The Effects of a Baseball Throwing Velocity Improvement Program on Shoulder Range of Motion

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Abstract

Corey James Rodrigo: The Effects of a Baseball Throwing Velocity Improvement Program on Shoulder Range of Motion
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Limited glenohumeral range of motion of the throwing shoulder in baseball players has been shown to be a risk for shoulder and elbow injury. Although there are many established programs that have been shown to improve glenohumeral range of motion, no program has been shown to effectively improve throwing velocity and range of motion. Identifying a throwing program that can improve range of motion could help to decrease the risk of shoulder injury in a way that is easily marketed to a performance-minded participant. Therefore, the purpose of this study was to determine the extent to which the Velocity Plus Throwing Program could alter shoulder range of motion. 32 youth baseball players between the ages of 8-17 years old completed the study; 12 in the intervention group and 20 in the control group. The participants underwent range of motion testing to measure dominant internal rotation (IR), dominant external rotation (ER), dominant total arc of motion (TAM), glenohumeral internal rotation deficit (GIRD), external rotation gain (ERG), and total arc of motion difference (TAMD). Participants in the intervention group demonstrated a significant TAM decrease of 10.1 ± 4.5 degrees (t(30): 0.95, p=0.03). No significant difference was found with dominant IR, dominant ER, GIRD, ERG, or TAMD. Further, no significant change in velocity resulted from the intervention, with a mean of increase of 1.2 ± 1.1 MPH (t(30): -1.09, p=0.29). Future research should focus on a larger sample size to increase the power of the findings and identify an effective performance program that can be utilized to improve athletic performance and help prevent injury.
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CHAPTER I

INTRODUCTION

Often touted as America’s favorite pastime, baseball is one of the most popular sports in the country. According to USA baseball, it is estimated that there are more than 12 million adolescents and children playing amateur baseball throughout the country (USA Baseball, 2012). Of these 12 million, approximately 474,219 are high schools players, making baseball the fourth most popular male sport in the country (National Federation of State High School Athletic Associations, 2012). While watching a pitcher throw over 90 mph with pinpoint precision is a true testament of the human body, the complex nature of throwing mechanics submits the shoulder and elbow to extreme forces that place players at a great risk for injury (Burkhart, Morgan, & Kibler, 2003a). Despite the physical demands placed on the throwing arm, it is common for players to participate in practice and competition year round, placing the elbow and shoulder at greater risk for injury with each repeated throw (House, Maison, & Preston, 2009). The high amount of repetitions can lead to the accumulation of microtraumas and a subsequent shoulder or elbow injury. This can be especially noted in pitchers, who account for a much higher incidence of shoulder injury than position players(House et al., 2009; Krajnik, Fogarty, Yard, & Comstock, 2010a; Shanley, Rauh, Michener, & Ellenbecker, 2011). Ulnar Collateral Ligament tears, Impingement, SLAP lesions, Little League Elbow, and Rotator Cuff injury are some of the most common injuries in baseball (Abrams & Safran, 2010; Burkhart et al., 2003a; Jones, Osbahr, Schrumpf, Dines, & Altchek, 2012; Krajnik, Fogarty, Yard, & Comstock, 2010b). Compared to other sports, baseball has a relatively low incidence of injury at 1.26 injuries per 1000 exposures (Rice, Congeni, & Council on Sports Medicine and Fitness, 2012). However, baseball ranks second in the percentage of injuries lasting longer than 7 days (Rice et al., 2012).
Injury prevention is highly important in order to reduce the amount of time lost due to shoulder and elbow pathologies.

Previous literature has identified range of motion differences in baseball players (Burkhart et al., 2003a; Kibler et al., 2013). The common range of motion alterations that are seen at the shoulder are external rotation gain (ERG), glenohumeral internal rotation deficit (GIRD), and total arc of motion (TAM). GIRD is the loss in internal rotation at the glenohumeral joint when comparing the dominant to non-dominant arm; this may lead to a decreased ability to safely slow the arm down during the follow through phase of the throw (Burkhart et al., 2003a). External rotation gain is an increase in glenohumeral external rotation in the throwing arm when compared to the non-throwing arm; this may lead to a posterior migration of the humeral head with subsequent rotator cuff instability and increased risk of injury (Burkhart et al., 2003a). Total arc of motion is the sum of internal and external rotation and is used to compare total range of motion between arms and may lead to an imbalance in joint kinematic (Kibler, Sciascia, & Thomas, 2012).

For throwers, velocity is a key factor in determining success. It is not hard to imagine that players are constantly trying to improve their velocity in whatever way they can in order to gain an athletic advantage. The most effective way to increase velocity is to increase the total arc of motion, which is often achieved by maximizing external rotation in the late cocking phase of the throw (Burkhart et al., 2003a). The longer the total arc of motion the longer the force can be applied, and thus the greater the final velocity of the ball. Consequently, it has been noted that many overhead throwers display an external rotation gain at the glenohumeral joint as a potential way to increase velocity (Burkhart et al., 2003a). However, in conjunction with this increase in ERG, throwers have also demonstrated a decrease in glenohumeral internal rotation in the
dominant throwing arm, leading to glenohumeral internal rotation deficit (Burkhart et al., 2003a; Shanley et al., 2011).

Overuse is especially noted in pitchers, whose high throwing volume places them at an increased risk of an overuse related injury (Fleisig & Andrews, 2012). A recent study on the injury incidence in high school baseball players reported that pitchers account for 73% of shoulder injuries requiring surgery and 38% of all injuries, making injured players twice as likely to be pitchers than any other position (Krajnik et al., 2010a). This increase in injury has also been correlated with a decrease in range of motion in the throwing arm when compared to the non-throwing arm in pitchers (Freehill et al., 2011; Garrison et al., 2012). While it is normal for baseball players to experience a lack of glenohumeral internal rotation in the throwing arm, special attention should be given to the demands placed on pitchers due to the high velocity and repetition demanded by the position, as well as the increased injury rate (Burkhart et al., 2003a; Krajnik et al., 2010a).

While range of motion changes are normal adaptations in baseball players, numerous studies have reported that these range of motion (ROM) changes also place the athlete at an increased risk of injury (Dines, Frank, Akerman, & Yocum, 2009; Kibler et al., 2012; Myers, Laudner, Pasquale, Bradley, & Lephart, 2006; Shanley et al., 2011; Wilk et al., 2011b). Altered range of motion measures demonstrated in studies of overhead athletes include Glenohumeral Internal Rotation Deficit, External Rotation Gain, and total range of motion at the glenohumeral joint that is sometimes termed Total Arc of Motion. (Dines et al., 2009; Kibler et al., 2012; Myers et al., 2006; Wilk et al., 2011b). These studies have continued to report a consistent trend which demonstrates that overhead-throwing athletes tend to present with glenohumeral internal rotation deficit and external rotation gain when compared with the non-dominant arm (Myers et
al., 2006). While all measures of range of motion are frequently recorded in experimentation, GIRD continues to present itself as the primary factor in overhead throwing injuries (Wilk et al., 2011b).

**Purpose and Clinical Relevance**

Due to the nature of the sport, baseball players are required to perform a high volume of throws at a high intensity. Overuse of the throwing shoulder places obvious stresses on the soft tissue components of the shoulder. As the shoulder begins to fatigue, neuromuscular control and strength are compromised. This not only places the shoulder at risk for biomechanical problems in the kinetic chain, but it forces the posterior capsule to provide a decelerative force to slow the arm down, which leads to a corresponding adaptive thickening of the capsule and a subsequent increase in GIRD (Burkhart et al., 2003a; Burkhart, Morgan, & Kibler, 2003b; Burkhart, Morgan, & Kibler, 2003c). Baseball experts advocate that a proper preventative strengthening program can help to prevent muscle fatigue and can consequently help to reduce the effects of fatigue on GIRD (House et al., 2009).

