shoulder injury (Kolber & Beekhuizen, 2009). The “full can” exercise has shown similar supraspinatus activity in EMG testing and MRI, while decreasing the chances of impingement (Tino & Hillis, 2010).

Outcome

The overall outcome of this case report has been positive. As of March 28th, 2014 the Gordon State College baseball team has participated in 32 baseball games. They have not sustained any significant arm injuries. Also, the Gordon State College coaching staff has reported fewer complaints of arm fatigue and soreness. The coaching staff has also noted an increase in throwing velocity, which is typical as the season goes on; however, the coaching staff has reported that this increase was seen earlier in the season than in previous years. The final improvement noted by the Gordon State College coaching staff is the pitchers' improved ability to sustain velocity throughout the game in comparison to years prior.

Discussion

During a face to face meeting with the Gordon State College baseball coaching staff the full 8 week shoulder strength and conditioning program outlined in the Appendix, Tables 4 & 5 was discussed. After an at length discussion, the coaching staff decided to implement the changes outlined in the intervention section of this case report. The reasons for not implementing certain exercises had to do with perceived time constraints, increased equipment need, and the coach's preferences for performing exercises with which he was comfortable.

Several of the changes, such as the changes to the stretching protocol and the replacement of the "empty can" exercise to the "full can" exercise, centered on reducing unnecessary strain placed on the shoulder. Based on the biomechanics of the shoulder, it can be theorized that forceful stretching into humeral extension can place strain on the anterior capsule of the shoulder. This is important because chronic anterior shoulder instability impacts muscle activation patterns in overhead throwers. Pitchers with chronic anterior shoulder instability demonstrate less activation of the pectoralis major, latissimus dorsi, subscapularis, and serratus anterior and greater involvement of the biceps brachii, infraspinatus, and supraspinatus. The increased activity of the biceps brachii can increase the stress that the insertion point of the long head of the biceps brachii has on labrum and may cause labral pathology (Glousman et al., 1988). Much like forced stretching into external rotation, the "empty can" exercise has been shown to produce unnecessary risk of shoulder injury. At approximately 60 degrees of scaption, the humerus must externally rotate to prevent impingement of the supraspinatus tendon between the greater tuberosity and the acromion process. Since this does not occur during the "empty can" exercise, the exercise must be terminated at 60 degrees of elevation to prevent impingement (Kolber & Beekhuizen, 2009). Also, the excess amount of middle deltoid activation causes superior humeral head migration, which, along with the scapular protraction, internal rotation, and anterior tipping taking place during the "empty can" exercises leads to a decrease in subacromial space. This risk of impingement is not necessary since similar supraspinatus EMG activity has been noted using the "empty can" exercise (Tino &Hillis, 2010).

The exercises added to the existing program included plyometric baseball throw and the 90/90 side throw with a 2lb medicine ball, as well as the supine eccentric internal rotation. The two plyometric exercises, along with other exercises already being performed at Gordon State College, were shown by Carter et al. (2007) to be effective in improving the pitching velocity of college baseball pitchers over an 8 week program. The implementation of the supine eccentric internal rotation exercise is based more the theory of it being useful for injury prevention. This is the theory that eccentrically training the internal rotators may augment tissue elasticity. The augmented tissue elasticity may reduce pitching effort and decrease the required concentric effort at the maximal external shoulder rotation moment and the maximal internal shoulder rotation moment. (Crotin & Ramsey, 2012).

The one exercise that the Gordon State College baseball coaching staff did not want to implement was the deceleration catch. The head coach was concerned about this exercise causing injury with his players. This exercise was demonstrated to be safe and effective by Carter et al. (2007). A 1992 article written in the National Strength and Conditioning Association Journal also supports its use as a safe and effective exercise for injury prevention in baseball players (Panariello, 1992).

There are two confounding variables that may also have influenced the increase in velocity and ability to sustain velocity throughout the game seen in the Gordon State College pitching staff. The first is a change in coaching style. The Gordon State College baseball coaching staff has decided to have their pitchers throw fewer innings per game than in seasons past. The starting pitchers are averaging 4 innings a game this season, compared to 7 innings a game last season. This will allow for the pitcher to pitch with more effort throughout their start, rather than having to conserve energy. The other change that may account for the increase in velocity seen in the Gordon State College pitching staff is the change from low intensity long duration cardiovascular training to sprinting in between starts. This change was based on a 2008 research article by Rhea, Oliverson, Marshall, Peterson, Kenn, and Aylon, which reported that power training and intense, lengthy cardiovascular endurance training are not compatible. The lengthy cardiovascular endurance training was shown to decrease lower body power during the baseball season, which leads to negative outcomes including decreased velocity.

