WEIGHTED BALL TRAINING, ISOKINETIC SHOULDER STRENGTH, AND FASTBALL VELOCITY IN HIGH SCHOOL ATHLETES

by
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ABSTRACT

The purpose of this study was to examine the effects of a 6-week weighted ball training program on throwing velocity and isokinetic shoulder strength in 23 high school baseball players. Preliminary throwing velocity was measured with a JUGS radar gun and isokinetic shoulder strength was measured with a Biodex System III Isokinetic Dynamometer at 300 deg/sec. Participants in the training group completed all practices and weight sessions with the team, then completed an over- and under-weighted ball throwing and eccentric hold intervention. Within the groups it was noted that TV, CER, EER decreased over time, no change in CIR was noted and a slight increase was noted in EIR. However, no statistical differences were noted between the intervention and control groups. Weighted ball training programs have merit, however must be implemented in such a way to target the population being trained.

TABLE OF CONTENTS

LIST OF TABLES

CHAPTER I

INTRODUCTION

The overhead throwing motion is one of the fastest human movements in skill sports with an internal rotation angular velocity of up to 7,000 degrees per second (Wilkin & Haddock, 2006; Zheng & Eaton, 2012). The shoulder endures a significant amount of stress to not only accelerate the arm, but also to decelerate or slow down the arm without causing any damage to the surrounding musculature (Noffal, 2003). It has been noted that the distraction forces at the glenohumeral joint during acceleration to ball release are up to one and a half times that of body weight (Sirota, Malanga, Eischen, & Laskowski, 1997). This overhead movement requires the rotator cuff muscles that engulf the head of the humerus to contract simultaneously to pull it into the glenoid fossa. These muscles fire concentrically to accelerate the arm and eccentrically to decelerate the arm.

Athletes strive to perform at the highest level. One measure of success for a baseball player is ball velocity. The faster a pitcher can throw the ball from the mound to the plate, the more likely it is that the batter strikes out. This gives the batter less time to react to the pitch, thus making it challenging to hit the ball. For the position player, the ability to field the ball and throw it to the base as quickly as possible is important. Training increases overall shoulder strength and can increase not only a pitcher's ability to throw the ball with more velocity across the plate but also a position player's ability to throw the ball faster to throw out a base runner. Training programs using different modalities have improved throwing velocity. Resistance band training with high school pitchers increased fastball velocity by 6.2 mph in the treatment group following a 6-week training program (Baheti & Harter, 2001). Similarly, following an 8-week dumbbell and resistance band training program, fastball velocity increased by 2 mph in high school pitchers. A slight increase in shoulder strength was noted after the program, however it was not statistically significant (Carter, Kaminski, Douex, Knight, & Richards, 2007).

Beyond maintenance, the ability to increase velocity and strength is appealing to the overhead-throwing athlete. Plyometric training using weighted ball programs has been shown to increase throwing velocity and shoulder strength in high-level and novice overhead athletes. Plyometric training consists of using over- and under-weighted baseballs. The standard weight of a baseball is 5 oz and research shows that training 20-25% over and under the standard baseball weight will increase fastball velocity and strength. Therefore, for this study, over-weighted baseballs weighed 7 oz and under-weighted baseballs weighed 2 oz. A new concept using eccentric training may also aid in training the baseball player to throw faster and gain increased muscular strength and stabilization around the rotator cuff. Further research needs to be done to investigate the effects of weighted ball training in high school athletes.

One of the pioneer studies on plyometric training in the overhead athlete was performed by Brose and Hanson (1967), which consisted of weighted ball throwing and weighted pulley-system throwing. The outcome measure was throwing velocity in both pitchers and position players over a 6-week training program. They noted a significant increase in throwing velocity following both training programs (Brose & Hanson, 1967).

Similar to Brose and Hanson (1967), Litwhiler and Hamm (1973) investigated the effect of over-weighted ball training on throwing velocity. This study consisted of a 12-week training program with fastball velocity measured pre and post training. Fastball velocity increased an average of 11.2 mph, however there were only 5 participants in this study, which makes it hard to generalize the results.

More recently, DeRenne, Ho, and Blitzblau (1990) investigated the effects of both under- and over-weighted ball training on high school senior baseball pitchers. The outcome measure over the 10-week program was fastball velocity. It was noted that the over-weighted ball group increased fastball velocity by 3.75 mph over the 10-weeks and the under-weighted ball group increased by 4.72 mph over the 10-week span (DeRenne et al., 1990)

Similarly, DeRenne, Buxton, Hetzler, and Ho (1994), investigated the effects of over-, under- and standard weight baseballs on fastball velocity over a 10-week program. This study was unique in that there were different combinations of training. The first group completed over- and under-weighted training in the same session, three times per week for 10-weeks. The second group completed over-weighted balls the first 5-weeks and under-weighted balls for the last 5-weeks. Finally, the third group was a control group only throwing standard weight baseballs. Fastball velocity increased in both groups one and two, however no differences were noted when breaking the 10-weeks into over- and under-weighted sessions (DeRenne et al., 1994).

The effects of eccentric training on muscular strength are important in force production. Studies have shown that a “pre-load” or an eccentric contraction followed quickly by a concentric contraction can increase force production. During the throwing motion, the athlete must cock the arm back, which places a stretch on the internal rotators of the shoulder causing an increase in force production. This increase in force production is due to an increase in muscle spindle activation as well as elastic recoil in the muscle itself (Bigland-Ritchie & Wood, 1976). With this increased force production, baseball players can increase fastball velocity. The concept of going through the throwing motion without releasing the ball from the hand is coined as a hold. To avoid confusion of a hold being isometric it will be termed a throwing hold. This throwing hold is a new concept created by baseball pitching coaches and strength and conditioning specialists. This allows for the throwing athlete to train the eccentric musculature during follow-through/deceleration.

In summary, the overhead baseball throwing motion is one of the most violent and fastest human motions in any skill sport. In order for a baseball player to be successful, shoulder strength and high fastball velocity are needed. Many programs have been designed to maintain and even increase both shoulder strength and fastball velocity. Plyometric training using both over- and under-weighted baseballs can further increase fastball velocity in high-level baseball player's as well as high school baseball players. In addition to throwing weighted baseballs, an eccentric component throwing holds should be implemented. This may be beneficial for the throwing athlete not only for force production and arm strength, but for overall fastball velocity. There is a need for further research within high school baseball players on the effects of not only the weighted ball program but also implementation of throwing holds.

Purpose Statement

The purpose of this study was to examine the effects of an over- and under-weighted ball training program with implementation of throwing holds on overall isokinetic shoulder strength and fastball velocity in high school baseball players.

Hypotheses

1. Participants who completed the 6-week training program would have significant differences in fastball velocities compared to those who did not complete the training program.