The current challenge for researchers, clinicians, and fitness professionals is to create a program that effectively alters rotational changes in overhead-throwing athletes in an effort to prevent injury. Not only will this involve cooperation in pitch count and overuse monitoring by the coaching staff, but it will require the implementation of evidence-based throwing programs to help decrease injury and promote proper mechanics. Due to the competitive nature of the sport, coaches and players are unlikely to focus solely on injury prevention. In order to effectively incorporate an intervention program into a practical baseball training regimen, it must be shown that performance can increase while the chances of injury decrease.
A program called the Velocity Plus Throwing Program has recently received a lot of attention for its purported claims to increase velocity and simultaneously reduce the risk of injury. Developed by Tom House, the program is being run through multiple performance centers, including The Player’s Dugout. Under its description, the Player’s Dugout illuminates the arm care marketing by branding the program with the tagline “throw harder by getting healthier” (Player's Dugout, 2014). Using a series of weighted balls, this program progresses participants through a throwing program that includes ballistic stretching with weighted balls to strengthen the shoulder decelerators through normal throwing mechanics. Using measurements of velocity, participant mass and height, the staff of the Velocity Plus Throwing Program can create individualized throwing programs in an effort to improve velocity and reduce GIRD. In an interview, House stated that the program developed as a means to decrease GIRD and the injuries tied to it(Revelette, 2013). He also stated, “that through mediating GIRD, we actually built balance into the shoulder capsule and once that got functional again, the really cool thing was that velocity just went crazy” (Revelette, 2013). This claimed increase in velocity has led to an increase in popularity in both professional and amateur baseball, with over 2,300 athletes across the country currently enrolled in the program (Player's Dugout, 2014; Revelette, 2013)

While this program is gaining in popularity and there are many reports of velocity increases, there is no current knowledge of any data to support the program’s effects on shoulder range of motion variables such as GIRD and TAM. Therefore, the purpose of this study is to determine if the Velocity Plus Throwing Program can have a beneficial effect on potentially injurious humeral rotation range of motion characteristics in youth baseball players. Understanding which components of neuromuscular and resistance training alter ROM may help
clinicians create intervention programs that will contribute to a reduction in injuries in youth baseball players.

**Research Question**

- **RQ 1**: What is the effect of the Velocity Plus Throwing Program on improving dominant shoulder range of motion?
  - RQ 1.1: What is the effect of the Velocity Plus Throwing Program on improving dominant glenohumeral internal rotation?
  - RQ 1.2: What is the effect of the Velocity Plus Throwing Program on improving dominant glenohumeral external rotation?
  - RQ 1.3: What is the effect of the Velocity Plus Throwing Program on improving dominant glenohumeral total arc of motion?

- **RQ 2**: What is the effect of the Velocity Plus Throwing Program on rotational range of motion side-to-side differences?
  - RQ 2.1: What is the effect of the Velocity Plus Throwing Program on glenohumeral internal rotation deficit?
  - RQ 2.2: What is the effect of the Velocity Plus Throwing Program on external rotation gain?
  - RQ 2.3: What is the effect of the Velocity Plus Throwing Program on improving dominant shoulder range of total arc of motion?

**Research Design**

- Case-control trial with an intervention group and control group
Dependent Variables

- Range of Motion
  - Glenohumeral Internal Rotation Change Score
  - Glenohumeral External Rotation Change Score
  - Glenohumeral Internal Rotation Deficit Change Score
  - External Rotation Gain Change Score
  - Total Arc of Motion Change Score
  - Total Arc of Motion Difference Change Score

Independent Variables

- Group: Participation in Velocity Plus Throwing Program or control group.

Hypothesis

- **H 1**: After completing the training program, players who participated in the Velocity Plus Throwing Program will exhibit an increase in dominant arm range of motion compared to those who participated in normal training or compared to controls.
  - **H 1.1**: Players who participated in the Velocity Plus Throwing Program will exhibit an increase in dominant glenohumeral internal rotation range of motion.
  - **H 1.2**: Players who participated in the Velocity Plus Throwing Program will exhibit an increase in dominant external rotation range of motion.
  - **H 1.3**: Players who participated in the Velocity Plus Throwing Program will exhibit an increase in dominant total arc of glenohumeral motion.

- **H 2**: After completing the training program, players who participated in the Velocity Plus Throwing Program will exhibit increased range of motion compared side-to-side.
o H 1.1: Players who participated in the Velocity Plus Throwing Program will exhibit a decrease in glenohumeral rotation deficit.

o H 1.2: Players who participated in the Velocity Plus Throwing Program will exhibit increased external rotation gain.

o H 1.3: Players who participated in the Velocity Plus Throwing Program will exhibit an increase in total arc of glenohumeral motion.
CHAPTER II

REVIEW OF THE LITERATURE

Injuries in Baseball

One of the most popular sports in the country, it is estimated that there are currently over 12 million amateur baseball players in the country (USA Baseball, 2012). Of these 12 million, over 2.5 million participate in Little League (House et al., 2009). Baseball is a game built around the amazing ability of humans to throw a baseball at high velocity with pinpoint accuracy and control. The overhead nature of the sport and the large amount of force required places athletes at a risk for injury, especially when coupled with the high frequency of throws required throughout a season (Fleisig & Andrews, 2012). While all players have a high frequency of throws over a season, pitchers are subject to a large number of high intensity throws during practice and games (Rice et al., 2012). Youth pitchers have a 5% chance of a serious arm injury (injury resulting in surgery or retirement) during a 10-year span (Fleisig & Andrews, 2012). The injury rate in baseball players (1.26 injuries per 1000 exposures) is lower than most sports(Powers & Howley, 2012; Rice et al., 2012). However, while baseball has a low injury rate, it also ranks second in the percentage of injuries lasting longer than 7 days (Rice et al., 2012). Of reported injuries, shoulder injuries account for 23.4% of injuries during games and 16.0% of injuries during practice; elbow injuries account for 9.3% and 10.8% respectively (Dick et al., 2007). Combined, elbow and shoulder injuries account for roughly 50% of the injuries for players on the disabled list in Major League Baseball (Dick et al., 2007). This makes elbow and shoulder injuries a serious concern from Little League to professional baseball. The most common injuries are ulnar collateral ligament tears, impingement, SLAP lesions, Little League elbow, and rotator cuff injury. Each of these is discussed in more detail below.
COMMON INJURIES IN BASEBALL

Ulnar Collateral Ligament Tear

The ulnar collateral ligament (UCL) is a three-ligament structure that helps prevent valgus stress in the elbow (Garrison et al., 2012). Its three bundles, the anterior oblique ligament (which provides the most valgus support), posterior oblique ligament, and transverse ligament all work together to provide support on the medial aspect of the elbow during motions that cause elbow valgum (Dines et al., 2009; Freehill et al., 2011; Jones, Osbahr, Schrumpf, Dines, & Altchek, 2012). When an excessive amount of valgus force is placed on the elbow joint, this ligamentous complex can become injured (Jones et al., 2012).

