THE EFFECTS OF A SPORT-SPECIFIC UPPER BODY RESISTANCE TUBE TRAINING PROGRAM ON OVERHEAD THROWING VELOCITY AND GLENOHUMERAL JOINT RANGE OF MOTION IN NCAA DIVISION II SOFTBALL PLAYERS

By

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Abstract

Sport-specific resistance tube exercises that target the muscles of the glenohumeral joint involved in overhead throwing have been effective in improving overhead throwing velocity and glenohumeral joint range of motion (ROM). However, past research has been solely based on male baseball players, a combination of male baseball players and female softball players, or female athletes of other overhead throwing sports; few studies have conducted research only on female softball players. **Purpose:** The purpose of the study was to investigate the effects of the addition of a sport-specific resistance tube training program to a regular resistance training program on NCAA Division II women softball players' overhead throwing performance, upper body strength, and glenohumeral ROM. **Methods:** Twenty-eight NCAA Division II softball players, with at least five years of experience, volunteered for the study (age: 19.75 $\pm$ 1.53 years; height: 165.42 $\pm$ 5.62 cm; weight: 71.57 $\pm$ 14.00 kg). Participants were randomly divided equally into two groups: an experimental group that performed sport-specific exercises with the resistance tubes, and a control group that performed non-sport-specific exercises with resistance tubes. The training intervention lasted eight weeks, during the softball season; testing days were implemented a week before and a week after the training intervention, making the entire study ten weeks long. Pre- and post-training tests included anthropometric measurements, one repetition maximum (1RM) Chop Test, overhead throwing velocity, and glenohumeral joint ROM. Body composition testing was measured using a seven-site skinfold technique. Overhead throwing velocity was measured using a SR-3300 Speed Radar Gun; peak and average throwing velocity of five throws was recorded. The 1RM Chop Test was measured using a standard 1RM protocol as outlined in Baechle and Earle (2016) and Palmer and Uhl (2011). Glenohumeral joint ROM was measured using a goniometer (model G-300), and was measured in the directions of internal and external rotation of the dominant arm. **Results:** A two-way repeated measures ANOVA revealed that peak and average throwing velocity, and 1RM Chop Test increased significantly ($p < 0.05$) from pre- to post-test regardless of the intervention used. Peak throwing velocity for the experimental group and control group showed an increase of 2.00 mph and 0.92 mph, respectively; average throwing velocity showed an increase of 1.65 mph and 0.91 mph, respectively. The 1RM Chop test showed increases of 6.35 kg and 4.87 kg for the experimental group and control group, respectively. A MANOVA revealed the mean increases for throwing velocity and 1RM Chop Test were not significantly different ($p > 0.05$) between the experimental group and control group. However, anthropometric measurements did show significant differences ($p < 0.05$) between groups, specifically weight, body fat percentage, and fat mass. The experimental group showed average decreases of 0.66 kg, 0.90%, and 0.75 kg in weight, body fat percentage, and fat mass, respectively; the control group showed an increase of 0.87 kg, 0.31%, and 0.30 kg in weight, body fat percentage, and fat mass, respectively. **Conclusion:** A sport-specific resistance tube training program does not improve throwing velocity, upper body strength, or glenohumeral joint ROM significantly more than a non-sport-specific resistance tube training program. Future studies should take into consideration what season the participants are currently in (i.e. off-season, pre-season, or in-season). This may result in different outcomes, and help maintain a schedule and reduce the risk of missed training sessions and the need for make-up days. **Practical Application:** Although no statistically significant difference was observed when comparing the experimental group to the control group in throwing velocity, there 0was significant difference when combined pre- and post-test values were analyzed. The experimental group experienced more of an increase in peak and average throwing velocity than the control group (1.08 mph and 0.74 mph, respectively). The results

showed a small effect size of $d = 0.25$ and $d = 0.21$ for peak and average throwing velocity, respectively. A larger population or longer training intervention may have resulted in a larger effect size, and thus, a statistical significance between groups. Although it is a small difference, an increase at the collegiate level is seen as meaningful when competing; this may convince coaches to include sport-specific resistance tube exercises that target the muscles of the glenohumeral joint in their athletes' regular resistance training program.

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Table of Contents

Abstract.. 2

Acknowledgements... 5

Chapter 1: Introduction.. 11

Statement of the Problem.. 13

Purpose of Study.. 13

Hypotheses... 14

Delimitations.. 14

Limitations.. 15

Assumptions... 16

Definition of Terms.. 17

Chapter 2: Review of Literature... 19

Differences between Male Baseball Players and Female Softball Players........................ 20

Breakdown of an Overhead Throw.. 23

Aspects of the Sport that Could Result In Injury.................................... 25

Glenohumeral Joint Range of Motion.. 26

Overhead Throwing Velocity.. 28

Throwing Performance Predictors.. 29

Adaptations to Resistance Training.. 32

Resistance Training for Women... 34

General Strength Training... 36

Weight Training to Improve Glenohumeral Health................................. 37

Resistance Band/Resistance Tube Training.. 41

Interval Throwing Programs 44

Summary 46

Chapter 3: Procedures 48

The Setting 48

Population 48

Instrumentation 49

Research Design 51

Reliability 57

Validity 59

Treatment of Data/Statistical Analysis 61

Chapter 4: Results 63

Data Analysis 63

Findings 65

Two-Way Repeated Measures ANOVA 67

MANOVA 68

Summary 69

Chapter 5: Discussion 71

Introduction 71

Throwing Velocity 73

Strength as Measured by the Chop Test 74

Glenohumeral Joint ROM 76

Anthropometric Measurements 79

Summary 81

Chapter 6: Summary and Conclusion 83

Summary of Results 83

Practical Applications 86

Recommendations for Future Research 88

Conclusions 91

References 93

Appendix A: Institutional Review Board Consent Form 99

Appendix B: Participant Demographic Questionnaire 111

Appendix C: Data Collection Sheet 112

Appendix D: Warm-Up Protocol 114

Appendix E: 8-Week Experimental Training Program 115

Appendix F: 8-Week Control Training Program 120

Appendix G: Regular In-Season Weight-Lifting Program 125

Appendix H: Exercises for Experimental Group 130

Appendix I: Exercises for Control Group 137

Appendix J: SPSS Output File 144

List of Tables

Table 4.1 Experimental Group Descriptive Statistics.. 64

Table 4.2 Control Group Descriptive Statistics.. 65

Table 4.3 Two-Way Repeated Measures ANOVA Results... 66

Table 4.4 MANOVA Results.. 67

List of Figures

Figure 1. Breakdown of an Overhead Throw........ 23

Figure 2. Additional Step Prior to Throw........ 25

Figure 3. Glenohumeral Joint Internal and External Rotation........ 54

Figure 4. Chop Test........ 56

Chapter 1: Introduction

Softball was first introduced in 1887, when a group of Harvard and Yale football fans gathered to watch the rival football game (Flyger, Button, & Rishiraj, 2006). When Yale was announced the winner, one of the Yale fans playfully threw a boxing glove at one of the Harvard fans, who quickly picked up a broom handle and hit the boxing glove back at the Yale fan (Flyger, Button, & Rishiraj, 2006). The ball used was designed to be much softer than a baseball, allowing male baseball players to practice indoors with no risk of damaging property. Since the ball itself was much different from that of a baseball (softer and much larger), the sport was not called baseball, but instead had names such as "smash ball" or "pumpkin ball"; however, by 1926, the sport was officially named "softball", and in 1934 the Amateur Softball Association (ASA) was formed (Flyger et al., 2006). The sport quickly grew and became very popular for females who wanting to play the baseball-like sport.

The sport of softball is played like that of baseball, where there is a defense and an offense consisting of nine players, and the main purpose is to score more runs than your opponent; however, that is about all that the two sports have in common. The mutual misconception is that softball and baseball are similar sports where one is primarily for males and the other for females; however, the two sports are very different. The most obvious difference is the two different pitching styles: baseball has an overhead pitching style while softball has an underhand pitching style (Axe, Windley, & Snyder-Mackler, 2002). However, other differences exist in the field and equipment; according to a study conducted by Hibberd, Oyama, Tatman, and Myers (2014) the softball is 20 percent larger and heavier than a baseball (Hibberd et al., 2014). The field is also smaller in softball than in baseball; base-to-base is only sixty feet apart in softball compared to ninety feet in baseball. In softball, the distance from home plate to the centerfield fence can be between 185 feet to 230 feet in softball, while baseball can be almost 500 feet (Hibberd et al., 2014). Since field dimensions in softball are much smaller than that of baseball, strain on the throwing arm in an overhead throw may differ in female softball players compared to male baseball players.

Female softball runners have the ability to reach sprinting speeds similar to those of a male baseball runner (McEvoy & Newton, 1998). With softball bases only sixty feet from each other compared to baseball's ninety feet, throwing velocity by defensive players is crucial in determining the victor of the game. This makes the implementation of an overhead throwing program to increase throwing velocity almost more important for female softball players than male baseball players.

In most cases, an increase in joint range of motion can help prevent injury to the joint, leading to an increase in flexibility; however, too much range of motion can also result in injury through joint instability. This increase in flexibility resulting in instability could also negatively affect overhead throwing velocity; if the muscles of the glenohumeral joint are working to stabilize the joint during an overhead throw, then those same muscles are not going to be able to produce enough force during the throw to achieve a desirable throwing velocity (Hibberd et al., 2014). The focus of any overhead throwing training program is to increase muscular strength in the muscles of the throwing arm – primarily the rotator cuff muscles – to increase glenohumeral joint stability and to improve range of motion and force production. Due to the longer distance between bases in baseball, it takes a base runner longer to make it to a base in baseball than in softball; this results in defensive baseball players having the ability to turn double plays more commonly than a defensive softball player does. An increase in glenohumeral strength could increase overhead throwing velocity, resulting in a defensive softball player increasing their chances of throwing a fast runner out at a base or turning a double play.

Statement of the Problem

Current research regarding overhead throwing velocity has been centered mainly around male baseball players, or male and female participants of other overhead throwing sports, such as water polo or team handball (Escamilla, Ionno, DeMahy, Fleisig, Wilk, Yamashiro, & Andrews, 2012; Kuklick, Martino, & Black, 2013; Raeder, Fernandez-Fernandez, & Ferrauti, 2015; Van Den Tillaar & Cabri, 2012; Zinner, Sperlich, Krueger, Focke, Reed, & Mester, 2015). Very little research has been conducted looking solely at the overhead throwing velocity in female softball players, and the research that is present is either vague or incomplete. Maddigan, Behm, and Belfry (2014) found that a resistance band training program implemented to increase muscular strength within the glenohumeral joint had a significant effect on overhead throwing velocity of female softball players compared to the control group; however, the group of selected participants were not participating in any other form of training, and the experimental group was the only group performing any exercises throughout the study. More structured intervention studies are needed to support the claim that resistance tube or band training, or resistance training in general, can increase overhead throwing velocity in female softball players.