2. Participants who completed the training program would have significant differences in internal rotation (IR) and external rotation (ER) strength concentrically and eccentrically in throwing arm, compared to those who did not complete the training program.

Delimitations

1. The study was limited to one high school baseball team in the Southeastern United States.

2. Participants were free from any shoulder or elbow injury in the past 6 months.

3. Participants routinely used the overhead throwing motion in their sport.

Limitations

1. There was no method to assess whether each participant gave his maximal effort during each testing session.

2. Although training regimens were standardized, any extra workouts or extra weight training performed could not be accounted for.

Basic Assumptions

1. Participants were truthful regarding previous medical history.

2. Participants gave maximal effort during each training and measurement session.

CHAPTER II

LITERATURE REVIEW

In this chapter, the importance of shoulder strength and throwing velocity will be examined. Due to the stresses placed on the shoulder during the overhead throwing motion, proper shoulder strengthening programs are of the utmost importance. Baseball pitching is about the combination of deceiving the batter and throwing the ball with significant velocity, thus the effects of weighted-ball training programs are investigated for their aid in increasing fastball velocity. The importance of ball velocity for position players is also significant. The ability to throw the baseball to the base as quickly as possible ensures that the opponent will not be safe. The chapter closes with an overall summary and a review of the purpose of this study.

The Overhead Pitching Motion

The overhead throw, one of the fastest human movements in any skill sport, requires major strength and muscular control of the shoulder (Wilkin & Haddock, 2006). Baseball players utilize all of these components while throwing a baseball with precision and speed. The throwing motion is classified into five phases: wind-up, cocking, acceleration, deceleration, and follow through (Starkey, Brown, & Ryan, 2010). The wind-up phase is considered the neutral position. During this phase, most of the forces are generated by the lower extremity preparing the body for forward movement. The ground reaction forces generated on the stride leg are up to 200% of body weight (Guido & Werner, 2012). The cocking phase is when the athlete reaches maximal ER of the shoulder and the arm is in 90 degrees of abduction. The acceleration phase begins at full glenohumeral (GH) ER with the arm beginning to move into IR. This phase requires the most concentric force from the internal rotators (Mikesky, Edwards, Wigglesworth, & Kunkel, 1995; Starkey et al., 2010). During the acceleration phase, shoulder IR velocity reaches 7,000 degrees per second with a rotational torque of 70 Nm (Zheng & Eaton, 2012).

Once the ball is released from the hand, the deceleration phase starts and the external rotators must contract eccentrically to slow down the arm. In the final follow through phase, the momentum of the arm is slowed, which requires the highest amount of eccentric control. In order to move the arm through the pitching phases and stabilize the arm throughout the throwing motion, strong musculature of the shoulder is needed.

Shoulder Strength

The throwing motion consists of concentric and eccentric contractions of the shoulder musculature. The four main stabilizers of the glenohumeral joint are the supraspinatus, infraspinatus, teres minor, and subscapularis. These four muscles are oriented such that when they simultaneously contract, they pull the head of the humerus safely into the GH joint, as well as internally and externally rotate the humerus (Starkey et al., 2010). During the acceleration phase, the internal rotators, the serratus anterior, and the upper trapezius muscles concentrically contract to catapult the arm forward. Conversely, during deceleration and follow through, the external rotators, the biceps, and the brachialis eccentrically contract to slow the arm as the ball is released from the hand (Altchek & Dines, 1995; Starkey et al., 2010). In a study aimed at determining the ratio of IR to ER strength in dominant shoulders of throwing athletes, it was determined that the eccentric contractions of ER of the shoulder are much stronger in the dominant arm compared to the non-dominant arm (Noffal, 2003). Additionally, gains in IR strength did not correlate with gains in ER eccentric strength. Therefore, specific eccentric strengthening is important for the throwing athlete (Noffal, 2003).

There are many ways to measure strength of the shoulder musculature. One of the most accurate is using a dynamometer. Isokinetic dynamometry is used extensively for quantitative assessments of the shoulder musculature (Cools, Witvrouw, Danneels, Vanderstraeten, & Cambier, 2002). The two most important measures of strength in throwing athletes are IR and ER, both concentrically and eccentrically.

Meeteren, Roebroeck, and Stam (2002) examined the test-retest reliability for measuring shoulder strength using a Biodex dynamometer across a 2-week period. The study included 20 participants, 10 who played sports with one arm and 10 who did not play any sports. All measurements were done in a seated position, straps were placed across the chest and across the lower extremity to limit excess motion and isolate the arm musculature. Internal rotation and ER measures were calculated with the participants in a 90/90 shoulder and elbow position, where the shoulder was in 90 degrees of shoulder abduction and the elbow was in 90 degrees of flexion. Low and high velocity measures were taken at 60 degrees/second and at 180 degrees/second. At the low velocity, the participants performed three repetitions and at the high velocity they performed 10 repetitions. The maximal peak torque was then calculated from the data. The IR and ER measures were similar (r = .74 - .94) across time indicating strong test-retest reliability of using the Biodex to assess IR and ER strength in throwing and non-throwing participants (Meeteren et al., 2002).

Similar to Meeteren et al. (2002), Edouard et al. (2013) completed a study on 1-week test-retest reliability of the Biodex in assessing strength imbalances. The ratios between measures of IR and ER strength during concentric and eccentric movements were measured. The participants (*N* = 46) were placed on the Biodex machine in scaption (45 degrees shoulder horizontal abduction) and measured at 60 and 120 degrees/second for five repetitions concentrically and 30 degrees/second eccentrically for five repetitions in both ER and IR. Like Meeteren et al., Edouard et al. noted that ER/IR peak measures were reliable in a seated position (*r* = .87 - .97) and test-retest was documented. It was confirmed that isokinetic testing is the most reliable device for objectively measuring muscular strength (Edouard et al., 2013).

Isokinetic testing machines such as the Biodex have high reliability for testing muscular strength of the shoulder in baseball pitchers. For dynamic stabilization and control of the arm during pitching, strong musculature is necessary. In addition to strength, another characteristic or skill needed to increase throwing success is ball velocity.

Ball Velocity

Coupled with shoulder strength, the ability to throw the ball faster increases the likelihood of striking out an opposing player or throwing a player out at the base. Likewise for the pitcher, accuracy, ball movement, and strategy also impact whether he is successful or not. A pitcher who can throw the ball with greater velocity will allow less time for a batter to identify the pitch and location over the plate (Escamilla et al., 2012). This is beneficial as pitchers enter into collegiate and professional baseball, as hitters have more skill and practice in hitting. Pitching also requires deception; this is where breaking balls/off speed pitches come into play. Pitchers that are able to control speed by throwing off-speed pitches excel. The most common breaking balls/off speed pitches are curve balls, sliders, splitters and change-ups. These are thrown with less velocity, however they have movement. As the ball moves to the plate, it breaks or dives at the last minute tricking the batter into swinging and hopefully, missing the pitch. A pitcher who has a faster fastball has a greater ability to deceive hitters with off-speed pitches.