UCL tears are commonly seen in baseball players (especially pitchers) who subject themselves to a high level of valgus force during normal throws (Freehill et al., 2011; Jones et al., 2012). The elbow joint is least stable during 90 degrees of flexion; this also happens to be the position of the arm during the late-cocking and early acceleration phases of the throw, when the elbow is experiencing the highest amount of force (Freehill et al., 2011; Jones et al., 2012). The main restraint that combats the joint instability and high force is the anterior bundle of the UCL, which accounts for roughly 54% of the stresses alone (Freehill et al., 2011; Morrey & An, 1983). During throwing, the UCL is subjected to roughly 34.5 N*m of torque; however, cadaveric studies have typically shown that the UCL can only withstand 32 N*m of torque (Freehill et al., 2011). Because the UCL cannot provide all the support, it is necessary that other structures such as the medial epicondylar mass and osseous articulation at the elbow provide additional support (Freehill & Safran, 2011). When these other static and dynamic structures do not account for the additional force, the UCL fails and ruptures (Freehill & Safran, 2011). A rupture of the UCL can happen due to both chronic and acute failure of the UCL, and is most often resolved with surgery.
to reconstruct the UCL (Hariri & Safran, 2010). While recovery typically takes about 6 months, metadata analysis has shown that 83% of players were able to return to the same or higher level of play within about thirty-eight months (Jones et al., 2012).

**Impingement**

The most common type of impingement seen in baseball players is posterior internal impingement. In the cocking phase, the rotator cuff muscles are in maximum external rotation and abduction; this may cause the tendons of the supraspinatus and infraspinatus to become impinged between the humeral head and the glenoid rim (Laudner, Myers, Pasquale, Bradley, & Lephart, 2006; Manske, Grant-Nierman, & Lucas, 2013; Wilk et al., 2009). While this is thought to be a normal occurrence in the shoulder, the biomechanical demands placed on the shoulder in a baseball throw may exacerbate the force of the contact between the humeral head and glenoid (Laudner et al., 2006). Repeated impingement can lead to damage or fraying of the supraspinatus and infraspinatus as well as the superior labrum, which could potentially contribute to SLAP lesions (Manske et al., 2013). In addition, internal impingement has been shown to have a significant correlation to GIRD in throwers (Myers et al., 2006). Current intervention programs recommend stretching and strengthening of the scapular stabilizers and rotator cuff muscles in order to improve overall strength and neuromuscular control (Abrams & Safran, 2010; Manske et al., 2013).

While not as common as internal impingement, subacromial impingement can be seen in baseball players and is described as a decrease in the space under the acromion (Burkhart et al., 2003a; Page, 2011). This decrease in subacromial space can lead to impingement of the contents of the subacromial space, which contains the long head of the biceps tendon, the subacromial
bursa, and the supraspinatus tendon (Jobe, Coen, & Scenar, 2000). This can further be divided into two classifications of impingement: primary and secondary. Primary impingement can be described as impingement of the subacromial space due to static characteristics in anatomy, particularly in the shape of the acromion (Jobe et al., 2000; Page, 2011; Zaremski & Krabak, 2012). Secondary impingement is due to glenohumeral instability and muscle imbalances, resulting in an altered positioning of the humeral head during dynamic movement, which leads to a decrease in the subacromial space (Jobe et al., 2000; Page, 2011; Wilk et al., 2009; Zaremski & Krabak, 2012). Non-operative treatment has been proven successful with rest, proper strengthening and stretching (Jobe et al., 2000; Wilk et al., 2009).

**SLAP Lesions**

A common cause of shoulder pain in overhead athletes, Superior Labral Anterior Posterior (SLAP) lesions are an abnormality of the labrum which involves an anterior to posterior pulling off or fraying of the labrum and is often associated with the long head of the biceps tendon (Chang, Mohana-Borges, Borso, & Chung, 2008). Type II SLAP lesions are specific to where the long head of the biceps tendon attached to the superior labrum and are the most common type of labral injury in overhead athletes (Abrams & Safran, 2010). As an adaptive way for baseball players to increase their velocity, many players will exhibit an anterior translation of the humeral head in order to allow for an increase in external rotation and thus can potentially increase their velocity (Abrams & Safran, 2010; Burkhart et al., 2003a). However, with this increased maximal external rotation, the forces placed on the labrum and long head of the biceps tendon are increased (Abrams & Safran, 2010). These increased forces placed on the attachment of the long head of the biceps tendon, coupled with the repetitive nature of throwing,
can lead to the development of type II SLAP lesions (Abrams & Safran, 2010). Arthroscopic repair with a suture anchor fixation has been shown to be the most effective way to manage SLAP lesions, with return to play rates in young overhead athletes estimated at roughly 90%, compared to a 67% return to play for all overhead athlete shoulder surgeries (Abrams & Safran, 2010).

*Little League Elbow*

“Little League Elbow” is a term used to commonly describe medial elbow problems in youth baseball players that are usually caused by a repetitive valgus stress on the elbow (Shanley & Thigpen, 2013). It is typically seen in skeletally immature throwers and has grown to encompass medial elbow conditions including irritation of the flexor pronator mass, medial epiconyilitis, medial epicondylar avulsion, apophysitis, or rapid apophyseal growth, all of which can potentially result in abnormal changes at the growth plate in developing athletes (Freehill & Safran, 2011; Shanley & Thigpen, 2013). This is highly prevalent in younger populations, and some studies have found that up to 95% of Little League and Pony League pitchers have accelerated growth and separation of the medial epicondylar apophysis (Hang, Chao, & Hang, 2004). Early rest and management to improve ROM and strength may help to decrease symptoms (Shanley & Thigpen, 2013). In more severe cases such as medial epicondylar avulsion or apophysitis, surgery may be required (Lawrence et al., 2013). While not always severe, the presence of Little League Elbow can lead to debilitating injury if not properly identified and managed.
**Rotator Cuff Injury**

Muscle strains are one of the most common injuries in baseball (Krajnik, Fogarty, Yard, & Comstock, 2010b; Shanley et al., 2011). The rotator cuff, which consists of the Supraspinatus, Infraspinatus, Teres Minor, and Subscapularis, can be subject to an acute muscle strain due to the rapid and forceful contractions which place an enormous amount of tensile load on the muscles when it exceeds the musculotendinous limits (Banks et al., 2005). This can happen in both the cocking phase and the deceleration phase. The opposite happens in the deceleration phase when the rotator cuff has a large tensile load placed on it while it eccentrically slows the arm, putting the rotator cuff at risk for a tear (Wilk et al., 2009). Prevention and rehabilitation both focus on improving range of motion and neuromuscular control in an effort to increase the roll of the dynamic stabilizers and decrease the stress placed on the static stabilizers of the shoulder and elbow (Shanley et al., 2011; Wilk et al., 2009).

**CONTRIBUTORS TO INJURY**

Athletes at every level of sport are subject to injury each time they step on the field. However, the inevitability of injury does not mean injuries are not preventable. Over the past few decades, research has been done to identify risk factors in baseball players that may predispose them to injury. This research has provided numerous studies which link injury to shoulder range of motion, meaning that shoulder range of motion may provide significant clues in predicting and preventing injury in baseball players. The three measures of range of motion that are frequently studied are glenohumeral internal rotation deficit (GIRD), external rotation gain (ERG), and total arc of motion (TAM). These measures have consistently been shown to correlate with shoulder and elbow injury in baseball players (Dines et al., 2009; Garrison et al., 2012; Myers et al., 2006; Ruotolo, Price, & Panchal, 2006).
Glenohumeral Internal Rotation Deficit

Glenohumeral Internal Rotation Deficit is the loss in internal rotation at the glenohumeral joint when comparing the dominant to non-dominant arm (Burkhart et al., 2003a). While there is some degree of contralateral difference in almost every athlete, researchers have typically defined GIRD as a loss of internal rotation ranging from 15-25 degrees or more when compared to the non-dominant arm (Burkhart et al., 2003a; Kibler et al., 2012; Shanley et al., 2012). While the cause of GIRD is not fully understood, it is postulated to be influenced by both soft tissue adaptation and bony adaptations. Soft tissue tightening of the posterior shoulder musculature and thickening of the posterior capsule have been shown to contribute to GIRD (Thomas et al., 2013; Wilk et al., 2011a). It is postulated that thickening is due to the repetitive microtrauma to the posterior capsule due to excessive tension causes by a lack of muscular control in the follow through phase (Abrams & Safran, 2010; Burkhart et al., 2003a).