Purpose of the Study

The purpose of this study was to study the effects of the addition of a resistance tube training program to a regular resistance training program on NCAA Division II women softball players' overhead throwing performance. Variables that could improve and result in an increase in throwing performance may include peak and average overhead throwing velocity, glenohumeral joint range of motion, and upper-body strength. Participants assigned to the experimental group performed sport-specific exercises designed to target the muscles associated with the overhead throwing motion. Participants assigned to the control group also performed exercises; however, the exercises in the control group training program were not sport-specific and were designed to match the training volume of those in the experimental group.

Hypotheses

Hypothesis 1: The experimental group performing the sport-specific exercises with the resistance tubes would experience an improvement in both peak and average overhead throwing velocity compared to the control group.

Hypothesis 2: The experimental group performing the sport-specific exercises with the resistance tubes would experience a greater increase in strength in the Chop Test compared to the control group.

Hypothesis 3: The experimental group performing the sport-specific exercises with the resistance tubes would experience an improvement in glenohumeral joint range of motion compared to the control group.

Delimitations

This study was delimited to the following:

- Participants were 28 Division II Rocky Mountain Athletic Conference (RMAC) Women's Fastpitch Softball players.
- Participants were limited to the Adams State University softball team.
- Participants for this study were required to have at least five years of competitive softball experience to ensure that the throwing arm and glenohumeral joint had been exposed to enough repetitions of throwing prior to the start of the study, and any

increases in throwing velocity or glenohumeral joint range of motion were due to the training protocol and not an increase in activity.

- Participants could not have had surgery to any part of their throwing arm or shoulder within the last year prior to the start of the study.
- Overhead throwing velocity was measured using a SR-3600 Radar Gun in the Athletic Field House in Plachy Hall on the Adams State University campus.
- Glenohumeral joint range of motion was measured using a goniometer in the Adams State University Athletic Training Room.
- The training program lasted a duration of eight weeks and was progressively increased based on recommendations from the certified strength and conditioning coach (Maddigan, Behm, & Belfry, 2014; Prokopy, Ingersoll, Nordenschild, Katch, Gaesser, & Weltman, 2008).
- The study was limited to women's fastpitch softball and excluded men's baseball.
- Pitchers and inexperienced players were excluded from the study.
- Each participant used a Worth 12" softball, Model NC12L.

Limitations

This study may have been limited due to the following:

- Results obtained through this study were limited to the selected group of athletes.
- It was asked of the participants to refrain from the use of supplementation that may result in muscular gains and skew the results of the study; however, there was no way to monitor the participants throughout the eight-week long study.

- Diet and sleep were not monitored by the researcher; however, participants were asked to maintain a regular diet (i.e. eat three meals a day), and get at least eight hours of sleep a night for the duration of the study.
- Participants were asked to give their best, and all-out effort; however, there was no way to measure each participant's given effort. Encouragement to give maximum effort during testing and training were given by the researcher.

Assumptions

It was assumed that:

- Any gains seen in overhead throwing velocity were due to the experimental resistance tube training program and not from an increase in exercise volume.
- Any improvements in glenohumeral joint range of motion were due to the experimental resistance tube training program and not from an increase in exercise volume.
- Any gains in strength were due to the experimental resistance tube training program and not from an increase in exercise volume.
- No gains would be seen in the control group compared to the experimental group.
- Participants would give their best, and maximal effort throughout the eight-week study.
- The goniometer (Model 12-1000) was a valid measure of glenohumeral joint range of motion.
- The SR-3300 Radar Gun was a valid measure of overhead throwing velocity.
- The SR-3300 Radar gun was sensitive enough to measure changes in pre- and post-testing of overhead throwing velocity.

Definition of Terms

Anthropometric Measurements – the measurements of height, weight, and body composition.

Average Throwing Velocity – the average of all five overhead throws with a step during pre- and post-testing.

Chop Test – A test to determine upper-body muscular strength in which the individual "chops down" by pulling down with the top hand and back with the bottom hand against a set resistance while grasping a bar attached to a cable; the motion is a downward diagonal movement across the torso. The cable was attached to one end of the bar and that end is designated as the top of the bar.

Glenohumeral Joint – where the head of the humerus bone meets the glenoid cavity of the scapula.

Goniometer – an instrument for the precise measurement of angles.

Peak Throwing Velocity – the highest throw velocity of the five pre- and post-test throws.

Range of Motion (ROM) – the measurement of movement around a specific joint or body part. For this study, external and internal rotation measurements of the glenohumeral joint were measured using a goniometer.

Resistance Tubes – an elastic tube used for strength training. Can be found in a variety of different colors, signifying different resistance; yellow is the equivalent of six to eight pounds of resistance, green is equivalent to nine to eleven pounds of resistance, and red is equivalent to twelve to fourteen pounds of resistance.

Throwing Velocity – the speed, in miles per hour (mph), at which the ball is traveling once released, measured using a hand-held radar gun.

Chapter 2: Literature Review

Success in the sports of softball and baseball rely heavily on speed and time. Milliseconds could be the difference of a fielder throwing an opposing player out at a base or the opposing player being called safe. The average male baseball player can reach sprinting speeds up to 6.22 meters per second or more (McEvoy & Newton, 1998). Based on this average sprint speed of baseball players, a fielder who is trying to throw an opposing player out at first has less than five seconds from the point of the ball being hit to field the ball and accurately throw it to first base before the hitter sprints the 90 feet to the base. In softball, the dimensions of the field are much smaller than that of baseball; 60 feet is all that separates the runner from the next available base (Hibberd et al., 2014). Female softball players also have the capability to reach similar sprinting speeds as those of baseball players, indicating that a fielder in softball may have only approximately three seconds to field the ball and throw the runner out at first base (McEvoy & Newton, 1998). This limited amount of time to make a throw to first base to throw a runner out makes it crucial for a softball defensive player to not only have a strong throwing arm, but also a strong and stable glenohumeral joint.

In throwing, the glenohumeral joint is the primary joint used and its structure includes the rotator cuff muscles, which are responsible for the rotation of the joint itself (Edouard, Bankole, Calmels, Beguin, & Degache, 2013). After years of consistently throwing overhead at high velocities, it is not uncommon for an overhead throwing athlete to suffer injury or instability at the glenohumeral joint, which can result in a decrease in throwing velocity (Hibberd et al., 2014). This makes it important for overhead throwing athletes to take preventative measures to improve the strength of the rotator cuff muscles in order to resist fatigue during competition, which increases the risk of injury.

After an injury to the glenohumeral joint occurs, it is common for the athlete to begin a rehabilitation program to strengthen the joint to return to competition as quickly as possible. After completion of a therapy program, athletes can see improvement in range of motion, muscular strength, and functional activity in the glenohumeral joint (Duzgun, Baltaci, & Ahmet-Atay, 2013). These programs have also been shown to improve the throwing velocity in overhead throwing athletes (Maddigan et al., 2014). If these programs can be implemented in a healthy population of overhead throwing athletes, it could result in fewer injuries to the 0glenohumeral joint and increased throwing performance. However, these programs should be designed and modified to meet the needs of the various types of overhead throwing sports; this includes the differences between male and female athletes.

Differences between Male Baseball Players and Female Softball Players

As well as different field and equipment dimensions, there are other differences between male baseball players and female softball players. Past studies have found that female softball players have a lesser degree of ROM in the glenohumeral joint compared to male baseball players (Hibberd et al., 2014). The researchers discussed that the reasoning for this could be due to both the smaller infield and outfield in softball; a typical softball field is about 200 feet fom home plate to the centerfield fence while a typical baseball field is about 400 feet (Flyger et al., 2006; Hibberd et al., 2014). The shorter distance of a softball field means the players place less of a strain on the glenohumeral joint due to the shorter throws compared to the longer throws often required in baseball. The researchers also mentioned that many male baseball players have experience in pitching, which is also an overhead throw. Unlike in softball, a pitch count in baseball is implemented to protect a pitcher from over-using their arm during a game; some professional baseball players are reported throwing over 100 pitches a game (Hibberd et al., 2014). This pitch count also requires a pitcher to have at least a full day of rest before pitching in another game, which can limit a team's pitching staff. During a long season, it is common for baseball teams to go through its entire pitching staff because of this rule, thus relying on other members of the team whose primary position is not pitching to pitch (Hibberd et al., 2014). This has resulted in many male baseball players who do not claim their primary position as pitching to still report experience in pitching (Hibberd et al., 2014). In softball, pitching is performed using an underhand throwing motion, which requires the muscles of the glenohumeral joint to be used differently than that of an overhead throwing motion; for this reason, very few softball players report having experience in pitching. Overhead pitching – which uses the same motion as an overhead throw – causes a large strain on the shoulder compared to a softball underhand pitch; this is due to the repetitive motion throughout a game (Hibberd et al., 2014). This repetitive strain on the glenohumeral joint could result in a larger ROM in male baseball players exposed to pitching; this is because the strain causes a stretch within the muscles surrounding the glenohumeral joint (Hibberd et al., 2014). The further the muscle is stretched, the higher the risk of the muscle losing its elasticity and becoming stretched out; this causes the muscles of the joint lose their ability to stabilize the joint, resulting in the joint having a greater ROM (Hibberd et al., 2014; Powers & Howely, 2012).

Actual throwing velocity also differs from baseball to softball; males tend to have higher throwing velocities than females (Van Den Tillaar & Cabri, 2012). Males, on average, are taller than their female counterparts; this means that their limbs are also much longer than female limbs (Van Den Tillaar & Cabri, 2012). This increases the moment arm in throwing, allowing for an increase in velocity when compared to a shorter moment arm (Van Den Tillaar & Cabri, 2012). Males also typically have a larger muscle mass than females; this is due to a higher level of testosterone production in males compared to females (Powers & Howely, 2012; Van Den Tillaar & Cabri, 2012). This increase in muscle mass results in males producing much higher strength and power outputs than females during muscle contraction (Powers & Howely, 2012).