In order to measure velocity objectively, a radar gun is used. This is a cost effective way to measure ball velocity as well as the easiest to travel with and use in the field. This tool is pointed at the ball as it is pitched, typically from behind the plate, and displays a read-out number in miles/hour (mph). With an easy to use radar gun, pitching velocity can be measured with accuracy to within +/- 0.5 mph (Crotin, Bhan, Karakolis, & Ramsey, 2013). Most teams also use a stopwatch to measure the amount of time it takes from the release of the ball from the athlete’s hand to the time it hits the catcher’s mitt. This helps hitters and base runners gauge when to swing at the ball while at the plate or when to run when stealing a base. However, if a pitcher has high-ball velocity, it is harder for hitters to time when to swing at the ball and harder to steal a base. Fastball velocity is important to measure in baseball pitchers and position players, as it is a key predictor of throwing success. Strength coaches, pitching coaches, and athletic trainers have devised specific training programs to help increase throwing velocity in the overhead athlete.

Season Strength and Velocity Changes

Wilkin and Haddock (2006) investigated the isokinetic strength of baseball pitchers during a season. They recruited National Collegiate Athletic Association (NCAA) division II baseball pitchers ($N = 9$) and measured isokinetic IR and ER strength three times throughout the season (preseason, midseason and postseason). Similar to other studies, a familiarization test was completed before the preseason testing so the athletes felt comfortable on the Biodex isokinetic machine. They completed internal and external testing (10 maximal repetitions) at both 300 and 450 degrees per second. There were no changes ($p = .648$) in either internal or external isokinetic strength throughout the season. The participants in the study performed weight training three times per week, which consisted of three sets of 10 repetitions. The exercises included bench press, squats, dead lifts, curls, lat pulls, triceps extension, adductor/abductor or equivalent, shoulder care (Jobes throwers ten program), sit-ups (200 repetitions), and back extension. Conditioning running was completed three times per week. This consisted of half-mile jog warm-up and four sets of 200 yard sprints. Distance work consisted of mile-and-a-half runs on lift days (Wilkin & Haddock, 2006).

A similar study conducted by Whitley and Terrio (1998) investigated the changes in abduction, adduction, internal, and external strength of the shoulder over a high school baseball season. This study included high school baseball pitchers ($N = 5$). Isokinetic strength was measured before and after the 4-month baseball season. The pitchers were measured at 150 and 300 degrees per second performing 10 repetitions of maximal internal and ER motions. The findings were similar to Wilkin and Haddock (2006) in that there was no change in shoulder strength, however they did note minimal decreases in strength in both adduction and internal rotation of the shoulder, which were not significant (Whitley & Terrio, 1998). These two studies further document that the typical shoulder training programs, which consist of resistance bands and dumbbells, serve in preserving shoulder strength throughout a baseball season.

Crotin et al. (2013) examined fastball velocity trends throughout a minor league season. The researchers recorded average fastball velocity over eight games in 12 minor league baseball pitchers. Altogether, 5,743 pitches were thrown and recorded over the season using a Stalker Radar gun positioned directly behind home plate. Crotin et al., found that there was a 4.4 mph increase on average from first game to the eighth game. Given that these were professional baseball pitchers, it was noted that they were completing specific shoulder care and strengthening program provided by the team's strength and conditioning coaches. On average, these pitchers threw approximately 20-60 pitches per game and only 2-4 innings (Crotin et al., 2013). The shoulder care completed by these professional athletes was enough to elicit a slight increase in throwing velocity over a season. Many new programs, however, have begun to surface that may actually increase strength and further increase throwing velocity.

Shoulder Programs

It is recognized that specific programs for maintaining and/or increasing shoulder strength are necessary for the overhead-throwing athlete. Many programs exist and are aimed at increasing strength and, in turn, increasing throwing velocity. Programs have developed over time from simple, single-plane strengthening to movements that are sport and position-specific strengthening in the plane of motion used. Extensive research has been done trying to investigate the most successful program for increasing shoulder strength, increasing throwing velocity, and limiting injury in high school and adolescent athletes.

Surgical tubing (resistance bands), cuff weights, and dumbbells are used widely in baseball for not only warm-up purposes, but also for resistance training. Baheti and Harter (2001) investigated the effect of a resistance band program on throwing velocity and shoulder strength. The 24 male participants were drawn from four local high schools and each high school was randomly selected for either the control (N = 12) or treatment group (N = 12). The treatment group completed a 6-week training program with resistance bands 5 days per week. The resistance program was supplemental to the routine shoulder care and weight training that the entire team completed. The control group completed all shoulder care exercises and weight training, however did not receive the supplemental resistance band program.

The control and treatment groups completed a pre-test isokinetic strength test using a KinCom dynamometer. Participants were seated with the shoulder in neutral at 90 degrees of abduction and 90 degrees of elbow flexion (90/90 position) with Velcro straps holding the arm in place. Both IR and ER were measured at 60 degrees/second and 240 degrees/second. A 3 minute warm-up on the arm ergometer was completed before measurements on the KinCom. Participants were to complete six maximal repetitions for both IR and ER concentrically and eccentrically followed by a 30-second break between sets. A familiarization test was performed to limit learning effect prior to initial testing. Pre-test throwing velocity was measured using a JUGS radar gun. Participants threw 10 fastballs off the mound in full wind-up and the five fastest pitches were averaged for maximal throwing velocity. Throwing velocity was measured in mph (Baheti & Harter, 2001).

The treatment group completed six resistance band exercises, which consisted of standing row, forward punches, shoulder shrugs, standing supraspinatus, standing external rotation, and standing internal rotation. The initial 2 weeks, the participants in the treatment group completed two sets of 10 repetitions with the red resistance band (light resistance). The third and fourth weeks, the participants completed three sets of 10 repetitions using the blue resistance band (medium resistance). The final two weeks, the treatment group completed three sets of 12 repetitions using the black resistance band (heavy resistance). The control groups did not perform any resistance band exercises during the 6-weeks, only shoulder care exercises and weight room training with the entire team.

Over the course of the training program, the treatment group increased throwing velocity by 6.2 mph compared to a 1.5 mph increase in the control group. Isokinetic strength measures also increased during the course of the program. The treatment group increased both internal and external rotator peak torque measures concentrically and eccentrically. In contrast, the control group decreased in both internal and external rotator peak torque measures concentrically and eccentrically (Baheti & Harter, 2001). Overall, the treatment group found increases in throwing velocity. However, it was noted that the participants were high school athletes and received little to no previous strengthening programs.