At birth, there is a natural twisting of the humerus, which will be described later as humeral retrotorsion (Kibler et al., 2012). While the humeral head may be in a neutrally rotated position, the distal portion of the humerus may be anteriorly rotated in comparison to the non-throwing arm, creating an osseous range of motion block which contributes to the measurement of GIRD by decreasing available internal rotation (Kibler et al., 2012). In addition to the osseous contribution, the tightening of the posterior capsule and rotator cuff provides a static restraint on the posterior aspect of the humerus during internal rotation (Kibler et al., 2012). It is unclear if humeral retrotorsion or soft tissue adaptations are the prime contributor to GIRD, but all play a role in preventing internal rotation and should continue to be addressed in future research (Burkhart et al., 2003a). Understanding the factors that influence GIRD can help to establish
intervention programs that aim at increasing range of motion and decreasing associated shoulder injuries.

Many recent studies have shown a link between GIRD and subsequent elbow and shoulder injury in baseball players. Myers et al., found that athletes who presented with internal impingement had significantly greater GIRD than uninjured athletes (Myers et al., 2006). Another study found that players with type II SLAP lesions had significantly more GIRD than players without SLAP lesions (Shanley et al., 2011). Dines et al., analyzed range of motion in a population that include professional, collegiate, and high school players that demonstrated a statically significant correlation between GIRD and UCL deficiency (Dines et al., 2009).

These incidences of injury may be due to the biomechanical changes at the glenohumeral joint which alter the joint mechanics. It can be hypothesized that the decrease in internal range in motion leads to an anterosuperior migration of the humeral head (Burkhart et al., 2003a). This migration allows an increased external rotation and stretches the anterior capsuloligamentous structures, which could lead to instability and subsequent injuries (Burkhart et al., 2003a).

External Rotation Gain

External rotation gain is an increase in glenohumeral external rotation in the throwing arm when compared to the non-throwing arm(Burkhart et al., 2003a). It is thought to be an advantageous adaptation to increase throwing velocity (Burkhart et al., 2003a). To date the research is inconclusive when addressing a correlation between external rotation gain and injury; most studies have failed to find a statistically significant difference in ERG in association with injury (Myers et al., 2006; Shanley et al., 2011), but a few unique studies have found a statistically significant change in external rotation gain that usually is accompanied by a
statistically significant change in GIRD (Freehill et al., 2011; Myers et al., 2006; Ruotolo et al., 2006; Shanley et al., 2011; Trakis et al., 2008).

This increase in ERG has been associated with biomechanical alterations that predispose the athlete to injury. In an attempt to gain more external rotation and increased velocity the humeral head will migrate anterosuperiorly, which will cause a tightening of the posterior inferior capsule (Burkhart et al., 2003a). As the capsule tightens and stretches, it places the labrum at an increased risk for SLAP tears (Burkhart et al., 2003a; Kibler et al., 2012). This excessive external rotation gain also translates to excessive valgus force at the elbow (Kibler et al., 2012). For this reason, this study analyzed external rotation gain in an effort to provide more insight on the relationship between injury and ERG.

**Total Arc of Motion**

Total arc of motion is the sum of internal and external rotation and is used to compare total range of motion between arms (Kibler et al., 2012). While the angle of internal and external rotation may be different on side-to-side, the total arc of motion may be the same bilaterally. However, when it is not the same, it has been shown that a total arc of motion deficit in the throwing arm in comparison to the non-throwing arm is associated with injury (Dines et al., 2009; Garrison et al., 2012; Ruotolo et al., 2006; Shanley et al., 2011; Wilk et al., 2011a). However, a study of adolescent pitchers failed to find a difference between injury and total arc of motion and instead suggested that associated shoulder and elbow pain was due to muscular deficiencies (Trakis et al., 2008). Like all shoulder range of motion measures, it is postulated that TAM is caused by both soft tissue and bony adaptations in baseball players but its true roll in injury is not fully understood (Kibler et al., 2012).
FACTORS AFFECTING RANGE OF MOTION

Muscle Stiffness

Muscle stiffness can be defined as the change in passive tension per unit change in length (Hung, Hsieh, Yang, & Lin, 2010). In response to an increased strain, muscles thicken to combat the increased stress on the tissue (Kibler et al., 2012). A relationship has been shown between increased muscle stiffness and decreased range of motion in the shoulder, specifically internal rotation (Hung et al., 2010). This loss of internal rotation is linked to increased muscle stiffness values in the posterior deltoid, infraspinatus, and teres minor, where the posterior deltoid is responsible for 50% of the associated loss in internal rotation (Hung et al., 2010). This association between muscle stiffness and loss of glenohumeral internal rotation may play a role in injury.

Posterior Capsule Thickening

In an effort to meet the velocity demands of the sport, throwers alter their biomechanics in an effort to meet a certain amount of external rotation which will help give them the range of motion to produce a competitive velocity (Burkhart et al., 2003a). This adaptive change in form leads to a muscle imbalance that results in tight posterior musculature that limits internal rotation (Burkhart et al., 2003a). Furthermore, it has been speculated that weakness in the muscle that decelerate the arm can lead to an increased stress on the posterior capsule. Following Wolfe’s Law, the capsule must respond to the increased tensile load by increasing its tensile strength. Thus, it is possible that repeated throws with poor control could lead to a thickening and tightening of the posterior capsule, which can lead to a loss of internal rotation (Burkhart et al., 2003a). A study of Division I collegiate baseball players used ultrasound to measure posterior capsule thickening and found significant increased thickening of the posterior capsule in the
throwing shoulder when compared to the non-throwing shoulder (Thomas et al., 2013). Furthermore, the researchers found a correlation between increased capsule thickness and active glenohumeral stiffness (Thomas et al., 2013).

**Humeral Retrotorsion**

Humeral retrotorsion is a twisting of the proximal and distal humerus that results in a posterior rotation of the distal humerus in relationship to the proximal humerus (Myers et al., 2009; Oyama, Hibberd, & Myers, 2013). While retrotorsion is a natural congenital characteristic, it is much more pronounced in the throwing shoulder compared to the non-throwing shoulder (Whiteley, Ginn, Nicholson, & Adams, 2009). This natural retrotorsion typically reduces early on in life, but the presence of it in the throwing shoulder of older populations supports the possibility that throwing before full development of the growth plate may delay the normalization of retrotorsion, leading to a fully developed arm with more retrotorsion than the contralateral (Whiteley et al., 2009). As the connection has already been made between shoulder ROM and retrotorsion, it is important that retrotorsion is addressed in the development of injury prevention programs to account for the loss of internal rotation (Crockett et al., 2002). Recent literature has illustrated that age-related increases in GIRD are due to changes in humeral retrotorsion and do not accurately reflect soft-tissue changes between varying age groups (Hibberd, Oyama, & Myers, 2014).

**TARGETED INTERVENTIONS**

Despite an increasing amount of knowledge over the past decade, the relationship between decreased range of motion and injury is still present in baseball. The established link between GIRD and injury has led to the development of many non-operative interventions in an
effort to prevent injury. The current challenge for researchers and clinicians is to develop a program that successfully increases range of motion and reduces injury.