Body composition is another difference between all males and females, not just baseball players and softball players. Females tend to have higher percentage of body fat than their male counterparts (Powers & Howely, 2012). Females produce the hormone estrogen at much higher levels than males do; this hormone is partly responsible for the female body storing larger amounts of adipose tissue than males (Powers & Howely, 2012). This hormone has also been linked to the joints in females having more "laxity", meaning that females generally have a greater degree in range of motion compared to males (Wild, Steele, & Munro, 2012). Males also produce testosterone in greater volume than females – as mentioned above – and this can help in fat loss (Powers & Howely, 2012). This reduction in relative fat mass might be due to an increase in lean body mass (muscle); larger muscles require more energy to sustain, so an increase in muscle mass could result in the utilization energy stores (Powers & Howely, 2012). If energy stores, specifically glycogen, are low then the body will break down relatively more fat in order to maintain the energy demands of the body (Powers & Howely, 2012). However, the main reason for females storing more fat than males is due to the need of more fat for reproduction; fat is a high energy source (9 calories for every gram of fat) and more energy is need during the development of a fetus in the womb (Powers & Howely, 2012). A male has the ability to reduce their fat mass to as low as three percent of their body weight – this is known as essential fat and is the fat your body needs to function properly; however, females' essential fat level is ten to twelve percent of their body weight (Powers & Howely, 2012). If a female has a fat mass percentage any lower than eight percent, additional health problems could occur and hormone production and reproductive functions could be negatively affected (Powers & Howely, 2012).

Breakdown of an Overhead Throw

With the exception of a softball pitcher, overhead throwing is the primary throwing motion in softball and baseball. It is important to understand and know the mechanics of an overhead throw to help prevent injury and increase throwing performance. Kibler, Wilkes, and Sciascia (2013) published an article that broke down the overhead throw. They break the overhead throw down into five steps: stance, arm back, step, elbow lead with torso rotation, and follow through (Kibler et al., 2013). Figure 1 shows these five steps of an overhead throw.

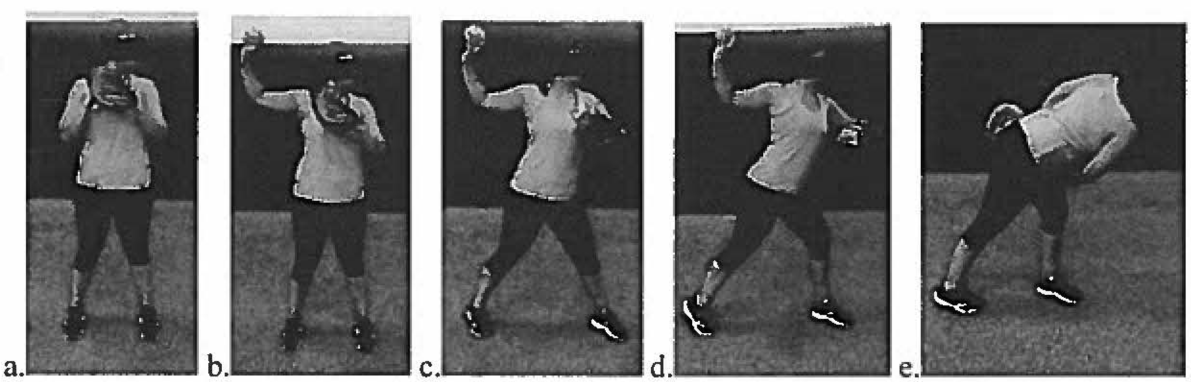
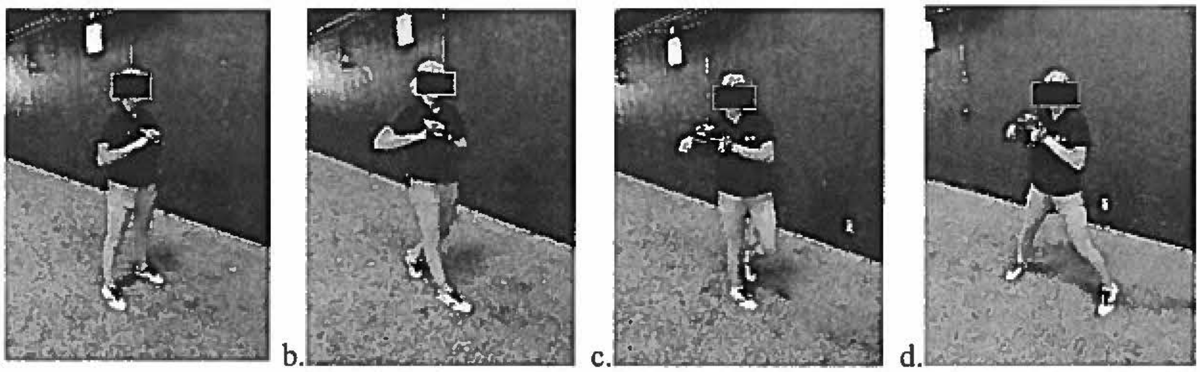


Figure 1. Breakdown of an overhead throw
Slides a-e represent the stages of an overhead throw

When the individual is preparing to throw, they should stand perpendicular to their desired target with their head facing towards their target – Figure 1a (Kibler et al., 2013). Standing perpendicular to the target will cause the individual to twist towards the target, generating more force to increase throwing velocity and getting the ball to their target quickly (Kibler et al., 2013). The next step is for the individual to bring their arm back – Figure 1b; their upper arm should be parallel to the ground and lateral to the shoulder (should not be out in front of the body), and the elbow should be bent to ninety degrees and be facing upwards (Kibler et al., 2013). This position decreases some of the force and torque that is applied to the shoulder; if the elbow drops below the shoulder, torque is increased and injury could occur (Kibler et al., 2013). At this point, the individual should step towards their target with their front foot – Figure 1c; this will break the individual's inertia and aid in a more forceful throw (Kibler et al., 2013).

The next step is what begins the actual throwing motion; the individual rotates their torso towards their non-throwing side and begins the throwing motion by leading with their elbow – Figure 1d (Kibler et al., 2013). If the elbow does not lead and the individual just simply rotates their torso, it will cause the ball to be thrown to the side and not towards the desired target (Kibler et al., 2013). The final step is the follow through – Figure 1e; in this step, the individual will continue the throwing motion until their arm is out in front of them (Kibler et al., 2013). When done correctly, the follow through should cause the individual to bend at the waist and their arm should cross the body completely and end at the opposite hip (Kibler et al., 2013). The authors stated that one of the most common errors that overhead athletes make while throwing is throwing the ball side-arm; instead of the thrower keeping their hand above their shoulder, they drop it below their shoulder and throw the ball from the side (Kibler et al., 2013). If immediate harm does not occur and the individual continues to throw side-arm, it could result in chronic injuries such as tendonitis, arthritis, or more serious injuries like tears to the muscles and/or ligaments (Kibler et al., 2013). Teaching and practicing proper throwing techniques may help reduce the chances of injury in later years of competition.

An overhead throw can be performed without stepping, but if the individual wishes to get the ball to their target quickly, stepping will support their throw; this is how an overhead throw is performed in softball (Kibler et al., 2013). Figure 2 shows the additional step prior to the first step that begins the throw, which was included in the complete throwing motion in this study.



a. b. c. d.

Figure 2. Additional Step Prior to Throw
Slides a-d represent the additional step that many softball and baseball players take before beginning their throw. The individual is a right-handed thrower; she steps first with her right foot for her additional step before the step that begins the throw.

Aspects of the Sport that Could Result In Injury

Injuries to the glenohumeral joint and other parts of the arm account for 45 percent of all time lost from baseball and 33 percent of all time lost in softball (Hibberd et al., 2014). Injuries that can occur during overhead throwing sports include, but are not limited to, dislocation of the glenohumeral joint, rotator cuff strain, rotator cuff tear, tendonitis, bursitis, and chronic pain (Hibberd et al., 2014; Sauers, Dykstra, Bay, Bliven, & Snyder, 2011; Shanley & Thigpen, 2013). Many injuries are caused by external trauma to the arm and glenohumeral joint; however, the most common reason for injury in overhead throwing athletes is overuse combined with improper mechanics (Plummer & Oliver, 2013). Petranek and Barton (2011) investigated throwing patterns in amateur female softball players. The researchers recruited thirty-eight female softball players, age 13.74 $\pm$ 0.64 years, from current Amateur Softball Association (ASA) fourteen years of age and under teams (Petranek & Barton, 2011). They then compared throwing mechanics of the softball players to past studies that analyzed the throwing mechanics of children of the same age in physical education classes (Petranek & Barton, 2011). By comparing the more advanced throwing mechanics of the softball players to the mechanics of the other children, and using a numbering system for scoring, it was found that proper form is dependent on several steps of the throw including humerus height, torso rotation, forearm lag, and follow-through (Petranek & Barton, 2011). The researchers found that failure to perform any of these steps correctly resulted in a lower score; however, failure to perform these steps correctly can also result in unnecessary stresses being placed on the arm causing injury (Petranek & Barton, 2011).

Glenohumeral Joint Range of Motion

Range of motion (ROM) is another issue that can cause injury to the glenohumeral joint. A common belief many individuals have is that increased ROM is a positive characteristic to have in sports. Gamma and colleagues (2014) stated that a baseball player should a higher degree of ROM than the general population, and even explored the effects of different warm-up exercises on glenohumeral joint ROM in male baseball pitchers. Ten baseball pitchers from surrounding baseball teams were selected to participate in the study; they were then divided into two groups – a total motion release warm-up group or a traditional warm-up group (Gamma, Baker, Iorio, Nasypany, & Seegmiller, 2014). The results of the study indicated there was no significant difference in glenohumeral joint ROM between the groups or within subjects from pre- to post-testing (Gamma et al., 2014).

Although a slightly higher ROM in the glenohumeral joint is beneficial, too much range of motion can also have a negative effect (Hibberd et al., 2014). A joint that exhibits a large range of motion may be at risk for injury due to joint instability (Hibberd et al., 2014). If the muscles in the joint are not strengthened then the joint becomes weak and more effort is needed to achieve maximal force production (Hibberd et al., 2014). By strengthening the muscles of the glenohumeral joint, less effort is needed to produce maximal throw velocity, and glenohumeral joint ROM is improved resulting in stability increasing; this decreases the chance of injury (Hibberd et al., 2014).