A similar study conducted by Carter, Kaminski, Douex, Knight, & Richards (2007) investigating the effects of an 8-week dumbbell and resistance band program on shoulder rotator cuff strength and throwing velocity. National Collegiate Athletic Association college baseball athletes (*N* = 24) participated in the study. Participants (*n* = 13) were randomly selected for the treatment group, which consisted of a mixture of all baseball positions. Pre-test and post-test measures consisted of isokinetic strength using a Biodex machine. A 5-minute arm ergometer warm-up was completed prior to testing. Isokinetic measures included concentric IR and eccentric ER at speeds of 180 degrees/second and 300 degrees/second. Throwing velocity was measured with a JUGS radar gun. Each participant completed five throws with 1-minute rest between each throw. The highest velocity was recorded for maximal velocity.

The treatment group completed an 8-week program (two days per week) supplemental to normal weight room strengthening completed by both the treatment and control groups. Participants completed the “ballistic six” exercise program twice a week. The exercises for the week consisted of ER with arm at side, ER at 90/90 position, with red resistance band (light resistance), an overhead soccer pass, 90/90 position ER side throw, deceleration throw, and baseball throw with medicine balls (2 pounds for single arm exercises and 6 pounds for two-handed exercises). Repetitions were increased throughout the 8-weeks. During the first 2 weeks participants completed three sets of 10 repetitions, weeks three through five consisted of three sets of 15 repetitions and weeks six through eight completed three sets of 20 repetitions.

There was a statistically significant increase in throwing velocity of 2 mph in the treatment group and a 0.27 mph increase in the control group. Increases in eccentric and concentric strength were noted in both groups, however the increases were not statistically significant (Carter et al., 2007). In summary the treatment group showed increases in throwing velocity over the 8-week program. Similar to Baheti and Harter (2001) this study focused on resistance training using dumbbells and resistance bands, however, this study was performed on NCAA baseball players. As noted, there were a minimal increase in velocity (2 mph) compared to the high school athletes increase of 6.2 mph. This is mainly due to lack of experience with resistance training in the high school athletes. Collegiate athletes require additional resistance training to further increase fastball velocity and overall shoulder strength. More research needs to be done to examine alternative methods on top of shoulder care strengthening programs, which include resistance bands and dumbbells. Programs need to focus on not only strengthen the shoulder girdle, but also strength within the functional motion of throwing.

Weighted Ball Training

Plyometric training is a common method for increasing strength; however previous research has been performed primarily on the lower extremities. Plyometric training is defined as “a technique that includes specific exercises that encompass a rapid stretch of a muscle eccentrically, followed immediately by a rapid concentric contraction of that muscle for facilitating and developing a forceful explosive movement over a short period of time" (Prentice, 2009, p. 118). Several articles have been published recently on the effect of plyometric training for upper body training specifically for shoulder strength and pitching velocity. The concept behind under-weighted ball training is that the arm is able to move at higher speeds with less muscular force generated. Over-weighted ball training, conversely, works on slower arm speeds with more muscular force generated. Training baseball players with both over- and under-weighted balls allows for speed and strength (power) to increase, maximizing the greatest amount of force in the least amount of time (Escamilla, Speer, Fleisig, Barrentine, & Andrews, 2000). These specific programs can be broken into three categories: overload of force (over-weighted balls), overload of velocity (under-weighted balls), and combination training with both over-weighted and under-weighted balls.

A study conducted by DeRenne et al. (1990), investigated the effects of both under- and over-weighted ball training on high school senior baseball pitchers (N = 30, 16-18 year olds). Participants were assigned randomly to the over-weighted implement group, the under-weighted implement group, or the control group. All groups completed a 10-week program three days per week. Pre- and post-velocity measures were taken using a radar gun averaging 10 consecutive throws. The control group completed all throws with the standard 5 ounce baseball, the over-weighted group completed throws with standard baseball and progressively increased by one-fourth an ounce every 2 weeks ending with a 6 ounce weighted ball and finally the under-weighted group started with a standard baseball and decreased by one-fourth an ounce every 2 weeks ending with a 4 ounce ball. The change throughout the 10-week program was a 20% increase or decrease from the standard 5 ounce baseball.

Participants started with a 10 minute warm-up consisting of jogging, stretching, and light tossing. Then the 10 minute controlled lesson plan was completed, which consisted of 50 throws for all groups. The over-weighted group completed 20 throws with a standard baseball, 20 throws with the over-weighted ball, and finished with 10 throws with a standard baseball. The under-weighted group completed 20 throws with a standard baseball, 20 throws with under-weighted ball, and finished with 10 throws with a standard baseball. The control group threw 50 throws with a standard baseball.

There was a statistically significant increase in fastball velocity in both the under- and over-weighted groups. The over-weighted group increased velocity by 3.75 +/- 2.42 mph and the under-weighted group increased velocity by 4.72 +/- 2.10 mph. The 2 groups showed increase over the control, however they were not significantly different than one another. The control group had a non-significant increase of 0.88 mph increase after the 10-week program (DeRenne et al., 1990). In conclusion, there was no difference statistically between completing either over- or under-weighted training. Both groups increased throwing velocity compared to the group who did nothing other than normal activity. This study presented information supporting the implementation of either an over- or under-weighted ball training program.

A similar study performed by DeRenne et al. (1994) looked into the effect of a 10-week over- and under-weighted ball training program on fastball velocity (45 high school pitcher and180 college pitchers). This study consisted of 3 groups. Group one pitched with over- under-weighted and standard baseballs, group two pitched with over-weighted and standard baseballs for the first 5 weeks and under-weighted and standard baseballs for the remaining 5 weeks, group three was the control group and only threw standard baseballs. Participants were randomly selected to one of the 3 groups. Pre- and post-fastball velocity measures were taken using a radar gun.

Training procedures included three sessions a week for 10-weeks. Group one completed a progression of standard ball, over-weighted ball, under-weighted ball, and a standard ball. Weights of balls were 5 (standard), 6 (over-weighted), 4 (under-weighted), 5 (standard) ounces, respectively. The total number of pitches thrown each session was increased every 2 weeks by six pitches starting with 54 and ending with 78 pitches. Group two completed two separate 5-week programs. The first 5 weeks consisted of standard ball, heavy ball, and standard ball, with weights 5 (standard), 6 (over-weighted), and 5 (standard) ounces, respectively. The final 5-weeks consisted of standard ball, light ball, and standard ball, with weights 5 (standard) 4 (under-weighted) 5 (standard) ounces respectively. Group three (control group) completed the same number of throws each week as other the two other groups, however only used the standard 5 ounce ball (DeRenne et al., 1994).

There was a statistically significant increase in fastball velocity in both groups for both high school and college pitchers. The exact increases were not noted within the text, however graphical information was provided. College athletes showed an approximate increase of 4 mph in group one and 3 mph in group two. High school athletes showed an approximate increase of 5 mph in group one and 4 mph in group 2. It was also noted that even when breaking the over- and under-weighted training into separate sessions, the same increases were found. Therefore, either protocol is sufficient for increasing fastball velocity.