Traditional methods for improving rotational range of motion include static stretching and have been shown to be effective (Burkhart et al., 2003a; Kibler et al., 2012; Laudner, Sipes, & Wilson, 2008; Tyler, Nicholas, Lee, Mullaney, & McHugh, 2010) While these methods are known to be effective, athletes and coaches do not utilize these correctly or as often as necessary because they want to use practice time for performance enhancement. Common stretches utilized in most programs include the sleeper stretch and a cross body horizontal adduction stretch (Burkhart et al., 2003a; Kibler et al., 2012; Tyler et al., 2010). This illustrates that stretching has proven to be a successful and easily self-managed tool by which an individual can effectively increase their range of motion and decrease GIRD. Through decreasing GIRD, it is possible that players will reduce the risk of injury.

In an interview with Inside Pitch Online, Tom House described how his observations of a low incidence of shoulder injury in tennis players led him to use weighted balls as a way to reduce injury (Revelette, 2013). Through his program, which has over 2,300 athletes participating, he claims to have seen a significant reduction in the amount GIRD (Revelette, 2013). While no specific protocol and no peer-reviewed research has been published, the program is known to consist of an eccentric throwing progression that is claimed to result in both a decrease in GIRD and an increase in velocity (Player's Dugout, 2014; Revelette, 2013) Due to the increased popularity and claimed decreases in GIRD, the Velocity Plus Throwing Program was chosen as the subject for this study. The Velocity Plus Throwing Program uses a progression of eccentric ball holds and throws to create a personalized program based on an individual’s height, weight, and velocity
measurements with various different balls. The program used in the current study is included in Appendix 1. Out of season players typically spend the first 2 weeks of the program with a progression from knee holds to knee throws at a 60-70% maximum intensity. Week 3 progresses to a full workout with holds and throws from a kneeling position, to a rocker position, to a run-n-gun position. The rocker position is a sideways standing throw and the run-n-gun utilizes the common cross over “crow-hop” step. Weeks 4 and 5 use the same workout schedule as week 3, but at 100% intensity. At the beginning of week 6, the velocity measurements are retested and sent back to the Velocity Plus Throwing Program staff to be adjusted. The resultant workouts vary with each individual.

While the exact prescription for exercise volume and intensity changes per individual, it could be postulated that throwing with weighted balls helps to increase the neuromuscular control of the posterior rotator cuff, particularly the infraspinatus. This increase in control could prevent the shoulder from using the posterior capsule as an aide in deceleration, which could decrease posterior capsule thickening and potentially improve range of motion. Repetitive eccentric muscle contractions have widely been considered a large contributor to glenohumeral range of motion and many researchers point to repetitive eccentric contractions as a potential cause for injury and capsular changes (Burkhart et al., 2003a; Kibler et al., 2012; Oyama, Myers, Blackburn, & Colman, 2011). Other researchers suggest a decrease in shoulder pain and dysfunction with increased eccentric strength (Maenhout, Mahieu, De Muynck, De Wilde, & Cools, 2013). Trakis et al. suggests a decreased incidence of injury in athletes with good ROM and eccentric strength (Trakis et al., 2008). Kibler et al. noted an unnamed study which found that eccentric strength did not lead to any decreases in shoulder ROM (Kibler et al., 2013). At the current moment, there is no clear consensus on the effects of eccentric training on shoulder
pain and dysfunction. Also, no known study has analyzed a specific relationship between eccentric strengthening and range of motion in overhead athletes.

**INSTRUMENTATION**

*Glenohumeral Range of Motion Assessment with digital inclinometer*

Glenohumeral range of motion measures was collected using a digital inclinometer (The Saunders Group, Inc. Chaska, MN). This method has been previously verified as a precise and valid way to measure glenohumeral ROM (Myers et al., 2006; Norkin & White, 2003). The intrasession, intersession, and intertester reliability coefficients for the ROM measures established by the investigators ranged from 0.93 to 0.97 with an standard error of approximately 1.9° (Myers et al., 2006).

**CONCLUSIONS**

Many studies demonstrated a correlation between range of motion alterations and increased shoulder and elbow injury in baseball players. These alterations include glenohumeral internal rotation deficit (GIRD), external rotation gain (ERG), and total arc of motion (TAM). These range of motion alterations may be impacted by a soft tissue or osseous adaptations that include posterior capsule thickening, humeral retrotorsion, and muscle stiffness. Tom House, a renowned pitching expert, has developed a new velocity improvement program that he claims reduces GIRD and increases velocity. The purpose of this study is to identify if there is a relationship between participation in this program and altered glenohumeral range of motion. Identifying a program that can effectively reduce GIRD can contribute to future research that may eventually help clinicians effectively treat and prevent elbow and shoulder injuries in baseball players.
CHAPTER III

METHODOLOGY

PARTICIPANT CHARACTERISTICS

Participants were recruited from a baseball performance academy in North Carolina. Fifty-seven healthy male baseball players, between the ages of 8-17, were selected to participate in the study. For the post-testing, data were collected 37 individuals, 20 of which were in the control group and 17 participants who were in the intervention group. Of those who completed post-testing, 7 of the controls and 5 of the intervention participants were excluded from the study due to the failure to complete the program within the 10-week time period. This was either to injury, opting out of the post-testing, or failure to adhere to the schedule. The facility staff spoke with, or emailed program information to the participants or their legal guardians prior to testing, to explain the research project and to obtain informed consent.

Primary and secondary positions were recorded for each individual. Of those who completed the program, 47% indicated pitcher as either their primary or secondary position. Of these, 12.5% indicated pitcher as their primary position and 34% indicated pitcher as their secondary position. 22% of the total players indicated catcher as their primary or secondary position. One participant did not indicate a primary position and one participant did not indicate a secondary position.

PARTICIPANT INCLUSION CRITERIA

Participants were included as intervention subjects in the study if they met all of the following criteria:

• A participant at the training center that has agreed to participate in the study and has registered and paid for the Velocity Plus Throwing Program.
Currently identifies as a baseball player

Between the ages of 8 and 18 years old.

No history of shoulder or elbow injury that required surgery or forfeit of participation for an entire season.

No current shoulder or elbow pain that limits normal pitching activity.

Participants were included as control subjects in the study if they met all of the following criteria:

• A participant at the training center that has agreed to participate in the study and is not participating in the Velocity Plus Throwing Program.

• Currently identifies as a baseball player

• Between the ages of 8 and 18 years old.

• No history of shoulder or elbow injury that required surgery or forfeit of participation for an entire season.

• No current shoulder or elbow pain that limits normal pitching activity.

PARTICIPANT EXCLUSION CRITERIA

Participants were excluded from being intervention subjects in the study if they:

• Currently were receiving treatment for elbow or shoulder pain.

• Started intervention program but were unable to complete in the allocated time.

• Had a history of shoulder or elbow injury that required surgery or forfeit of participation for an entire season.

• Had pain or discomfort that limited range of motion testing.

Participants were excluded from being intervention subjects in the study if they:
• Currently were participating in Velocity Plus Throwing Program, even if not associated with this study.
• Currently were receiving treatment for elbow or shoulder pain.
• Started the study but were unable to complete testing.
• Had a history of shoulder or elbow injury that required surgery or forfeit of participation for an entire season.
• Had pain or discomfort that limited range of motion testing.