An increase in ROM in the glenohumeral joint can be a result of a repetitive high torque and force strain on the joint itself (Gamma et al., 2014; Hibberd et al., 2014). If the muscles of the joint are not strengthened, the muscles of the joint will not get stronger in an attempt to counter this constant stretching of the joint; this may result in an extreme ROM in the glenohumeral joint that causes the joint to become unstable (Hibberd et al., 2014). This stretch can also cause a decrease in force production in the glenohumeral joint; if a muscle is stretched too far, it could lose its elasticity and is not be able to "snap" back to a neutral position to produce high levels of force (Powers & Howely, 2012). To obtain the same levels of force produced by a muscle not stretched beyond its capabilities, the individual would have to stretch the muscle even further; in this case, the throwing arm would have to be rotated externally even further, putting an even bigger strain on the joint and increasing the risk of injury (Hibberd et al, 2014; Powers & Howely, 2012). This makes a strength program essential to maintaining healthy, elastic muscles surrounding the glenohumeral joint. Assessment of an individual's throwing performance by the individual's coach or athletic trainer may help determine the individual's risk of injury to their throwing arm. Hibberd and colleagues (2014) measured the internal-rotation and external-rotation of the glenohumeral joint of the dominant throwing arm in both male baseball and female softball players. It was determined that these two rotations are the most prominent rotations found in an overhead throw, and thus the most significant in determining the joint's ROM (Hibberd et al., 2014). A program can then be created to prevent further or future injuries to the individual's throwing arm, while also improving the individual's overall performance in overhead throwing.

Overhead Throwing Velocity

Throwing velocity is an important aspect of fielding in softball and other throwing sports; if a fielder can improve their throwing velocity, they are more likely to throw faster runners out at each base. In softball – with the exception of the pitcher – the primary form of throwing is overhead, which is the process of throwing an object by rotating the throwing arm above the head. Freeston and colleagues (2016) found that there was a direct relationship between muscular strength and power and overhead throwing velocity. In their study, seventeen male cricket players participated in a study to assess muscular strength and power and throw velocity. The researchers revealed a correlation between throwing performance and strength exercises that utilized the same muscles used in throwing (Freeston, Carter, Whitaker, Nicholls, & Rooney, 2016). Participants who recorded lower throwing velocities also recorded lower strength and power output while performing exercises such as medicine ball chest pass and shoulder internal-rotation, while those who had higher throwing velocities also had higher strength and power outputs in the same exercises (Freeston et al., 2016). To improve overhead throwing velocity, an individual must strengthen the muscles associated with the overhead throw (i.e. rotator cuff muscles in the glenohumeral joint) (Freeston et al., 2016). However, testing an individual's throwing performance level should be the first thing assessed before designing a strength program to improve muscular strength and power of the muscles utilized in overhead throwing.

Throwing Performance Predictors

Tests that can effectively predict an athlete's performance in a specific movement become very important in all areas of sports. These tests are able to give coaches and trainers an insight into how well an athlete is prepared for the sport and what the athlete needs to work on to improve. Muscular strength testing is one of the best ways to predict how well an athlete may perform a specific movement by using weight-bearing lifts that reflect a movement the athlete may perform during competition (Negrete, Hanney, Kolber, Davies, & Riemann, 2011). Negrete and colleagues (2011) tested different weight-bearing lifts to determine which would be the best predictor of a softball throw for distance. One hundred eighty subjects (one hundred eleven females and sixty nine males, age eighteen to forty-five years) participated in the study, where each participant performed four different exercises in random order to predict throwing performance in the Underkoffer softball throw for distance (Negrete et al., 2011). The first exercise was a single arm seated shot put with a 2.72 kg medicine ball; the participant would press upwards with the medicine ball but would not throw it (Negrete et al., 2011). The second exercise was a timed push-up test, where the participant would complete as many push-ups (standard push-up for men and modified for women) in fifteen seconds; this was repeated three times with forty-five second rest between trials (Negrete et al., 2011) The third exercise was the modified pull-up test; the participants had to pull themselves up as many times as possible in fifteen seconds from a supine position with their legs elevated on a bench (Negrete et al., 2011). The fourth exercise was the Davies closed kinetic chain upper extremity stability test; this test required the participants to remain in a starting push-up position and touch two pieces of tape separated by three feet, alternating hands as they touch (Negrete et al., 2011). The final exercise was the actual Underkoffer softball throw for distance, and all the participant had to do was throw a standard league softball as far as possible with their dominant arm; this exercise was what the researchers used to compare to the other exercises (Negrete et al., 2011). The researchers found that the modified pull-up test predicted performance the best within their participants (Negrete et al., 2011). This could be because the modified pull-up test requires the participant to pull themselves upward using the muscles of the glenohumeral joint, meaning that the test is measuring the same muscles used in throwing (Negrete et al., 2011). This demonstrates the importance of using sport-specific exercises – those which mimic the same motion of a specific skill or utilizes the same muscles – to improve strength within the specific movement or skill and to predict the individual's performance in completing the movement or skill.

Glenohumeral joint ROM could also predict the performance of overhead throwing in overhead throwing athletes. Although having an increase in ROM is considered a good thing, too much ROM in a joint could also be detrimental to the performance of that joint (Hibberd et al., 2014). Overhead throwing athletes tend to have more ROM in the glenohumeral joint due to conditioning their arms to the constant overhead throwing motion; however, an excessive ROM indicates that the muscle fibers of the joint have been stretched beyond their elasticity and can no longer return to a neutral, relaxed length (Powers & Howely, 2012). Normal ROM in both the internal and external-rotation of the glenohumeral joint is zero to ninety degrees; anything beyond that is considered hyper-flexibility of the glenohumeral joint (Hibberd et al., 2014). The more the muscle is stretched, the more energy the muscles must exert to obtain the same overhead throwing velocity as before they were stretched; this means that if the glenohumeral joint ROM is excessive, the individual's throwing performance may suffer (Powers & Howely, 2012). If an individual with excessive ROM has to constantly apply more force and energy to produce the same throwing velocity as an individual who does not have excessive ROM, then energy efficiency is not occurring and the individual will become tired much more quickly (Hibberd et al., 2014; Powers & Howely, 2012).

An overhead throw is an explosive, functional task that involves active trunk control as well as rotation of the glenohumeral joint (Palmer & Uhl, 2011; Palmer et al., 2015). The Chop Test has been shown to have a correlation between muscular strength and explosive movements, such as the overhead throw, which require trunk control and glenohumeral joint rotation (Palmer & Uhl, 2011; Palmer et al., 2015). Palmer and Uhl (2011) recruited eighteen healthy volunteers from the general population (ten men and eight women) to participate in a study that analyzed the reliability and validity of the Chop Test to measure upper body muscular strength. The participants completed one day a week of 1RM testing using the Chop Test, for four weeks (four total testing days), and results showed a correlation coefficient of 0.98 from day one of testing to day four of testing (Palmer & Uhl, 2011). Muscular power produced by the Chop Test was compared to past anaerobic power tests; it was found that the peak and average muscular power from the Chop Test was comparable (correlation coefficient of 0.70, $p = 0.05$) to the peak and average muscular power of the other anaerobic power tests (Palmer & Uhl, 2011). It was concluded that the Chop Test provided repeatable measures of power output from week to week and is both a reliable and valid test of upper body muscular strength (Palmer & Uhl, 2011).

Palmer went on to complete further studies utilizing the Chop Test; in a study conducted by Palmer and colleagues (2015), forty-six Division III baseball and softball players (age: 20 $\pm$ 1.3 years) participated in a seven-week long training study. It was discovered that throwing velocity within these participants increased simultaneously with the strength gains observed in the Chop Test (Palmer et al., 2015). The test mimics the motion of an overhead throw, which could make it an accurate test in determining overhead throwing performance. Familiarization of these sport-specific, resistance exercises can greatly increase the muscular strength of specific movements found in sports that can greatly improve an individual's performance level. As well as increases in muscular strength, other adaptations occur because of resistance training.

Adaptation to Resistance Training

Baechle and Earle (2016) stated that skeletal muscle adapts to anaerobic training by increasing its size, facilitating fiber type transitions, and enhancing its biochemical and ultra-structural components such as architecture, enzyme activity, and substrate concentrations (Baechle & Earle, 2016). Stefan, Sporis, and Samija (2015) categorize the physiological changes to resistance training as differences in muscle fibers, muscle power/strength, repetition maximum (RM) and training loads, neural adaptations, cardiovascular responses and adaptations, body composition, and adaptation of hormonal systems. Neural adaptations will first be experienced by the individual, but it would not be visible to the individual; motor neurons will fire much more efficiently and with other motor neurons to aid in the muscular strength (Stefan et al., 2015). As the neural adaptations occur, the individual will experience an increase in muscular strength, but a noticeable change in appearance will not yet be seen (Stefan et al., 2015).

An increase in muscle volume will occur as training continues, and is due to hypertrophy of individual muscle fibers; it is shown that it takes a minimum of four weeks for untrained individuals to experience hypertrophy of the muscles (Stefan et al., 2015). Muscle hypertrophy refers to the increase in size of individual muscle fibers, type II fibers in particular (Powers & Howely, 2012; Stefan et al., 2015). Males will experience a greater amount of muscle hypertrophy than females due to a hormonal increase in testosterone – a hormone that aids in the development of muscles during resistance training (Powers & Howely, 2012). Since testosterone is produced primarily in the male reproductive organs, they produce a much greater amount than females (Powers & Howely, 2012). However, females can still increase muscular strength to the same relative extent as males following the same training program; this is due to more enhanced neurological function within muscle fibers (Baechle & Earle, 2016; Powers & Howely, 2012). Muscle strength and power is improved when the muscles are stressed beyond what is considered comfortable for the individual; amount of weight being lifted or repetitions may need to be increased so muscles are experiencing maximal muscular work (Stefan et al., 2015). As training progresses and maximal muscular work is achieved, one repetition maximum will also increase – this is the maximum amount of weight an individual is able to lift in one repetition (Stefan et al., 2015).

With resistance training, individuals will also experience hypertrophy of the heart wall thickness; this allows the heart to be able to pump blood throughout the body more efficiently with fewer beats per minute due to an increase in contractile strength of the heart (Stefan et al., 2015). This allows the body to be able to withstand greater amounts of physical stresses in general (Stefan et al., 2015). Those who utilize the overhead throw consistently in their sport will have an increase in blood flow to their working muscles of the throwing arm, fueling the muscles with the necessary nutrients needed to maintain forceful contractions to produce high throwing velocities (Bacelar et al., 2015; Baechle & Earle, 2016; Stefan et al., 2015)

Another positive adaptation to resistance training in all individuals is the change in body composition; increasing muscle mass will cause the body to burn more calories throughout the day, resulting in a possible reduction in fat mass (Stefan et al., 2015). More muscular individuals tend to burn calories at a much higher rate than those with less muscle mass because it takes higher levels of energy to maintain muscle mass (Stefan et al., 2015). Hormonal adaptations are also present during resistance training; the body will experience an increase in human growth hormone and testosterone to aid in the development of the muscles (Stefan et al., 2015). Males will experience a higher level of these hormones since testosterone is produced primarily in the male reproductive organs; however, both hormones will still be released into circulation in females as a result of resistance training, but in lower doses (Powers & Howely, 2012). This higher level of testosterone found in males results in a greater occurrence of muscle hypertrophy among males, which results in a greater increase in strength gains in males as well (Powers & Howely, 2012).