Litwhiler and Hamm (1973) conducted a study to look into the effect of over-weighted ball training on throwing velocity. This study included college pitchers (*N* = 5) who completed a 12-week program using over-weighted baseballs ranging from 7 to 12 ounces. The participants used a 7 ounce weighted ball for the first 2 weeks, and an increase of 1 ounce every 2 weeks thereafter until the last week in which they used a 12 ounce ball. Each participant trained for three days per week during the 12-week program. A warm-up was completed prior to the program with a standard sized baseball. Participants then completed 15 throws with a standard baseball, 20 throws with over-weighted ball, and finished with 10 standard baseball throws. Pre- and post-test velocity measures were compared. There was a statistically significant increase in throwing velocity post-program. An average increase of 11.2 mph was noted. No control group was present in this study and there was a small sample of 5 participants (Litwiler & Hamm, 1973).

Similar to Litwhiler and Hamm (1973), Brose and Hanson (1967) investigated the effects of over-weighted training on velocity in collegiate position players and pitchers (*N = 21)*. Participants were evenly divided into three separate groups, which consisted of a control group, over-weight throwing group, and a wall-pulley throwing group. All groups trained three days per week for 6 weeks. The control group completed throwing with only standard baseballs, the over-weighted group threw with standard baseballs and 10 ounce balls, and the wall-pulley group performed throwing motion with a baseball attached to a wall-pulley device that provided 10 pounds of resistance.

Participants completed an active warm-up consisting of throwing standard weighted baseballs to get their arms loose. Participants then completed five throws at moderate effort and finished with 20 throws of maximal effort using specified balls depending on group (wall pulley, standard ball, or 10 ounce ball). Then, all groups completed 20 throws with a standard baseball to finish the day's protocol. Pre- and post-test velocity measures were taken prior to the program and directly after the program. There was a statistically significant increase in velocity in both the wall-pulley group and the over-weighted ball group, however no increase in the control group. No specific increase was noted in study (Brose & Hanson, 1967).

Many studies have indicated the positive effects of weighted ball training for the increasing fastball velocity and shoulder strength. Although many different protocols and techniques have been proposed, all programs have shown positive effects. Finding the protocol that elicits the highest success rates is important in effectively training the overhead athlete. The concept of eccentric training could be an important piece of the overall puzzle to find the most successful protocol.

Eccentric Training

It is documented that eccentric strength training is important for all athletes. Research has shown that a "pre-load" or an eccentric contraction followed quickly by a concentric contraction can increase force production. The delay between the eccentric contraction and concentric contraction must be less than 1 second for greatest effects

(Bigland-Ritchie & Wood, 1976). During the throwing motion, the athlete must cock the arm back, which places a stretch on the internal rotators of the shoulder causing an increase in force production. This increase in force production is due to an increase in muscle spindle activation as well as elastic recoil in the muscle itself (Bigland-Ritchie & Wood, 1976). With this increased force production baseball pitchers can increase fastball velocity due to increased force production in the shoulder.

In addition to throwing weighted baseballs, an eccentric component should be implemented. This type of exercise has been coined as holds due to the concept of not releasing the baseball, however, to avoid confusion, they will be called throwing holds. Completing the throwing motion without releasing the baseball from the hand and holding it through deceleration will strengthen the eccentric decelerator muscles of the shoulder as well as increase the concentric muscles that accelerate the arm. This is beneficial for throwing athlete for not only force production and arm strength but also, overall fastball velocity.

Overall Summary

Athletes strive to perform at the highest level possible. One measure of success for a baseball player is ball velocity. The faster the pitcher can throw the ball from the mound to the plate, the more likely he is to strike out the batter, because the batter has less time to react to the pitch, thus making it challenging to hit. Likewise, the quicker a position player can throw the ball to the base, the more successful he is at getting the runner out. Any type of training that increases overall shoulder strength will likely increase the ability to throw the ball with more velocity. Many specific training programs have been put into place to help maintain shoulder strength and throwing velocity. There is documentation indicating that surgical tubing and dumbbell routines work to maintain shoulder strength. However, athletes are always striving to do better than simply maintaining strength and velocity. The ability to increase velocity and strength is appealing to the typical athlete and plyometric-weighted ball programs have been shown to increase throwing velocity and shoulder strength.

Through the research it has been concluded that a program, which includes over-, under- or a combination of the two will increase shoulder strength and fastball velocity. There are no significant differences between any of the three methods, although a combination of the two may increase arm speed with the under-weighted ball and arm strength with the over-weighted ball. The concept of eccentric contractions within the program (throwing holds) could further increase overall strength and velocity of the pitchers fastball.

Further research needs to be done to document the effects of weighted ball training in high school athletes implementing throwing holds for their effectiveness. Therefore, the purpose of this study was to examine the effects of a weighted ball training program with implementation of throwing holds on overall isokinetic shoulder strength and fastball velocity in high school baseball players.

CHAPTER III

METHODS

Participants

Participants in this study were baseball players at one area high school located in the Southeastern United States. A physician previously cleared all athletes to participate in baseball during pre-participation physical examinations. Any athletes with previous history of shoulder, elbow, or wrist injury or surgery within the past 6 months were excluded from the study. Participant's ages ranged from 14 years to 18 years old. Due to the lack of specialization in high school baseball, few athletes are pure pitchers or position players. This allows for the ability to test all positions due to player's ability at this age to play multiple positions. However, the pure pitchers, were distributed between groups using stratified randomization. This was done to ensure there was not an uneven balance of pure pitchers between the control and treatments groups as pure pitchers are more trained in the skill of throwing.

Instrumentation

Height and body mass. Participant's height and body mass were taken prior to testing for demographic purposes. Height was measured using a portable stadiometer (Seca 217, Chino, CA) and was measured in cm to the nearest 0.1cm. Body mass was measured in kg on a digital scale (Seca 869, Chino, CA). Participants removed shoes and emptied all pockets prior to the measures. All participants wore gym shorts and a tee shirt for the measurements.

Shoulder strength. Shoulder IR and ER strength were measured on a Biodex System 3 Isokinetic Dynamometer (Shirley, New York). Participants were measured in 90 degrees shoulder abduction and 90 degrees elbow flexion, as this is the most powerful position, which is also known as throwing position (Meeteren et al., 2002; Noffal, 2003). Concentric and eccentric IR and ER were measured at 300 degrees/second for five maximum trials and the highest measurement in ft/lbs was recorded. Prior to the testing protocol, a 10-min arm ergometer warm-up was completed to ensure the participant's muscles were warm and ready for testing. Following the warm-up, a familiarization session was completed, allowing for the participant to complete 10 repetitions to see how the machine felt and worked. A 30-second break between the two sets allowed for the participant to prepare for the next set (Noffal, 2003; Wilkin & Haddock, 2006). A short 30-second break was used, as the two tests require different sets of muscular firing, thus fatigue was not a concern.