Conclusion

The practical application of this case report is that the proposed shoulder strength and conditioning program can be safely implemented at the college baseball level without the oversight of highly qualified strength and conditioning specialists for the purpose of injury prevention and increasing performance. The proposed program offers general recommendations based on current literature that can be modified to meet each program's needs; however, when performed without modification, can offer a solid basis for a comprehensive arm care program.

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Appendix

Current and Proposed Arm Care Programs

Tables 1 A-D – Current Arm Care Program

Table 1 A

Tubing Exercises		
Power Ts	1 set of 10 repetitions	Extend straight arms in from of shoulders toward tubing with your palms facing together. Pull tubing away from the base until your arms are extended out at the side of your body at shoulder height. Pause and return to starting position. Hands remain in the same position and arms straight throughout the entire movement.
Pulldowns	1 set of 10 repetitions	Extend arms straight out in front of shoulders toward the tubing with palms facing the ground. Pull the tubing down and away from the base until your hands pass your hips. Pause and return to the starting position. Hands remain in the same position and arms straight throughout the entire movement.
High Double Arm External Rotation	1 set of 10 repetitions	Extend arms out to the side of the body with your elbows at shoulder height and bent to 90 degrees with your palms facing the ground in full internal rotation. Rotate your shoulders into full external rotation, maintaining the elbows at shoulder height and your elbows bent to 90 degrees. Pause and return to starting position.
Y Flex	1 set of 10 repetitions	Extend arms straight out in front of your shoulders toward the tubing with your palms facing the ground. Pull your arms up and above you into a Y until your arms are extended overhead. Pause and return to starting position.
Lower Single Arm External Rotation	1 set of 10 repetitions	Elbow should be down and bent 90 degrees with forearm across stomach, arm should be in the full internal rotation position. Rotate your shoulder into full external rotation, pointing your hand out away from band while keeping elbow bent at 90 degrees. Pause and return to starting position.

Table 1 B.

Weighted Exercises (3-5 lbs)		
Angel Wings	1 set of 10 repetitions	Stand with your arms at your sides with palms facing the sides of your legs. Raise your arms out to your sides to shoulder height, pause , rotate arms pointing thumbs up, then raise arms up above until weights touch. Repeat movements in reverse.
Shoulder Raises to the Top	1 set of 10 repetitions	Standing with your arms in front of your hips, thumbs pointing together. Raise your arms out front to shoulder height, pause, rotate arms pointing thumbs up, then raise arms above head. Repeat movement in reverse.
Empty Cans	1 set of 10 repetitions	Standing with your arms at your sides and thumbs pointing to your thighs. Raise your arms to shoulder height, keeping thumbs pointed down, pause, then lower back to the starting position. Arms should be on a plane just inside your shoulders.

Table 1 C.

Body Weight Exercises		
Scapular Dip	1 set of 10 repetitions	Place your hands on bench/chair in a dip position with legs extended out. Lower your body toward the ground allowing your shoulders to rise toward your ears, pause, then push up your shoulders back down raising your body back up to the starting position. Keep your arms straight during the entire movement.
Straight Arm Pushups	1 set of 10 repetitions	Place your hands shoulder width apart, arms extended in the pushup position. Let your shoulders relax and lower your body bringing your shoulder blades together and pause. Then push your chest back away from the ground. Elbows remain straight throughout the entire motion.

Table 1 D.

Medicine Ball Training		
Rotational Chest Pass	1 set of 10 repetitions 6-10 lb. medicine ball	Assume athletic stance with feet slightly wider than shoulder width, facing a wall about 10 feet away. Hold medicine ball in front of right shoulder with both hands. Leading with hips, explosively rotate toward the wall and throw the ball against the wall as hard as possible. Catch rebound on the left shoulder and repeat while alternating shoulders.
Forward Overhead Throw	1 set of 6 repetitions each side. 2-6 lb medicine ball	In a stride throwing position hold the ball in both hands facing the wall, about 10 feet away. Raise ball over and behind head. Explosively throw ball forward to the wall as hard as possible without stepping.
Two-Legged Overhead Toss	1 set of 10 repetitions 6-10 lb medicine ball	Stand in an athletic stance with feet slightly wider than shoulder width while holding medicine ball in both hands. Lower medicine ball between your knees as you squat down slightly. Leading with hips, explosively throw ball over head as high as possible.
Rocker Toss	1 set of 10 repetitions 6-10 lb medicine ball	Lying on your back holding medicine ball over your head, rock onto your shoulder s with your feet coming over your shoulders and head. Explosively rock forward bringing hips and feet back to the ground. As back begins to come off the ground explosively throw ball as hard as forward as possible.
Medball Slams	1 set of 10 repetitions 6-10 lb medicine ball	Stand in an athletic stance with feet slightly wider than shoulder width while holding medicine ball with both hands. Raise ball over head then explosively slam ball to the ground.