Resistance Training for Women

Despite physiological differences, men and women both respond to resistance training in a similar way when compared to their pre-training baselines (Powers & Howely, 2012). Although women may not see an enormous change is muscle size like a man might see, they still receive positive benefits from the training such as improved strength, resistance to injury, reduced rate of bone loss, stabilization of joints, and increased blood flow (Baechle & Earle, 2016). A study conducted by Bacelar and colleagues (2015) looked at the effects of a resistance training program on strength and bone density in elderly women. Eighteen sedentary elderly women (mean age of 64 $\pm$ 3 years) volunteered to participant a study that examined the effects of a resistance training program on muscular strength and bone density (Bacelar et al., 2015). The study lasted for ten weeks and participants met with researchers twice a week for weight-bearing exercise sessions, for a total of twenty sessions; the exercises involved weight-bearing exercises that put a strain on the bones of the limbs being utilized (i.e. leg press, lunges, chair squats, etc.) (Bacelar et al., 2015). Results did not show a significant change in bone density in participants; however, a significant increase in muscular strength was demonstrated by all participants

(Bacelar et al., 2015). This increase in muscular strength may aid in the participant's ability to resist injury; by increasing their strength, they may have increased their ability to stabilize themselves while walking or doing other activities, and reduce their risk of an injury-inducing fall. Falls themselves are due to low muscular strength and poor balance (caused by muscle weakness); however, most injuries that occur from a fall are usually a result of low bone density (Bacelar et al., 2015; Powers & Howely, 2012). Bone loss due to age is much more prominent in women than in men, making women more susceptible to osteopenia and osteoporosis (Bacelar et al., 2015; Powers & Howely, 2012). Including a resistance training program earlier in life can help individuals increase their muscular strength and balance, while increasing their bone density before bone loss occurs and decelerating the rate at which the individual loses bone density (Powers & Howely, 2012).

Schoenell and colleagues (2016) investigated the effects of a resistance training program on muscular strength and endurance in 66 sedentary, young females (age, 24.7 $\pm$ 4.3 years old). They were divided equally into two groups: group one performed a single set of 30 seconds per exercise, and group two performed multiple sets (three sets) of 30 seconds for each exercise; exercises included squats, jump squats, push-ups, pull-ups, and other weighted exercises (Schoenell et al., 2016). Muscular strength and endurance was assessed before and after the ten-week training program (Schoenell et al., 2016). No difference was found between protocols; participants in both groups improved both muscular strength and endurance significantly compared to pre-test values, indicating that neuromuscular adaptations in sedentary, young females can occur after ten weeks of training regardless of training volume (Schoenell et al., 2016).

Mansell and colleagues (2005) observed the effects of a resistance training protocol on male and female collegiate soccer players. Seventeen males and nineteen females volunteered to participate in the study, an eight-week resistance training program focused on head-neck segment dynamic stabilization (Mansell, Tierney, Sitler, Swanik, & Stearne, 2005). The exercises consisted of three sets of ten repetitions of neck flexion and extension with resistance, performed twice a week (Mansell et al., 2005). Results showed no significant increase in neck stabilization; however, pre- and post-test measurements showed that both male and females increased neck muscular strength and activity (Mansell et al., 2005). This indicates that both males and females respond similarly to the same training protocol (Baechle & Earle, 2016; Mansell et al., 2005; Powers & Howely, 2012).

General Strength Training

Resistance training is an important form of training if an individual, male or female, wishes to increase their muscular strength and/or endurance. However, it is important for an individual to understand periodization with resistance training – this is the idea that training should progress in a way that the individual (or team) reaches their peak performance level during competition (Baechle & Earle, 2016). During periodization, individuals should train and exercise their hardest and focus on general strength gains during their off-season; this is a time when they do not have to be worried about being too sore or tired from training to perform well during competition (Baechle & Earle, 2016). There is then a transition from general strength gains to specialized strength – exercises that focus on strength gains that pertain to their sport or event; this is done during their pre-season (Baechle & Earle, 2016). Once the individual is in their competitive season, their focus for strength training is maintaining strength gains; their focus should be on competition and not on increasing their strength (Baechle & Earle, 2016).

Theoretically, if done correctly the individual will experience peak performance during their competitive season; however, it is possible for an individual to become overtrained if they do not follow this model (Baechle & Earle, 2016; Powers & Howely, 2012). Overtraining is a result of inadequate rest and/or nutrition during training, and usually occurs when an athlete tries to do too much at one time (Baechle & Earle, 2016; Powers & Howely, 2012). An athlete or coach may believe that they have to do more during the competitive season than just maintaining their strength, so they make their workouts harder than they should. Since focus is now on both strength gains and competition, performance during competition suffers and peak performance is not reached due to the athlete being sore and/or tired (Baechle & Earle, 2016; Powers & Howely, 2012). Understanding how periodization works and how it can help an individual reach their peak performance will aid in developing a strength program that suits the needs for a team or individual athlete.

The training protocols for the current study began during the softball team's competitive season. Both training protocols contained low intensity exercises and low volume to prevent fatigue during the competitive season. The focus was on targeting the muscles of the upper body and glenohumeral joint to improve joint ROM, joint stability, and throwing velocity.

Weight Training to Improve Glenohumeral Joint Health

Most training programs to improve glenohumeral health (joint ROM, joint stability, and throwing velocity) are like those found in many rehabilitation programs. Many of the programs involved weight exercises performed with dumbbells, machines, cables, and other weighted equipment; and targeted specific muscles of the upper-body such as the biceps, triceps, deltoids, trapezius, etc. (Escamilla et al., 2012; Kuklick et al., 2013; Prokopy et al., 2008; Raeder et al., 2015; Van Den Tillaar & Marqes, 2011). Each of the studies had their participants complete a training program lasting six to twelve weeks, consisting of several different lifts that specifically targeted the muscles of the glenohumeral joint, and then researchers tested whether the program improved the performance of overhead throwing velocity (Escamilla et al., 2012; Kuklick et al., 2013; Prokopy et al., 2008; Raeder et al., 2015).

Kuklick and colleagues (2013), eighteen Division II baseball players volunteered to participate in a four-week long training intervention. The participants were divided into two groups: a battle rope training (BRT) group where battle ropes were used for upper body training exercises, and a running program (RP) group where participants ran for their training (Kuklick et al., 2013). The purpose of the study was to determine which training intervention would increase peak throwing velocity of the throwing arm and improve throwing stamina (Kuklick et al., 2013). Pre- and post-testing showed that the BRT group had a significantly greater increase in their peak throwing velocity from pre- to post-tests compared to the RP group (Kuklick et al, 2013). Researchers also found that the BRT group improved their throwing stamina compared to the RP group; stamina was measured by how many baseballs they could throw accurately to a designated target in three minutes (Kuklick et al., 2013). This means that the BRT program improved the stamina in the throwing arms of the participants, which improves the length of time the individual can throw with maximum effort before fatiguing (Kuklick et al., 2013).

Prokopy and colleagues (2008) studied fourteen female NCAA Division I softball players (mean age of 20.6 years) who participated in a weight training program three times a week for twelve weeks during their off-season strength and conditioning program in the fall. Participants were divided into two groups, an experimental group and a control group (Prokopy et al., 2008). Exercises included body weight exercises, Olympic style lifts, and exercises involving weights such as dumbbells, barbells, kettle bells, etc., and focused on targeting the muscles of the upper body (Prokopy et al., 2008). The program was designed with the intent to increase the softball players' throwing velocity. Researchers found that the experimental group had a two mile per hour (mph) increase in throwing velocity compared to the 0.3 mph increase observed in the control group (Prokopy et al., 2008).

Raeder, Fernandez, and Ferrauti (2015) investigated the effects of a six-week long medicine ball training program on throw velocity in female handball players. Twenty-eight competitive female handball players (age: 20.8 $\pm$ 3.3 years) volunteered for the study and were randomly assigned to a medicine ball training group: one specific to handball throwing and one that was not (Raeder et al., 2015). After completion of the six-week long training program, participants who were part of the handball throwing specific program saw a fourteen percent increase in throwing velocity compared to a four percent increase in the non-specific training program (Raeder et al., 2015). The researchers concluded that this could be since those in the sport-specific training program mimicked movements that were natural to the sport, and trained the muscles responsible for the movement of throwing (Raeder et al., 2015).

Van Den Tillaar and Marques (2011) compared three training programs that used different weighted balls and investigated their effects on two-handed overhead soccer throwing velocity. Sixty-eight high school soccer players participated in the six-week study and they were divided into three groups: soccer ball group, medicine ball group, and combination group (both soccer ball and medicine ball) (Van Den Tillaar & Marques, 2011). Training volume was modified to produce the same workload within all training groups; this meant that the group with just the soccer ball performed six sets of fourteen throws per session, the medicine ball group performed three sets of six throws per session (Van Den Tillaar & Marques, 2011). Since the combination group used both the soccer ball and the medicine ball, fewer throws were needed from each; nine throws total with the medicine ball (instead of three sets of six throws) and three sets of fourteen throws with the soccer ball (instead of six sets of fourteen throws) (Van Den Tillaar & Marques, 2011). Results indicated that all three groups increased throwing velocity equally and no one training program was more successful than the other two (Van Den Tillaar & Marques, 2011). This indicates that an increase in training volume can have an effect on overhead throwing velocity similar to training intensity.

Escamilla and colleagues (2012) investigated how to improve throwing velocity with sixty-eight high school baseball players who were randomly assigned to one of three resistance training groups; a group of non-athlete male subjects were also included and divided into the three training programs to compare the results of the baseball players with those of non-baseball players (Escamilla et al., 2012). The three resistance training programs included throwing motions with resistance, exercises involving weights, and plyometric exercises (Escamilla et al., 2012). Post-testing revealed that there was a significant increase in throwing velocity in the baseball players in all three training programs compared to the untrained control group (Escamilla et al., 2012). An increase in throwing velocity was observed in both the untrained control group and the baseball players in all three conditions; however, the increase from pre-test to post-test in the untrained control group is most likely due to the individuals improving strength and conditioning of a movement they are not accustomed to. Some high school baseball players have been throwing overhead for many years, so their arms are conditioned to the movement; this could make it much more difficult to improve throwing velocity compared to those who have not conditioned their arms. If the baseball participants in this study were well conditioned in overhead throwing, that could make the increase in throwing velocity observed in the baseball participants of this study from pre- to post-test much more significant than that of the untrained control group (Escamilla et al., 2012).