Throwing velocity. Velocities of the participant's maximal throws were measured using a radar gun (JUGS professional sports radar), which has an accuracy of within 0.5 mph (Crotin et al., 2013). The radar gun was placed 3 feet behind the net with a 4-foot circular target and five pitches were measured and the highest speed in mph was recorded. The net was set up 60 feet from the participant and the throwing took place on flat ground. The participant completed a 5-minute light toss at 90 feet as a warm-up prior to completing the throwing velocity measures. Each participant was given five throws as a warm-up into the net then, completed five throws and the highest speed was recorded. Pre-testing was completed one day prior to beginning of the program and post-testing was completed one day following the last session of the protocol. This allowed for the athlete's arms to recover following the testing sessions and the throwing program.

Shoulder ROM. Shoulder range of motion was measure by two separate means. While the athlete was on the Biodex, total range of motion was measured passively with the examiner slowly rotating the participant's arm until terminal motion was met either from verbal communication from the participant or anterior tilting of the shoulder complex noting end range. The second means of measurement consisted of goniometric readings. Participants were supine on a portable treatment table with throwing arm in 90 degrees of abduction and 90 degrees of elbow flexion. Each participant was measured passively and actively and measurements were recorded in degrees. The participant's arm was rotated slowly through IR and ER while stabilizing the anterior shoulder to limit accessory motion of the shoulder during passive motion. During active range of motion, the participant moved his arm through IR and ER and verbally communicated end range while the primary researcher stabilized the anterior shoulder. The goniometer was placed over the olecranon process for center of rotation, the movement arm was in line with the ulna, and the stationary arm was perpendicular to the floor.

Procedures

Approval was obtained from the Institutional Review Board (IRB) at the university (see Appendix A). The baseball coach was informed of the nature of the study and agreed to allow the student-athletes to volunteer to participate in the study.

Participants volunteered to participate in the study after reading and signing an assent form if under 18 years of age or a consent form if over the age of 18. Parents or guardians of each student also signed a consent form prior to participation of any athlete under the age of 18 in the study. Each participant was aware that he was able to withdraw from the study at any time. All participants were free from any shoulder, elbow, or wrist injury within the last 6 months.

Pre- and post-testing. Participants were dropped off by the head coach in a school bus, one group in the morning and the other in the afternoon. Participants were randomly assigned to either a morning or afternoon testing session, 12 participants in each group. Two randomized drawing were used to set the treatment and control groups and another separate one for testing times. To ensure sound results, athletes completed pre- and post-testing at the same time, either morning or afternoon. Isokinetic shoulder strength, maximal throwing velocity, and shoulder range of motion measurements were taken at the university with university equipment.

Control group. Participants randomly selected for the control group did not complete any weighted ball program throwing. Training was limited to any practice or strength training regularly completed by the entire team. The entire team completed strength training three days per week and a throwing program with a standard ball. A dynamic warm-up was completed prior to the regular team throwing program. The team's strength training program is shown in Appendix B. Maximal throwing velocity, isokinetic strength testing and shoulder range of motion measurements were assessed pre- and post- for this group.

Treatment group. Participants in the treatment group completed a 6-week weighted-ball training program three days per week. Participants completed a dynamic warm-up with the team conducted by the coach and all standard training prior to completing the protocol for the day. The participant then threw to get loose with a standard 5 ounce ball for 5 minutes. Following the warm-up, the participant completed the protocol as noted in Appendix C. Pre- and post-test measures of maximal throwing velocities, isokinetic strength measures, and range of motion were assessed.

Data Analyses

Descriptive information, including means and standard deviations, were calculated for the data collected for both groups for across the testing sessions. A one-way repeated measures MANOVA was used to determine if there were any differences between the control and training group in the changes in shoulder strength and throwing velocity following the 6-week weighted-ball training program. Univariate post-hoc tests were used to determine any within group measures.

CHAPTER IV

RESULTS

A total of 24 high school baseball players initially volunteered to participate in this study. Participant's ages ranged from 14 years to 18 years. One participant quit the baseball team after initial testing, thus his data were excluded from the study. Another participant missed the preliminary throwing velocity assessment, therefore only his strength data were included. Demographic characteristics of the sample are found in Table 1.

A repeated measures MANOVA was used to determine if there were any differences between the control and training group in the changes in shoulder strength and throwing velocity following the 6-week weighted-ball training program. There was no statistically significant interaction between group and time for throwing velocity and shoulder strength measures (F (5, 16) = 0.771, p = .584). There was a significant effect of time (see Table 2) for both groups for throwing velocity and shoulder strength measures (F = (5, 16) = 26.618, p < .001). Additionally, univariate tests for EIR, CER, and EER showed that both groups significantly decreased in strength from pre-test to post-test (see Tables 3 and 4). There was no significant change in CIR strength in either group (see Tables 3 and 4). Both groups demonstrated significant decreases in throwing velocity during the post-test. Thus, the research hypotheses that there would be a significant difference in throwing velocity and all strength measures between the control and training group were not supported.

Table 1

Demographic Characteristics of the Sample

	Group		
	Control (n = 11)	Treatment (n = 12)	Full sample (N = 23)
Height (cm)	173.1 ± 7.9	177.8 ± 7.8	175.5 ± 8.1
Mass (kg)	72.5 ± 14.6	73.2 ± 11.3	72.9 ± 12.7
Age (years)	15.9 ± 1.1	16.2 ± 1.1	16.1 ± 1.1

Note. Values represent mean ± standard deviation.

Table 2

Means and Standard Deviations for Shoulder Strength (ft/lbs) and Throwing Velocity (mph)

	Control group (n = 11)		Treatment group (n = 12)	
	Pre	Post	Pre	Post
CIR	26.6 ± 17.7	16.7 ± 14.1	27.5 ± 14.8	24.1 ± 11.7
EIR*	11.2 ± 13.2	42.0 ± 6.8	17.9 ± 11.3	48.3 ± 7.9
CER*	42.4 ± 16.1	24.0 ± 18.3	49.6 ± 7.2	26.0 ± 15.7
EER*	21.4 ± 8.7	12.3 ± 14.2	28.8 ± 5.7	15.5 ± 10.1
TV*†	71.3 ± 4.2	68.5 ± 6.7	80.2 ± 4.6	76.8 ± 4.2

Note. * = $p < .05$ denoting significant change from pre to post in both groups. † = participant number for the control group varied, n = 10. CIR = concentric internal rotation, EIR = eccentric internal rotation, CER = concentric external rotation, EER = eccentric external rotation, TV = throwing velocity.