**INSTRUMENTATION**

*Digital Inclinometer*

Testing for internal and external rotation was performed using the methods described by Myers et. al (Myers et al., 2006; Norkin & White, 2003). A digital inclinometer (The Saunders Group, Inc. Chaska, MN) was used to collect range of motion measurements at the glenohumeral joint. With participant lying supine on a treatment table with 90° of shoulder abduction and elbow flexion, a tester passively moved the shoulder into internal or external rotation until the end feel was appreciated. The tester stabilized the participant's shoulder by applying posteriorly directed force to the anterior shoulder, and thereby stabilizing the scapula against the treatment table and preventing the shoulder from lifting up from the table. At the end range, a research assistant aligned the ruler attached to the inclinometer with the participant's forearm, and recorded the ROM value. The ruler was used instead of the body of the inclinometer for the ease of aligning the instrument with the forearm. The intrasession, intersession, and intertester reliability coefficients for the ROM measures established by the investigators ranged from 0.93 to 0.97 with a standard error of approximately 1.9°.
RESEARCH DESIGN

A case control trial repeated measures research design with an intervention and control group was used for this study. Fifty-seven participants were enrolled in the study as either a control participant or intervention participant. Researchers were blind to group assignment. The participants reported for a pretest screening and to sign a consent waiver form. During the initial screening, the participant completed a survey to evaluate demographics, participant characteristics, and previous injury history. Athletes under the age of 18 completed this survey with the help of a parent or legal guardian. The participants then continued to be tested for range of motion, for which they were retested for 10-weeks later.

TESTING PROCEDURES

Upon arrival to the facility, participants (and the parents of participants under 18) were introduced to the experiment and read and signed a consent form approved by the University of North Carolina at Chapel Hill Institutional Review Board. The participant then underwent the pre-intervention testing to assess bilateral internal and external rotation range of motion. The following processes are described below.

PRE-INTERVENTION TESTING

Range of motion assessment

Internal and external glenohumeral range of motion was assessed with the participant supine on a portable treatment table, with the shoulder at 90 degrees of abduction and the elbow at 90 degrees of flexion (FIGURES 1 and 2). Placing the palm over the acromion, a posterior force was applied to the acromion to stabilize the scapula and isolate motion at the glenohumeral joint. Once stabilized, the investigator passively rotated the participant’s limb to the end range
of motion in both external and internal rotation, while a second investigator placed a digital inclinometer on the forearm to assess the rotation angle from the vertical for each. This was done on the dominant and non-dominant side to assess glenohumeral internal rotation, external rotation.

**INTERVENTION PROGRAM**

Participants in the intervention group participated in the Velocity Plus Throwing Program four days a week, two days with the supervision of the facility staff, and two days of self-disciplined home training. The facility staff took individual measurements of velocity for each participant by calculating the velocity thrown with balls of differing weights. The velocity data, in addition to height and mass, was then sent to the Velocity Plus Throwing Program staff in order to calculate an individualized progression plan for each athlete. Athletes were then given a detailed protocol that involves a progression of ball holds and throws from a kneeling, rocker and run-n-gun position. The initial protocol lasts 5 weeks, at which point velocity is reassessed, sent to the Velocity Plus Program Staff, and modified for the remaining 5 weeks.

The control group was made up of participants who normally participate in training at the facility. The research team had no participation in determining exercise prescription for either group and was blinded to the group assignment. With consent, the athletes allowed range of motion to be tested at the pre- and post-intervention data collections.

**POST-INTERVENTION TESTING**

Following the 10-week intervention program the participants reported back to the training facility and range of motion was reassessed using the same procedures as previously described.
DATA REDUCTION

Range of Motion Calculations

- Total Arc of Motion was calculated by taking the sum of the range of motion for glenohumeral internal rotation and external rotation. Three trials were used to calculate a mean. The change score was calculated by subtracting the pre-intervention results from the post-intervention results.

- GIRD was calculated by taking the difference in internal rotation between the dominant arm and the non-dominant arm. Three trials were used to calculate a mean. The change score was calculated by subtracting the pre-intervention results from the post-intervention results.

- ERG was calculated by taking the difference in external rotation between the dominant arm and the non-dominant arm. Three trials were used to calculate a mean. The change score was calculated by subtracting the pre-intervention results from the post-intervention results.

- Change scores were collected for dominant IR, dominant ER, and dominant TAM. The change scores were calculated by subtracting the pre-intervention results from the post-intervention results.

Velocity

- Velocity was calculated by taking the mean of three max effort throws of a 5oz ball. The change scores were calculated by subtracting the pre-intervention results from the post-intervention results.
STATISTICAL ANALYSIS

Group (intervention vs. control) comparisons were conducted using an independent samples t-test. An a priori alpha level of 0.05 was set with a power of 0.8. All statistical analyses were calculated using SPSS version 21 for Windows.
CHAPTER IV

RESULTS

Data were collected from 32 participants for the current study. Participants were youth baseball players between age 8-17. The demographics of the participants appear in Table 1. For the initial pre-testing, data were collected for 57 participants. For the post-testing, data were collected for 37 individuals, 20 of which were in the control group and 17 who were in the intervention group. Of these, 5 of the intervention participants were excluded from the study due to the failure to complete the program within the 10-week time period. This was due to injury, opting out of the post-testing, or failure to adhere to the prescribed schedule. Of those who completed the study, 50% of the intervention group and 45% of the control group identified their primary or secondary position as pitcher.

The shoulder range of motion data is represented in Table 2. Statistical analysis between the intervention and control group revealed a significant difference in Dominant Total Arc of Motion. The intervention group had a mean decrease of 16.4 ± 11.0 degrees and the control group had a mean decrease of 6.2 ± 13.0 degrees. This led to a mean difference of 10.1 ± 4.5 degrees (t(30): 0.95, p=0.03) between the two groups.

No significant differences between groups were present in the change scores for velocity, TAMD, GIRD, ERG, Dominant IR, or Dominant ER. Velocity had a mean difference of -1.2 ± 1.1 MPH (t(30): -1.09, p=0.29). TAMD had a mean difference of 4.8 ± 3.2 degrees (t(30):0.95 , p=0.52). GIRD had a mean difference of 3.2 ± 3.5 degrees (t(30): 0.92, p=0.37). ERG had a mean difference of 1.6 ± 4.1 degrees (t(30): 0.38, p=0.71). Dominant IR was near significance and had a mean difference of 5.5 ± 2.7 degrees (t(30): 2.25, p= .05). Dominant ER had a mean difference of 4.7 ± 3.5 degrees (t(30): 1.345 , p= 0.19).
CHAPTER V
DISCUSSION

Summary

Numerous studies have reported that shoulder range of motion alterations place athletes at an increased risk of injury (Dines et al., 2009; Kibler et al., 2012; Laudner et al., 2006; Myers et al., 2006; Shanley et al., 2011; Wilk et al., 2011a). This is especially noted with the presence of GIRD (Dines et al., 2009; Myers et al., 2006; Shanley et al., 2011). The purpose of this project was to determine the extent to which a velocity improvement program altered shoulder range of motion in youth baseball players. Understanding the way that performance based programs contribute to range of motion would allow clinicians to develop targeted intervention programs which not only increase velocity, but also improve range of motion. These components were assessed by measuring changes in throwing velocity and shoulder range of motion changes in 32 youth baseball players from North Carolina, over a 10-week period. This study found that the intervention group had a significant decrease in Dominant Total Arc of Motion when compared to the control group. No other significance was present with the other variables.

The hypothesis stated that players who participated in the Velocity Plus Throwing Program would exhibit an increase in dominant total arc of glenohumeral motion. Based on this study, there was a statistically significant decrease in dominant TAM (p=0.03). Because there is statistically significant data that shows that dominant TAM decreases, we must reject this hypothesis. Further, the hypothesis also states that there will be a decrease in GIRD, an increase in ERG, an increase in side-to-side TAM, an increase in internal rotation, an increase in dominant ER, and an increase in dominant IR. There was no statistically significant data to support changes in GIRD (p=0.37), ERG (p=0.71), TAMD (p=0.52), dominant ER (p=0.19), or
dominant IR (p=0.05). The significant reduction in the dominant TAM of the intervention group, coupled with the lack of significant data to support improvements in dominant ER, dominant IR, TAMD, GIRD, or ERG, illustrates that there were no significant improvements with range of motion following the Velocity Plus Throwing Program. Therefore, we must reject the hypothesis.