Each of these programs had to be done in a weight room where the equipment was provided and where researchers and the strength and conditioning coach could closely monitor the players so they do not cause harm to themselves or others while using the weights. Performing a program such as this can become difficult for teams who may not have access to a weight room or are traveling a lot during their season. Resistance training is a vital aspect of any sport, so it is important to find a practical solution for those who do not have access to a weight room and standard weight equipment. This solution needs to have the option of portability so the team can perform the exercises anywhere, but also needs to be financially possible for a team to obtain on their budget.

Resistance Band/Resistance Tube Training

Resistance bands and tubes are very similar, they provide a resistance during an exercise without the need for heavy weights; the only difference between the two are that resistance tubes are less likely to tear during exercise because of the re-enforced "tube" design (Tirumala & Motimath, 2014). Resistance bands and tubes are a great way to strengthen the muscles of the glenohumeral joint that does not require the need for a weight room or a field (Escamilla et al., 2012). Resistance bands and tubes are light weight and very portable, and they do not require a lot of room to complete exercises; they can also have the same degree of effect on throwing velocity as traditional weights (Escamilla et al., 2012; Sundstrup et al., 2014). Resistance bands and tubes also do not cause as much hypertrophy of the muscles, which can negatively affect ROM in free-moving joints (Yasuda et al., 2014). This is due to resistance band and tube exercises being completed with a higher repetition workload, which falls under the endurance aspect of resistance training (Baechle & Earle, 2016). Muscle hypertrophy is viewed in the first two spectrums of resistance training (power and strength), but less in endurance (Bacelar et al., 2015). Overhead throwing athletes need full ROM in their glenohumeral joint to produce maximal throwing velocity; if the muscles in the glenohumeral joint increase in size too much, it will take away from the joint's mobility (Yasuda et al., 2014).

Maddigan and colleagues (2014) investigated the effects of a resistance tube training program in collegiate level softball players on their throwing velocity. Thirteen healthy female softball players from the University of Western Ontario participated in the study; their ages were between eighteen and twenty-nine years of age (Maddigan et al., 2014). The participants completed five sets of twenty throwing motions with resistance bands three days a week for three weeks (Maddigan et al., 2014). The study took place during the athletes' off-season and each subject was asked to refrain from additional training sessions while participating in the study (Maddigan et al., 2014). The results indicated that the program improved each of the participants' throwing velocity compared to the control group (Maddigan et al., 2014). Tirumala and Motimath (2014) analyzed the effects of a two-week resistance tube training program on kicking accuracy and velocity, and vertical jump performance in twenty-three competitive soccer players (eleven male and twelve female), age eighteen to twenty years. All players participated in one resistance tube training program; pre- and post-test measurements were compared to each other to determine if the training program had an effect (Tirumala & Motimath, 2014). The researchers found that the training intervention resulted in a significant improvement in kicking accuracy and velocity, and vertical jump performance from pre- to post-test measurements (Tirumala & Motimath, 2014). The data collected was compared to previous research that analyzed the effects of typical weight-lifting exercises (i.e. squat, leg extensions, lunges, etc.) on kicking accuracy and vertical jump performance; results indicated similar findings between studies (Jovanovic, Spris, Omrcen, & Fiorentini, 2011; Tirumala & Motimath, 2014). This demonstrates that resistance tubes are just as effective as typical weight training in improving strength and functional performance.

Resistance bands and tubes are also useful in helping reduce pain during exercise by taking the strain of having heavy weights pressing against the joints. In a study conducted by Sundstrup and colleagues (2014), exercises using resistance bands were compared to traditional weight-bearing exercises. Forty-two untrained adults participated in the study, all of who have reported back pain (Sundstrup et al., 2014). The participants performed a forward lunge using resistance bands to provide resistance during the exercise and then with dumbbells (Sundstrup et al., 2014). Nearly all participants reported pain in their back during both forms of the exercise; however, participants reported that less pain was experienced during the exercise with the resistance band (Sundstrup et al., 2014). Since the bands stretched through a selected range, the participants did not have to apply more effort to keep the band stabilized while guiding it through the selected range – more stress is applied to the body when a weight must be stabilized, such as dumbbells or a barbell (Sundstrup et al., 2014). This demonstrates that resistance bands may be used to reduce weight-bearing stresses that could cause chronic pain on the body during workout regimens. Thus, resistance bands could be used as a form of resistance training to strengthen the glenohumeral joint in overhead throwing athletes to maintain muscle force production and improve ROM of the joint. Resistance bands and tubes could be substituted for heavy weights, thus making it a more financially affordable form of resistance training for teams who do not have access to a weight room or weight-lifting equipment.

Interval Throwing Programs

Access to a fully equipped weight room can be difficult for some teams, making it almost impossible for performance to be improved through a regular resistance training program for some individuals participating in sports. Some sports may benefit from a resistance program that does not call for the need of weights and a weight room, or a strength and conditioning coach present. Axe, Windley, and Snyder-Mackler (2002) investigated the effects of an interval throwing program on collegiate level softball players. Often, a player is re-introduced to sport and activity too soon after injury; the program that these researchers designed required the athletes to progress through a series of throwing phases which needed to be passed before the athletes were permitted to return back to competition (Axe et al., 2002). The researchers observed over 220 half-innings and 2,785 pitches of a full NCAA single softball season to gather enough data to determine how many throws on average each position threw; the program created was specified to each of the positions (Axe et al., 2002). The information they discovered was that pitchers threw the most out of all nine positions on the field, catchers threw the second most, then infield position players, and finally outfield position players (Axe et al., 2002).

The program reintroduced the mechanics of throwing to each of the athletes and then eased them back to maximal effort (Axe et al., 2002). In the program, each participant had to pass a series of phases before being released back to full sport participation (Axe et al., 2012). The pitchers' and catchers' program was two phases longer than the infielders' and outfielders' program due to their larger quantity of throws during a season (Axe et al., 2012). Phase one and two never had the player throw beyond the distance of the infield (about sixty feet), while phase three and four involved further throws and more effort; each phase could be passed when the player no longer felt excessively sore after the workout or experienced pain during the workout

(Axe et al., 2012). Depending on the degree of the injury, infielders and outfielders only had to complete phases three and four before returning to full participation (Axe et al., 2012). The researchers' method was successful in decreasing the chances of re-injury in the injured athletes (Axe et al., 2002).

It is important to understand the quantity of throws each position player performs in a season because this can help explain why some are much more susceptible to injury. Those who play a position that throws overhead more often than other positions have a greater strain on the joints of the arm and may increase their glenohumeral ROM more rapidly, increasing their risk of injury. Axe and colleagues (2002) demonstrated that a weight room is not needed to provide progression-type therapy to injured athletes, and that portability of a resistance program can aid in an athlete's recovery when their team is traveling. In addition, the introduction of a resistance training program that targets both the throwing arm of an overhead throwing athlete and the glenohumeral joint as a means of preventive care and strength gains can reduce the risk of injury to the arm and joint in all players.

Those who have a higher number of overhead throws during competition (such as catchers and shortstops) could be expected to have more ROM in the glenohumeral joint, making them susceptible to injury. If a resistance training program that targets the glenohumeral joint muscles is implemented before injury – especially in players with a higher number of overhead throws during competition – then the glenohumeral joint ROM can be improved and joint stability improved (Axe et al., 2002; Hibberd et al., 2014). This addition of a resistance training program and improvement in glenohumeral joint health could result in the individual increasing their overhead throwing velocity and overall throwing performance (Hibberd et al., 2014; Plummer & Oliver, 2013; Prokopy et al., 2008).

Summary

Overhead throwing is a very forceful movement that puts enormous amounts of strain on the glenohumeral joint as well as the rest of the arm. The importance of incorporating a training program to improve the strength and ROM of the glenohumeral joint in overhead throwing athletes does not just extend to being able to throw with greater velocity, but to also improve the health of the joint as well. Developing a program that will strengthen the joint will help return injured athletes back to competition sooner, with less risk of re-injury (Axe et al., 2002) and will also aid in the prevention of injury due to excessive range of motion that causes the joint to become unstable and weak (Hibberd et al., 2014).

Training programs targeting the glenohumeral joint have been shown to improve overhead throwing velocity in athletes; these programs can include weights, throwing interval programs, and resistance bands (Axe et al., 2002; Escamilla et al., 2012; Kuklick et al., 2013; Maddigan et al., 2014; Palmer et al., 2015; Prokopy et al., 2008; Raeder et al., 2015). No single one is more effective than the others; however, resistance bands or tubes offer the luxury of portability, affordability, and accessibility (Escamilla et al., 2012). Very limited research has been conducted to analyze the effects of a structured resistance tube program on overhead throw velocity in female softball players. Most studies use exercises that involve weights instead of bands (Escamilla et al., 2012; Kuklick, Martino, & Black, 2013; Palmer et al., 2015; Prokopy et al., 2008; Raeder, Fernandez, & Ferrauti, 2015). Creating a program to improve throwing velocity with resistance bands may give trainers and coaches the possibility to improve their athletes' throwing anywhere, with limited space and without having to transport heavy equipment. By increasing an athlete's throwing velocity, it may increase the athlete's chances of throwing a runner out at a base. If a majority of the athletes on a specific team can increase their throwing velocity, then the team's chances of winning may also increase.

Chapter 3: Procedures

The Setting

The study was conducted at a NCAA Division II university. To control the possibility of weather causing a problem, pre- and post-testing were conducted indoors. All participants were required to complete both pre- and post-test measurements of overhead throwing velocity and glenohumeral range of motion. Throwing velocity testing was conducted in the university field house. Glenohumeral joint range of motion measurements were conducted in the athletic training room. Anthropometric measurements such as height, weight, and body composition, were conducted in the human performance lab on campus. The 1-repetition maximal Chop Test was conducted in the university's weight room. The training program took place at the university softball field. However, if the training program could not be performed outside on any given day due to weather, the training program was conducted indoors in the field house. All testing measurements were conducted indoors to provide a consistent testing environment for pre- and post-testing, and eliminated the risk of weather affecting results.

Population

The study originally consisted of thirty female fastpitch softball players who volunteered from an NCAA Division II softball team, ranging from 18 to 23 years of age. However, the final number of participants was twenty-eight; one participant was disqualified from the study due to an illness that resulted in her missing more than eighty percent of the training sessions, and another left the university to return home. Members of the team whose primary position was pitcher were excluded from the study due to their position's requirement of throwing underhand for the most part in a typical softball game. After permission had been obtained from the head coach of the softball team, each participant was required to sign a written informed consent that had been approved by the university Institutional Review Board (Appendix A) before participation in the study could occur. A demographic questionnaire was required for all volunteers to complete, and consisted of the athlete's characteristics and past playing and exercise experience (Appendix B). Those who reported less than five years of competitive softball experience were excluded from the study. The thirty participants were randomly selected from the remaining members of the team's roster who volunteered, once pitchers and under-experienced players had been removed. The participants were then randomly placed into one of two groups – an experimental group or a control group. Participants were divided by years of experience and were also divided to allow for an equal number of infielders and outfielders in each group.