Table 3

Univariate Analyses of Strength (ft/lbs) and Velocity (mph) Pre- and Post-Measures for the Full Sample

	F	$_p^2$	*p*
CIR (*N* = 23)	1.7	.078	.207
EIR (*N* = 23)	94.9	.826	.000
CER (*N* = 23)	32.8	.621	.000
EER (*N* = 23)	19.7	.496	.000
TV (*N* = 22)	22.8	.533	.000

Note. There were no significant between-group differences in the dependent variables. CIR = concentric internal rotation, EIR = eccentric internal rotation, CER = concentric external rotation, EER = eccentric external rotation, TV = throwing velocity.

CHAPTER V

DISCUSSION

This study was conducted to examine the effects of a 6-week weighted ball training program on isokinetic shoulder strength and TV in 23 male, high school baseball players. Following the 6-week study, there were no significant differences between the training and the control group, however TV, CER, and EER decreased, EIR increased, and there was no change in CIR for the full sample. Therefore, the weighted ball training program did not have positive effects on TV or shoulder strength measures.

A major exercise principle behind using weighted ball throwing programs is the overload principal, which notes that the body will adapt to stresses placed upon it. These programs consist of overloading the muscles through increased resistance (over-weighted balls) and increased TV (under-weighted balls). In the current sample, application of these overloads did not result in positive changes in strength or velocity. In contrast, the literature suggests that weighted ball training programs will increase TV in collegiate, professional, and high school senior pitchers. In the current study, decreases in TV were found in the full sample. The finding that the deficits in strength and TV occurred in both groups provides evidence that the training program itself was not the reason for the deficits. One factor that may have contributed to findings is that the extracurricular activities that the participants may have completed outside of structured baseball practice were not monitored or controlled. There is also a possibility that the full team experienced fatigue due to some other component of team practice or strength training.

Both groups continued to participate in all structured team activities including throwing, batting, running, and resistance training.

Overtraining is a concern within youth athletics. High school athletes play a variety of sports throughout the year and the sport seasons overlap. This may not be taken into consideration while coaching a team and this can easily lead to overtraining. Overtraining is defined as a physiological and/or psychological state that may occur in response to insufficient recovery following overload (Rearick, Creasy, & Buriak, 2011). Overtraining is one factor that may have contributed to the decreases in TV, CER, and EER noted in both the training and control groups.

Throughout the training program, the athletes in the training group threw 2 oz, 5 oz, and 7 oz weighted balls into a net with maximal effort with the throwing repetitions increasing each week (see Appendix B). These weights were selected based upon previous research indicating that plyometric weighted ball training should be completed using no more than 20-30% over or under the standard 5 oz baseball (DeRenne et al., 1990; DeRenne et al., 1994). Eccentric holds were also completed in hopes of increasing shoulder strength and subsequently TV. Specifically, the holds were included to target the external rotators, which act to decelerate the arm during the throwing motion. Eccentric training can further increase strength through muscle spindle activation (Bigland-Richie & Wood, 1976). The decreases in CER and EER in this study are concerning as a decrease in these strength measures increases risk of shoulder injury. These outcomes do not support the use of weighted ball and eccentric holds in high school athletes. However, the individual influences of each of these training components cannot be separated since athletes in the training group completed both activities. Because all athletes also completed all regular team training activities and the full sample decreased in these measures, there is also the potential that some component of the base team training could have contributed to fatigue or the decreases in performance.

Although not included in data analysis as a primary study outcome, the ROM of the participants was assessed as supplemental information. The participant’s active and passive IR and ER were measured using a goniometer pre- and post-intervention. Changes in ROM can provide information regarding shoulder strength and injury prevention. Typically overhead athletes have higher ER than IR, due to the over-cocking in the wind-up phase of throwing and the need for strong eccentric contraction of the external rotators during the deceleration phase (Zachazewski, Magee, & Quillen, 1996). With over-weighted ball training, one concern is that heavier ball may lead to attenuation of the internal rotators and increase ER, leading to a decrease in IR. This is a concern as decreased IR has been shown to lead to injuries of the shoulder and elbow. Pitchers are twice as likely to sustain an injury if they have a total ROM deficit greater than 5 degrees compared to their contralateral side (Wilk et al., 2014). Shanley et al. (2012) investigated the changes in glenohumeral internal rotation deficit (GIRD) in professional baseball pitchers (N = 33) and found a significant increase in ER (12 ± 8 degrees) and a significant decrease in IR (-8 ± 11 degrees) over two spring training seasons (Shanley et al., 2012).

Overall ROM decreased in both active and passive IR, which may be an indicator of possible predisposition to injury. External rotation measures remained unchanged in both training and control groups during the study. The decrease in IR over the course of the training program may provide an explanation for the decreases in CER and EER strength measures. Throwing a heavier baseball forces the internal rotators to work harder to propel the ball forward. This fatigues the muscles and can lead to overuse, which decreases overall ability to produce force (Mullaney, McHugh, Donofrio, & Nicholas, 2005). Due to this overuse, the musculature does not have enough time to recover, which causes tightness in the muscles. Implementation of a stretching protocol in combination with weighted ball training programs in future studies may help limit decreases in IR ROM, which may increase strength measures and, in turn, increase TV.

Data from the current study may be unique due to the application of the weighted ball and eccentric hold program primarily to position players. DeRenne et al. (1990) noted a 2-5 mph increase in fastball velocity in high school senior pitchers (*N* = 30) over the course of a 10-week program. Similarly, Litwhiler and Hamm (1973) found an average increase of 11.2 mph over the course of a 12-week program in 5 college-aged pitchers. A large study conducted by DeRenne et al. (1994) examined the effect of the weighted ball training on college (*N* = 180) and high school baseball pitchers (*N* = 45). The training groups for both college and high school pitchers increased fastball velocity by 3-5 mph in a 10-week program. Previous research focused primarily on pitchers, not position players, which must be considered, as demands are different between position players and pitchers. The pitcher's training programs must focus on muscular endurance to avoid fatigue, but also muscular power to create enough force to throw the ball with high velocity. Training for position players training focuses on ability to field the ball quickly and throw it to teammates in order to throw out an opponent. This requires muscular power, however within a short amount of time. Training programs may require specialization depending on the position played on the field.

The current literature includes training programs that were completed over a period of at least 10-12-weeks, which could also help to explain the lack of significance in this study. The duration of the training program may dictate the increases in TV and shoulder strength. In order to elicit changes within the musculature and neuromuscular adaptations, more time may be needed to see results. Thus, the length of the training program must be considered in order to elicit specific strength and TV outcomes. It is possible post-testing occurred prior to positive adaptations during a period when the athletes were still adapting to the overload.