It should be noted that dominant TAM had a statistically significant decrease, even though there was no statically significant decrease in dominant IR (p= .05) and ER (p= 0.19). This is due to the fact that the larger values given by differences in total arc of motion have a bigger effect on the data. This gives the TAM score more power than the IR and ER scores on their own. While it does not meet the a-priori level of 0.05, the dominant IR is very near significance with a mean of 5.5 ± 2.7 degrees (t(30): 2.25, p= .05). Provided more statistical power and statistical significance, this would represent a significant decrease in internal rotation range of motion of the dominant arm that would directly correspond to the loss in TAM. This could indicate a stronger correlation between eccentric contractions with posterior capsule thickening and the subsequent loss in internal range of motion.

Due to the marketing aim to brand the Velocity Plus Throwing Program as an “arm care” program as well, it is significant that this study found a significant reduction in range of motion (Player's Dugout, 2014). While there is more research to support GIRD as a predictor of injury than dominant arm TAM, the significant decrease in dominant TAM could indicate an increased risk of injury (Garrison et al., 2012; Kibler et al., 2013; Ruotolo et al., 2006).

While there is no known publication that looks at the Velocity Plus throwing program, many researchers have studied the effects of eccentric exercises on the shoulder complex. Studies have shown that eccentric strengthening exercises leads to increased muscle stiffness and
a decrease in range of motion, especially characterized by a loss of internal range of motion (Murayama, Nosaka, Yoneda, & Minamitani, 2000; Oyama et al., 2011; Reinold et al., 2008; Thomas et al., 2013). It has been hypothesized that the eccentric contractions of the shoulder during throwing may lead to an increase in fibroblastic activity within the posterior capsule, leading to a thickened posterior capsule and subsequent reduction in shoulder internal rotation (Thomas et al., 2013). This effect can be expected after the posterior musculature becomes overly fatigued. As the posterior muscles perform repeated eccentric contractions during internal rotation of the arm, they become weaker and fatigued, leading to an increased reliance on the posterior capsule and a resultant thickening of the capsule with a loss of internal range of motion(Kibler et al., 2013; Wilk et al., 2011a). Because the nature of this throwing program involved repeated bouts of eccentric muscle contractions above the normal requirements of the sport, it is likely that the repeated eccentric contractions led to a decrease in range of motion and a “tightening” of the shoulder complex.

It is also possible that the participants in the intervention program were completing more training the control. It was the off-season, so both groups were likely not involved in team training sessions. As a result, the control group may have been resting more than the intervention group. The intervention group may have been more fatigued and had more muscle tension due to the repeated eccentric bouts, which could have led to a subsequent decrease in range of motion. This difference in the presence and amount of training for each group may be why there is a decrease in TAM and an increase in IR.

The Velocity Plus Throwing Program did not include a specialized stretching routine. Stretching of the shoulder, in particular the sleeper stretch has been show to improve shoulder range of motion (Laudner et al., 2008; Wilk et al., 2009). Each athlete’s stretching routine varies
based on personal preferences and team preferences. However, because the program omits a standardized stretching protocol it is possible that the participants did not continue to stretch on their own. If the participants did not stretch, they would not have seen any range of motion improvements. The combination of eccentric contractions with muscle stiffening and the lack of a stretching protocol is likely a contributor to the decrease in dominant TAM and the near significant decrease in IR.

There were many limitations to this study. The age range for both groups was very large, 8-17 years old. The range of the control group was 10-17 years old, and the range for the intervention group was 8-17 years old. This represents a large age range in which participants may have inherent physiological and morphological differences, as well as differences in practice and competition characteristics. In regards to morphological changes, the presence of humeral retrotorsion was not assessed. Humeral retrotorsion has been suggested to develop prior to high school and may be a factor that influences GIRD (Oyama et al., 2013). Further, it has recently been noted that the increase in GIRD is primarily attributed to humeral retrotorsion rather than soft tissue tightness (Hibberd et al., 2014). The potential presence of varying levels of humeral retrotorsion in the participants and the mean difference in age between groups could have lead to range of motion measurements that did not accurately reflect changes in range of motion of each participant group. If humeral retrotorsion was not fully developed in the younger participants, but was fully developed in the older participants, the younger participants could have different degrees of humeral torsion between the two time periods. While the mean age range only differed by one year, it could cause a significant change in the perceived range of motion differences.
Adherence to the program and the presence of a variable external training program could alter the results. Individual effort and adherence to the portion of the intervention program that occurred outside of the facility could not be assessed. It is possible that not all individuals followed the exact protocol or performed the intervention exercises to the best of their abilities. It is also possible that each individual was completing supplemental workouts either individually or with their baseball team. Further, the study did not control for any alternative activities that the participants may have been engaging in. Because this study did not address these external factors, it is possible that these external programs affected the results of this study.

Researchers were blind to group assignments. However, participants were not blind to their group assignment. Furthermore, researchers did not know the exact methodology in developing the intervention program. Using velocity readings at the training facility, the Velocity Plus throwing procedure was calculated by an off-site staff and then sent to the participants. It was likely that many participants in each group had varying exercise prescriptions. Participants who may have produced larger velocity numbers may have been prescribed a more advanced program than participants who were new to throwing. As a result there could have been a wide range of throwing protocols and each individuals’ specified exercise protocols could have affected the outcomes of the program.

Further, this study did not have adequate statistical power to support its findings. Power is essentially the probability of finding a true significant difference. The resultant power calculations are presented in Table 2. Typically, a power of 0.8 is desired to support the statistical significance of the data. In this case, the variables with the highest power were dominant TAM (P=0.73) and dominant IR (P=0.64). This is not surprising as dominant TAM is the only statistically significant value and dominant IR is very near statistical significance.
However, given the low sample size in relation to the population of baseball players in the 8-17 year old range, and the lack of any power values greater than 0.8, this study does not have adequate power to support its findings. It should be noted that only 32 of the original 57 participants completed the study. This demonstrates a large dropout rate of 44%. With varying schedules and reliance on the participants to return within the time frame, it was difficult to reduce the drop rate. However, the lower number of participants resulted in a lower power than desired. Despite the difficulty for the researchers to ensure compliance with the study, the large dropout rate and resultant low power lead us to conclude that no statistical significance can be supported at this time.

**FUTURE RESEARCH**

Future research should aim to increase the sample size and reduce the dropout rate in order to increase the power of the study. This would help the study to obtain statistically significant data if there was adequate effect size. In obtaining higher numbers and reducing the dropout rate, it may be beneficial to provide opportunities to monitor adherence to the protocol more closely. Because half of the program is performed at home, it is hard to ensure that subjects are adequately completing the program with good effort. Future research may benefit from studying a velocity improvement program that does not have individual workouts away from the training facility. Also, future research may consider using a detailed activity log for both controls and participants to identify any notable changes in activity trends between the two groups.

It may be beneficial to reduce the inclusion age of the subject groups as well. Humeral retrotorsion is present at a young age, and decreases as individuals progress through adolescence (Whiteley et al., 2009). It is possible that participants of varying age levels may have varying
degrees of humeral retrotorsion that may make it difficult to determine if range of motion alterations are the results of true soft-tissue changes. Using a smaller age range may help to avoid issues caused by these morphologic changes.