Instrumentation

All participants use the same softball for pre- and post-test measurements: A Worth 12" softball, model NC12L, the standard ball used for all official NCAA fastpitch softball competitions. Overhead throwing velocity was measured using the SR-3300 Sports Radar Speed Gun to measure each of the participants' five throws in miles per hour (mph). The five throws were then averaged to determine each of the participants' average overhead throwing velocity; peak velocity, the highest of all five throws, was also recorded.

Glenohumeral joint range of motion was measured in the directions of internal rotation and external rotation of the dominant throwing arm in the university's athletic training room, using a goniometer (Model G-300). Internal and external rotation were selected as appropriate measurements of glenohumeral joint ROM in softball players due to these rotation movements being the most prominent rotations is an overhead throw (Gamma et al., 2014; Hibberd et al., 2014). All anthropometric measurements were measured in the human performance lab, and included height, weight, and body composition; participants were asked to arrive at the lab wearing appropriate clothing (i.e. shorts and sports bra). Height and weight measurements were collected using a Seca digital medical scale, Model #220. Participants were required to remove shoes and baggy clothing while being measured on the scale. Lange skinfold calipers (model C-130) were used to collect body composition measurements. A 7-site skinfold technique was used to obtain body composition measurement.

The 1-repetition maximal (1-RM) Chop Test was measured using the weight stacks found in the university weight room. The 1-repetiton maximal Chop Test was included to test for any strength gains that may have occurred due to the training intervention.

Fit Spirit was the brand of resistance tubes used for this study. Participants were assigned a bag number that contained the resistance tubes they would use for the duration of the study. Three participants were assigned to each bag to prevent one resistance tube being used more than another, which could cause that resistance tube to not provide as much resistance as the others due to overuse. Three different resistances were used: light resistance, medium resistance, and heavy resistance. Light resistance was a red tube equivalent to six to eight pounds of resistance, medium resistance was a blue tube equivalent to nine to eleven pounds of resistance, and heavy resistance was a green tube equivalent to twelve to fourteen pounds of resistance.

Data sheets were used to record all pre- and post-test measurements, and each participant had a separate data sheet for their measurements (Appendix C). To monitor training compliance by the participants, the researcher kept an attendance log to ensure that at least eighty percent of the study was completed by each participant.

Research Design

The study took place during the softball team's competitive season in the spring of 2017. In addition to participating in their regular in-season weight-lifting sessions, the participants were asked to volunteer for an eight-week long resistance tube training program that took place three times a week on Monday, Wednesday, and Friday. There was an additional week before and after the training program for data collection for pre- and post-testing, thus a total of ten weeks – twenty-four training sessions and four data collection sessions. The training program required the participants to perform a variety of different resistance tube exercises that targeted the muscles associated with an overhead throw. Training sessions were held at the softball field; however, if weather required the use of an indoor facility to perform the training regimen for that day, the exercises for that day were conducted in the athletic field house. Training sessions were conducted 45 minutes prior to the start of the softball team's scheduled practice; this allowed plenty of time for the participants to complete their ten-minute warm-up and the four exercises scheduled for that session. Training days were also conducted on the days that the participants were not completing their regular in-season weight-lifting program; Tuesdays and Thursdays were when the team's regular in-season weight-lifting was scheduled, so this study's training programs was held Mondays, Wednesdays, and Fridays. If a training day was missed, a make-up day was scheduled that still allowed for one day of rest between training sessions.

The study was a pre-test/post-test randomized group design, where participants were randomly selected and divided equally into two groups. Pitchers and athletes with less than five years of competitive softball experience were excluded from the study. Participants completed pre- and post-test measurements that included anthropometric measurements, glenohumeral joint range of motion, overhead throwing velocity, and 1-RM Chop test. To prevent fatigue during data collection, testing was divided into two days, with a full day's rest before the second testing day; anthropometric measurements and overhead throwing velocity were measured on the first day, while glenohumeral joint range of motion and 1-RM Chop Test were measured the second day.

The group that performed the sport-specific exercise intervention was classified as the experimental group; however, in an attempt to keep the groups anonymous to the participants, this group was referred to as group one. The control group – group two – also performed an exercise intervention; however, these exercises were not sport-specific and were designed to equal the training volume of that of the experimental group. A general warm-up (Appendix D) was required for all participants to perform prior to the start of any training session or testing. The training programs for both the experimental group (Appendix E) and the control group (Appendix F) were developed by the researcher and the university's head strength and conditioning coach. Both groups were required to not only participate in this study's eight-week long training program, but their team's in-season weight-lifting sessions as well, which is outlined in Appendix G. The training programs required the participants to complete three days of training sessions a week with one day of rest between each session: Mondays, Wednesdays, and Fridays; if a training day was missed, a make-up day was scheduled that still allowed for one day of rest between training sessions. Each session took no more than forty-five minutes to complete; and with a full day's rest between sessions and short exercise durations, the chances of overtraining and injury should have decreased while maintaining strength and power gains (Szymanski & Fredrick, 1999). A ten-minute warm-up consisting of dynamic exercises was also implemented to the beginning of each training session to increase blood flow to working muscles and the quality of exercise training (Powers & Howely, 2012; Thompson, Cobb, & Blackwell, 2007). Appendix H includes a written explanation and illustrations of each exercise that was used in the study by the experimental group. Appendix I includes a written explanation and illustrations of each exercise that was used in the study by the control group.

Although throwing velocity, 1-RM Chop test, and glenohumeral joint ROM was only measured in the throwing arm, the training protocol required the participants to perform the exercises for both arms. This was to prevent muscle imbalances that could have possibly led to other injuries in the future. The implementation of two testing days instead of one helped to prevent fatigue during data collection, and assure maximal effort was given by all participants during testing.

Pre- and post-test anthropometric measurements were conducted at the human performance lab, while glenohumeral joint ROM measurements were conducted in the athletic training room. To measure glenohumeral joint range of motion in the directions of internal rotation and external rotation, a goniometer (Model G-300) was used – an instrument for the precise measurement of angles. The participant lay supine on a table while range of motion was collected. One side of the goniometer was placed in a fixed position that was perpendicular to the ground, indicating neutral position. The arm was then passively moved internally or externally by the researcher until the joint could not be moved any further, or the participant asked to stop (Hibberd et al., 2014). Figure 2 demonstrates how this looked for both internal rotation and external rotation. Internal and external-rotation were selected to measure glenohumeral joint range of motion since they are the most evident rotations of the glenohumeral joint when performing an overhead throw (Gamma et al., 2014; Hibberd et al., 2014). Using the second side of the goniometer, the angle of the joint was measured for both internal-rotation and external-rotation. Scapular stabilization was also provided by an additional researcher through posteriorly directed force at the acromion to prevent the glenohumeral joint to raise up off the table (Hibberd et al., 2014).

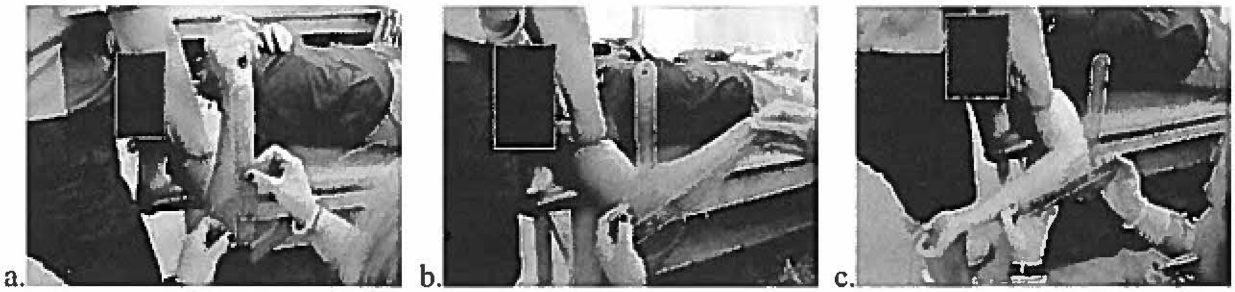
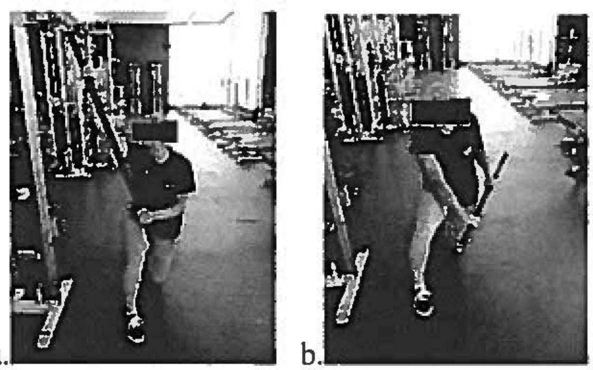


Figure 3. Glenohumeral Joint Internal and External Rotation
Slide a represents the starting position of both internal rotation and external rotation, while slides b and c represent internal shoulder rotation and external rotation, respectively.

The participants were required to train both right and left arms to prevent muscle imbalances; however, for pre- and post-tests of overhead throwing velocity, participants were required to throw with the same arm throughout the entire study. Although uncommon, it is possible for a softball player to have the ability to throw with both arms effectively. For this study, the participants were asked to throw with the arm they utilize the most during competition. For example, if the participant reported that they use their right arm for throwing for the majority of competitions, then they were required to throw using their right arm for all overhead throwing velocity tests. Pre- and post-test measurements of overhead throwing velocity were measured in the athletic field house at the university. Before testing could begin, a ten-minute self-regulated throwing warm-up session was completed by all participants after completion of the general warm-up – participants paired up and threw for ten minutes at a distance the participants chose to throw at. Each participant was then given five practice throws, in which they threw into a net stationed sixty feet away (the distance from base to base on a softball field). The practice throws were designed to familiarize the participant with the testing station and to reduce any pre-test anxiety (Consonero, 2016; Thompson, Cobb, & Blackwell, 2007). The participants were then instructed to throw five additional softballs into the target with maximal effort. Since most overhead throws in softball are completed by first stepping towards the target, participants were permitted to take one step before throwing the ball; however, they could not pass the tape marker because that marked the distance of sixty feet to the throwing target. Throwing velocity was measured using a SR-3600 Sports Radar Speed Gun positioned behind the throwing target and guarded by a screen.