The age range of the samples in existing studies differ from that of the current sample. Many of the studies included college baseball player or senior high school baseball players (Brose & Hanson, 1967; DeRenne et al., 1990; DeRenne et al., 1994; Litwhiler & Hamm, 1973). In this study, all high school baseball players were sampled, including the 14 year-old athletes. The weighted ball training programs may have been too much for the developing bodies of the young athletes. The muscular development and skill level of the young athletes may not be at a point where overtraining will benefit them. Therefore, it is important to recognize the age of the participants and define a range that is appropriate for overload training.

One possible limitation to this study is the learning effect of isokinetic testing. The participants had no prior experience with this machine and even with the familiarization trial and explanations on how to use the machine; participants may have gained confidence and skill during the post testing. Specifically, the gains in EIR may be linked to the familiarization of testing equipment. This movement pattern is unfamiliar and in isolation may have been awkward for the athletes during pre-testing. Future studies should include longer familiarization periods, allowing a few days of practice on the machine before initial baseline testing. Additionally, the participants were expected to give maximal effort during the testing sessions, however this can only be assumed, thus is a study limitation. Another limitation was the duration of the study, as the school calendar limited the ability to extend the training program without running into school breaks. Future research should aim to determine the amount of time that is sufficient for the highest gains in strength and throwing TV. Although TV measures were taken prior to the training program and following the training, taking mid-training program measures may provide insight onto initial gains or decreases in throwing velocity.

There were no significant improvements from the intervention in the training group for shoulder strength and TV. In the full sample, it was noted that EIR increased significantly, CER, EER, and TV decreased and there was no change in CIR strength measures. These results provide insight into the effect of a 6-week training program on high school athletes, which included 14 year-old athletes who may not be physically developed or skilled enough for overload training. Despite the limitations of this study, previous research has shown significant increases in TV with completion of weighted ball training programs. It is important to recognize that each group of participants may need specific training programs based upon the needs of the group. Based on current findings, this training protocol is not recommended for this population. Future research should focus on the deficits that may occur in shoulder motion, specifically decreases in IR and increases in ER that may predispose young athletes to shoulder injury during plyometric, weighted ball training. Furthermore, it must be noted that these athletes are at a high risk of overtraining and precautions must be taken to ensure that the athletes are receiving appropriate rest and load is sufficient for gains not deficits in performance.

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APPENDICES

APPENDIX A

IRB Letter of Approval

11/25/2014

Investigator(s): Carter Pallett, Dr. John Coons
Department: Exercise Science
Investigator(s) Email: ccp3e@mtmail.mtsu.edu

Protocol Title: "**Weighted-Ball Training**"
Protocol Number: 15-118

Dear Investigator(s),

The MTSU Institutional Review Board, or a representative of the IRB, has reviewed the research proposal identified above. The MTSU IRB or its representative has determined that the study poses minimal risk to participants and qualifies for an expedited review under 45 CFR 46.110 and 21 CFR 56.110, and that you have satisfactorily addressed the points brought up during the review. You have approval to collect data at Lavergne High School.

Approval is granted for one (1) year from the date of this letter for 40 participants.
Please note that any unanticipated harms to participants or adverse events must be reported to the Office of Compliance at (615) 494-8918. Any change to the protocol must be submitted to the IRB before implementing this change.

You will need to submit an end-of-project form to the Office of Compliance upon completion of your research located on the IRB website. Complete research means that you have finished collecting and analyzing data. **Should you not finish your research within the one (1) year period, you must submit a Progress Report and request a continuation prior to the expiration date.** Please allow time for review and requested revisions. Failure to submit a Progress Report and request for continuation will automatically result in cancellation of your research study. Therefore, you will not be able to use any data and/or collect any data. Your study expires **11/25/2015**.

According to MTSU Policy, a researcher is defined as anyone who works with data or has contact with participants. Anyone meeting this definition needs to be listed on the protocol and needs to complete the required training. **If you add researchers to an approved project, please forward an updated list of researchers to the Office of Compliance before they begin to work on the project.**

All research materials must be retained by the PI or faculty advisor (if the PI is a student) for at least three (3) years after study completion and then destroyed in a manner that maintains confidentiality and anonymity.

Sincerely,

William Langston
Chair, Institutional Review Board
Middle Tennessee State University

APPENDIX B

High School Strength Program

Monday		**Monday**	
Bench Press	2x8	Flat DB Press	5x5
3G Press	5x2 @ 50%	DB Rows	2x10
Super Rows	2x10	Skull Crushers	2x5
Single Arm Incline DB	2x10	Straight Bar Curls	2x20
Incline Single Arm Pulls	2x10	Incline Single Rev Fly	2x20
AB Twist W/Bar	2x10	Pull Overs	2x10
Reverse Curls	2x10	Side AB Rolls	2x20

Wednesday		**Wednesday**	
Squat	3x10	Front squat	8x4 @ 50%
Regular Deadlift	5x2 @ 80%	Sumo Deadlift	3x8
Lunges	2x10	GH Get Ups	2x10
GH Get Ups	2x10	Split Jumps	2x10
Weighted Box Jumps	2x10	DB Side Lunged	2x10
Calf Extension	2x10	Back Ext	2x10
Back Extensions	2x10	Ab Circuit	3x

Friday		**Friday**	
Power Cleans	5x2 @ 70%	Chair Clean	5x5 @ 50%
DB Upright Rows	2x10	Shoulder Cuff Rolls	2x10
Lateral Raises	2x10	Seated DB Flys	2x5
DB Incline	2x10	Front Raises	2x20
Roll Backs	2x10	Face Pulls	2x20
Side Bends	2x10	Floor Sweepers	2x20
Pull Ups	2x10	Weighted Diamond	2x10

Note: Completed same program throughout 6-weeks alternating each week

APPENDIX C

Training Program

	7 oz	5 oz	2 oz	Throw/Hold Total	Total Each Session
Wk 1	6 throw/6 hold	6 throw/6 hold	6 throw/6 hold	18/18	36 + 10 Fastballs
Wk 2	7 throw/7 hold	7 throw/7 hold	7 throw/7 hold	21/21	42 + 10 Fastballs
Wk 3	8 throw/8 hold	8 throw/8 hold	8 throw/8 hold	24/24	48 + 10 Fastballs
Wk 4	8 throw/8 hold	8 throw/8 hold	8 throw/8 hold	24/24	48 + 10 Fastballs
Wk 5	9 throw/9 hold	9 throw/9 hold	9 throw/9 hold	27/27	54 + 10 Fastballs
Wk 6	10 throw/10 hold	10 throw/10 hold	10 throw/10 hold	30/30	60 + 10 Fastballs

Note: Complete program three times per week, throwing into a net with maximal effort. Throwing holds athlete will not let go of the ball. Finish with 10 fastballs each session with standard ball (5oz) to partner.