Future research should also record humeral retrotorsion, and use it as a measurement to adjust GIRD. Given the varying age ranges, and the various levels of osseous adaptations, it is likely that GIRD may not accurately reflect soft-tissue tightness across such a wide age group. Myers et. al (2009) found that there was a significant relationship between the amount of humeral retrotorsion and the amount of posterior shoulder tightness. Because it has been illustrated that GIRD changes with age reflect change in humeral retrotorsion and do not reflect true range of motion measures, humeral retrotorsion should be considered when developing methods to analyze true shoulder range of motion changes. These findings suggest that future research may consider using humeral retrotorsion in conjunction with soft-tissue tightness to adequately address range of motion changes at the shoulder.

CONCLUSION

The results of this study found a significant decrease in the dominant arm total arc of motion in the intervention group, which may be a predictor of injury. The Velocity Plus Throwing Program did not provide any statistically significant data to support its use as a velocity improve program or a range of motion improvement program. At this time, there is no data to recommend this program as a means to improve velocity or improve range of motion. Ultimately, given the small sample size and low power of this study, no definitive conclusions can be made and further attempts should be made to establish more power.
FIGURES

Figure 1. Measurement of Glenohumeral Internal Rotation

Figure 2. Measurement of Glenohumeral External Rotation
### Table 1: Participant Demographics

<table>
<thead>
<tr>
<th></th>
<th>Intervention</th>
<th>Control</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of Participants (n)</strong></td>
<td>12</td>
<td>20</td>
</tr>
<tr>
<td><strong>Age (yrs)</strong></td>
<td>12.8 ± 2.6</td>
<td>13.8 ± 2.5</td>
</tr>
<tr>
<td><strong>Mass (kg)</strong></td>
<td>56.3 ± 22.5</td>
<td>61.7 ± 18.5</td>
</tr>
<tr>
<td><strong>Height (kg)</strong></td>
<td>161.3 ± 18.9</td>
<td>168.4 ± 15.3</td>
</tr>
</tbody>
</table>

### Table 2: Group Comparisons for All Dependent Variables

<table>
<thead>
<tr>
<th></th>
<th>Intervention</th>
<th>Control</th>
<th>Mean Difference</th>
<th>Significance</th>
<th>Power</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Velocity (MPH)</strong></td>
<td>1.6 ± 3.5</td>
<td>0.4 ± 1.9</td>
<td>-1.2 ± 1.1</td>
<td>0.29</td>
<td>0.20</td>
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<td><strong>TAMD (°)</strong></td>
<td>-1.9 ± 10.1</td>
<td>2.9 ± 15.4</td>
<td>4.8 ± 3.2</td>
<td>0.52</td>
<td>0.16</td>
</tr>
<tr>
<td><strong>GIRD (°)</strong></td>
<td>-0.9 ± 6.6</td>
<td>2.3 ± 13.2</td>
<td>3.2 ± 3.5</td>
<td>0.37</td>
<td>0.13</td>
</tr>
<tr>
<td><strong>ERG (°)</strong></td>
<td>-1.0 ± 10.4</td>
<td>0.6 ± 11.6</td>
<td>1.6 ± 4.1</td>
<td>0.71</td>
<td>0.07</td>
</tr>
<tr>
<td><strong>Dominant IR (°)</strong></td>
<td>-9.4 ± 7.2</td>
<td>-3.9 ± 7.5</td>
<td>5.5 ± 2.7</td>
<td>0.05</td>
<td>0.64</td>
</tr>
<tr>
<td><strong>Dominant ER (°)</strong></td>
<td>-7.0 ± 7.7</td>
<td>-2.3 ± 10.4</td>
<td>4.7 ± 3.5</td>
<td>0.19</td>
<td>0.40</td>
</tr>
<tr>
<td><strong>Dominant TAM (°)</strong></td>
<td>-16.4 ± 11.0</td>
<td>-6.2 ± 13.0</td>
<td>10.1 ± 4.5</td>
<td>0.03</td>
<td>0.73</td>
</tr>
</tbody>
</table>

TAMD= Total Arc of Motion Difference  
GIRD= Glenohumeral Internal Rotation Deficit  
ERG= External Rotation Gain  
IR= Internal Rotation  
ER= External Rotation  
TAM= Total Arc of Motion
APPENDIX 1: Velocity Plus Throwing Program Protocol

THE PERFORMANCE ACADEMY
VELOCITY PLUS+ ARM CARE

WARM UP

1. HANDS BEHIND – PUSH 8 seconds
2. HANDS BEHIND – PULL 8 seconds
3. HANDS IN FRONT- PINCH & PUSH 8 seconds
4. HANDS IN FRONT- PINCH & PULL 8 seconds
5. WEIGHTED BALL ARM SWINGS
   a. 15 FORWARDS
   b. 15 BACKWARDS
   c. 15 IN FRONT ACROSS CHEST
   d. 10 FIGURE 8’S
   e. PULSES 15 REPS
   f. 3 RUN AND GUN HOLDS W/ 2LB BALL
   g. 3 RUN AND GUN HOLDS W/ 1LB BALL (IF NECESSARY)
   h. THROW A FEW TO GET LOOSE AND RIGHT INTO HOLDS
Go to Playersdugout.com/test.asp to submit your test results.

Authorization:  
Players Name:  
Test Date:  
Height: 4' 7"  
Weight: 63  
Players Age: 11

**OUT OF SEASON**

### Testing Velocities

<table>
<thead>
<tr>
<th></th>
<th>2 lbs.</th>
<th>1 lbs.</th>
<th>6 oz.</th>
<th>5 oz.</th>
<th>4 oz.</th>
<th>2 oz.</th>
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<tbody>
<tr>
<td></td>
<td>1 2 3</td>
<td>1 2 3</td>
<td>1 2 3</td>
<td>1 2 3</td>
<td>1 2 3</td>
<td>1 2 3</td>
</tr>
<tr>
<td>1st Throw</td>
<td>25</td>
<td>32</td>
<td>41</td>
<td>43</td>
<td>45</td>
<td>49</td>
</tr>
<tr>
<td>2nd Throw</td>
<td>25</td>
<td>32</td>
<td>41</td>
<td>42</td>
<td>47</td>
<td>48</td>
</tr>
<tr>
<td>3rd Throw</td>
<td>25</td>
<td>31</td>
<td>41</td>
<td>45</td>
<td>45</td>
<td>50</td>
</tr>
<tr>
<td>Average</td>
<td>25</td>
<td>31</td>
<td>41</td>
<td>43</td>
<td>45</td>
<td>49</td>
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### Holds

<table>
<thead>
<tr>
<th></th>
<th>Knee</th>
<th>Rocker</th>
<th>Run-n-Gun</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 lbs.</td>
<td>2</td>
<td>2</td>
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<tr>
<td>1 lbs.</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>6 oz.</td>
<td>3</td>
<td>3</td>
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<tr>
<td>5 oz.</td>
<td>2</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>4 oz.</td>
<td>3</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Towel / 2 oz.</td>
<td>3</td>
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<td>4</td>
</tr>
<tr>
<td>Just Hand</td>
<td>2</td>
<td>2</td>
<td>3</td>
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</tbody>
</table>

### Throws

<table>
<thead>
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</tr>
<tr>
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<td>2</td>
<td>4</td>
</tr>
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</tr>
</tbody>
</table>

**Out of Season**

First 2 Weeks: Knee Holds (3 Reps Each) Knee Throws (2 Reps Each) - Mon, Tue, Thu and Fri (Intensity at 60%-70%).

Week 3: Pull workout using the schedule that follows (Intensity at 60%-70%). Weeks 4&5: Increase intensity to 100%.

Day One - Holds and Throws
Day Two - Day Off
Day Three - Holds Only
Day Four - Day Off
Day Five - Holds and Throws
Day Six - Holds Only
Day Seven - Day Off
Reetest at the beginning of week 6.
References