Table 2. Current Stabilization Exercises

Exercise:	Prescription:	Description:
Touchdowns-Thumbs Up	Weeks 1-3: 30 second hold Weeks 4+: 45 second hold	Arms extended above shoulders, Thumbs up, Scapulae retracted.
Crosses- Thumbs Up	Weeks 1-3: 30 second hold Weeks 4+: 45 second hold	Arms extended straight out from shoulders, Thumbs up, Scapulae retracted
Straight Arm Pushups	Weeks 1-3: 30 second hold Weeks 4+: 45 second hold	Assume a plank position. Squeeze shoulder blades together, which will lower your torso slightly. Do not bend your arms. When you have brought your scapula together as much as possible, release the exercise and return to your starting position.
Crosses with Bent Elbows	Weeks 1-3: 30 second hold Weeks 4+: 45 second hold	Arms extended straight, Thumbs up, Scapulae retracted
Touchdowns-Thumbs Down	Weeks 1-3: 30 second hold Weeks 4+: 45 second hold	Arms extended above shoulders, Palms Down, Scapulae retracted
Crosses-Thumbs Down	Weeks 1-3: 30 second hold Weeks 4+: 45 second hold	Arms extended straight out from shoulder, Palms down, Scapulae retracted
Plane Jumpers	Weeks 1-3: 30 second hold Weeks 4+: 45 second hold	Arms extended down at 160 degrees, Palms down. Scapulae retracted.

Table 3. Current Stretching Program

Stretch:	Prescription:	Description:
Sleeper Stretch	30 second hold	Lying on your side with throwing arm on the bottom at 90 degrees, internally press your arm down.
Arm Across	30 second hold	Grab elbow and pull across your chest. Switch arms and repeat.
Arm Over & Behind	30 second hold	Grab elbow and pull arm behind head. Switch arms and repeat.
Arms Back & Up	30 second hold	Pull your partners arms back and up with palms facing together.
Arms Back & Together	30 second hold	Pull your partners arms back and together with palms facing away.
Arm Through the Arm Pit	30 second hold	With partner on his knees pull his throwing arm through the opposite arm pit.
Arm Through the Hip	30 second hold	With partner on his knees pull his throwing arm through opposite hip.

Table 4. Eight Week Prescribed Strength and Conditioning Program

Exercise	Weeks 1-2	Weeks 3-5	Weeks 6-8
Side-lying External Rotation	3 sets of 15 repetitions	3 sets of 10 repetitions	3 sets of 6 repetitions
Prone Ys- Thumbs Up	3 sets of 15 repetitions	*	*
Prone Is	3 sets of 15 repetitions	*	*
Prone Ts- Thumbs Up	3 sets of 15 repetitions	*	*
Prone Ts- Thumbs Down	3 sets of 15 repetitions	*	*
Scapular Pushups	3 sets of 15 repetitions	3 sets of 10 repetitions	3 sets of 6 repetitions
Supine Eccentric Internal Rotation	3 sets of 15 repetitions	3 sets of 10 repetitions	3 sets of 6 repetitions
Rhythmic Stabilization	3 sets of 30 second trials	3 sets of 30 second trials	3 sets of 30 second trials

*After two weeks these exercises were replaced with low rows due to time constraints

Table 5. Eight Week Prescribed Plyometric Strength Program

Exercise	Weeks 1-2	Weeks 3-5	Weeks 6-8
Band External Rotation at 90/90	3 sets of 10 repetitions	3 sets of 15 repetitions	3 sets of 20 repetitions
Band Internal Rotation 90/90	3 sets of 10 repetitions	3 sets of 15 repetitions	3 sets of 20 repetitions
Soccer Throw- 6lb medicine ball	3 sets of 10 repetitions	3 sets of 15 repetitions	3 sets of 20 repetitions
90/90 Side Throw	3 sets of 10 repetitions	3 sets of 15 repetitions	3 sets of 20 repetitions
Deceleration Baseball Throw- 2lb medicine ball progressed to football	3 sets of 10 repetitions	3 sets of 15 repetitions	3 sets of 20 repetitions
Baseball Throw- 2 lb medicine ball	3 sets of 10 repetitions	3 sets of 15 repetitions	3 sets of 20 repetitions