A 1-repetition maximal (1RM) test was used to measure maximal strength in the Chop test. Figure 4 demonstrates the Chop Test. The 1RM Chop test was the first test conducted during the second testing day, after completion of the general warm-up. The test was conducted in the weight room, under the supervision of the head strength and conditioning coach. The technique for the Chop test followed the guidelines set by Palmer and Uhl (2011). Participants knelt on the ground with the same knee up as their dominant throwing arm and bent at a 90-degree angle. The participant was instructed to keep their torso upright throughout the entire test – if the participant bent forward, the lift was not counted and the participant was asked to rest and attempt the lift again (Palmer & Uhl, 2011). Although the non-dominant arm was permitted to bend, the dominant arm had to maintain a fixed position; a slight bend is allowed for comfort, but any further resulted in a failed attempt (Palmer & Uhl, 2011). A demonstration by the researcher was given followed by one practice session; during this practice session, each participant was monitored by the researcher so technique could be corrected and the participants could familiarize themselves with the lift before beginning the 1RM test.

The testing protocol for a 1RM test was taken from Baechle & Earle (2016); since the Chop Test was performed on a cable machine, weight increased in increments of ten pounds (one plate). Participants were instructed to warm-up with a light resistance that easily allowed five to ten repetitions to familiarize themselves with the exercise; a rest of one minute was allowed (Baechle & Earle, 2016). An estimate of a conservative, near-maximal load that allowed the participant to complete two or three repetitions was added and then completed; a two to four-minute rest period was allowed (Baechle & Earle, 2016). The participant then increased the weight and attempted a 1-RM; if successful, the participant rested for two to four minutes, and then increased the weight and attempted another 1-RM (Baechle & Earle, 2016). If the participant failed, there was another two to four-minute rest period, and the load was decreased and the participant again attempted the 1RM; if completed, that weight became the participant's 1-RM (Baechle & Earle, 2016). Ideally, the participant's 1-RM was to be measured within three to five testing sets (Baechle & Earle, 2016).


a. b.
Figure 4. Chop Test
Slides a and b represent the starting and ending position of the Chop Test, respectively (Palmer & Uhl, 2011; Palmer et al., 2015)

The eight-week training program took place during the beginning of the softball team's competitive season in the spring of 2017. Pre-testing took place a week before the start of the eight-week training program, and tests were conducted over two days to prevent fatigue. The first testing day consisted of anthropometric measurements and overhead throw velocity, while the second day measured glenohumeral joint ROM and the 1RM Chop Test. Anthropometric measurements was measured in the human performance lab, while glenohumeral joint ROM was measured in the athletic training room. Overhead throwing velocity testing was held in the university's athletic field house. The 1RM Chop Test was measured in the university weight room. Post-testing was conducted a week after the completion of the eight-week training program, and was conducted in the same way as pre-testing.

Reliability

All exercises found in each of the training interventions were developed with the assistance of the NSCA strength and conditioning certified, head strength and conditioning coach at the university. Similar exercises have also been used in previous studies, and have been shown to have a positive effect on throwing velocity (Escamilla et al., 2012; Maddigan et al., 2014; Sundstrup et al., 2014). To ensure reliability, the head strength and conditioning coach supervised the 1-RM Chop tests, and both pre- and post-tests was conducted by the same researcher. The Chop Test is a test designed to measure strength gains in the upper body. The Chop Test has been found to be reliable in testing the strength of functional tasks such as an overhead throw (Palmer & Uhl, 2011; Palmer et al., 2015). According to Palmer and Uhl (2011), intra-class correlation coefficients for peak muscular power were highly reliable for the Chop Test (range, 0.87-0.98). Both the regular in-season training program and the study's training program were supervised by the head strength and conditioning coach and conducted by the same researcher.

The SR-3300 Sports Radar Speed Gun is similar to radar guns used in previous studies (Escamilla et al., 2012; McEvoy & Newton, 1998; Palmer et al., 2015; Prokopy et al., 2008; Van Den Tillaar & Marques, 2011). The researchers of these studies report this model radar gun has been used in studies before their own and used in similar pre- and post-test research (Escamilla et al., 2012; Palmer et al., 2015; Van Den Tillaar & Marques, 2011). These pre- and post-test studies used the same model radar gun (SR-3300) for both pre- and post-tests, and report it to be a repeatable measurement of throwing velocity (Escamilla et al., 2012; McEvoy & Newton, 1998; Palmer et al., 2015; Prokopy et al., 2008; Van Den Tillaar & Marques, 2011).

A goniometer (Model G-300) was used to measure the degree of internal and external rotation; the goniometer has been used in other studies to measure degrees of ROM (Edouard et al., 2013; Gamma et al., 2014; Hibberd et al., 2014; In-Gui, Il-Young, Soo-Yong, Dong-Kyu, & Jae-Seop, 2015). The same researcher measured pre- and post-test measurements of internal rotation and external rotation, and used the same goniometer for pre- and post-testing. In-Gui and colleagues (2015) tested the measurements of ankle dorsiflexion using a goniometer against the measurements obtained using a Biodex dynamometer. The intra-rater reliability using the goniometer was 0.892 compared to 0.968 using the Biodex dynamometer (In-Gui et al., 2015). The use of the Biodex dynamometer to measure ROM is preferable; however, it was determined that the goniometer is a reliable tool to use in measuring joint ROM (In-Gui et al., 2015). Hibberd and colleagues used a goniometer to measure internal and external rotation of the glenohumeral joint and found a correlation coefficient of 0.976, indicating that the goniometer is reliable instrument in measuring joint ROM (Hibberd et al., 2014).

Skinfold measurements were measured using a Lange skinfold caliber (model C-130). Due to the development of advanced technologies used in body composition analysis, scientists developed equations that can predict body density from a collection of skinfold measurements (Powers & Howely, 2012). Measurements were collected from seven different sites – the chest, axilla, triceps, subscapula, suprailiac, abdomen and thigh. To ensure reliability, the same researcher conducted both the pre- and post-test skinfold measurements.

Validity

The exercises for each training program were chosen by the researcher, with the help of the university's NSCA certified strength and conditioning coach, to work the targeted muscles for each group. The experimental group's exercises were designed to be sport-specific, in that these exercises targeted the muscles responsible for overhead throwing. The control group's exercises were designed to be non-sport-specific, where the upper body muscles were being worked but the muscles specific for overhead throwing were not targeted; some of the control group's exercises might work the muscles responsible for overhead throwing slightly, but the throwing muscles are not the target muscle in the exercise. Supervision by the head strength and conditioning coach ensured that the participants did each of the exercises properly so the correct muscles were targeted.

The SR-3300 radar gun is a valid instrument for measurement of throwing velocity (Escamilla et al., 2012; McEvoy & Newton, 1998; Palmer et al., 2015; Prokopy et al., 2008; Van Den Tillaar & Marques, 2011). The radar gun uses the Doppler Effect, which allows the use of narrow band receiver filters to reduce or eliminate signals from slow moving and stationary objects in order to measure accurate velocity speeds of moving objects. Van Den Tillaar and Marques (2011) reported the SR-3300 to have a ± 0.03 $m \cdot s^{-1}$ accuracy within a field of ten degrees from the gun. To ensure proper measurements, the researcher was behind the target the participants threw into with the radar gun aimed down the center of the throwing lane. A screen to ensure their safety from any throws that were thrown off-target protected the researcher.

By mimicking the same motion of an overhead throw, the Chop test uses the same muscles as an overhead throw to chop downward with the bar against the resistance (Palmer & Uhl, 2011; Palmer et al, 2015). The Chop Test was used in a study conducted by Palmer and colleagues (2015), and they found that an increase in Chop Test strength occurred simultaneously with overhead throwing velocity. They reported to have a correlation coefficient of 0.98, making the Chop Test a valid test in measuring strength gains during this overhead throwing study (Palmer & Uhl, 2011; Palmer et al., 2015).

The goniometer is a valid tool used in measuring joint range of motion and has been used in previous research studies (Edouard et al., 2013; Gamma et al., 2014; Hibberd et al., 2014; In-Gui et al., 2015). The measurements obtained using a goniometer in measuring joint angles has been tested against the measurements obtained by a Biodex dynamometer (In-Gui et al., 2015). It was found that results from the goniometer were similar to those obtained from the Biodex dynamometer, with a correlation coefficient as high as 0.97 reported; thus the goniometer is a suitable tool for measuring joint angle and ROM (Hibberd et al., 2014; In-Gui et al., 2015).

Skinfold measurements can be an accurate form of testing of body composition; with practice, a researcher can come within one percent of the actual body composition as determined by the golden standard of underwater weighing (Powers & Howely, 2012). However, skinfold measurements do not require the participants to hold their breaths and remain completely still while submerged underwater (Powers & Howely, 2012). The researcher's validity of skinfold measurements was tested against a criterion supervising researcher who is certified in skinfold measurements.

Treatment of Data/Statistical Analysis

Dependent variables of the study included pre- and post-intervention anthropometric measurements, measurement of a 1-RM Chop test, peak and average overhead throwing velocity, and glenohumeral joint range of motion. The experimental resistance tube and control group training programs represented the independent variables. Each dependent variable was measured twice throughout the ten-week long study, once before the eight-week training program and again after the eight-week training program. Individual data sheets for each participant were used to record the participant's pre- and post-test measurements; a blank copy can be found in Appendix C. In addition to data sheets, an attendance log was also kept by the researcher to track training compliance for each participant. To obtain the most valid results, it was required that a minimum of eighty percent of the study's training sessions was completed by each participant for their measurements to be used; if less than eighty percent was completed, then the participant's results and measurements were excluded from the study.

To keep the study confidential and anonymous, the primary researcher kept all information on a password-protected computer and changed all names of the participants to their school identification number when needed. Loose-leaf documentation was converted to digital and saved on the same password-protected computer, and then properly disposed of to ensure the privacy of all participants. Results were reported as group means ± standard deviation; no individual data was revealed.

All data was compiled in a Microsoft Excel spreadsheet, and analysis of data was completed using SPSS Version 24 (2015) statistical software. Pre- and post-test values of body composition, glenohumeral joint range of motion, peak and average overhead throwing velocity, and 1-RM Chop test were inputted into a two-way repeated measures ANOVA. A post-hoc test did not occur since there were not three or more groups compared. Change scores from pre- to post-testing were inputted into a MANOVA to determine if a significant difference between groups occurred. A p value of $p<0.05$ indicated a statistical significance. Effect size (d) was also calculated; a large effect size was represented as $d \geq 0.80$, a moderate effect size was represented as $d = 0.50\text{-}0.79$, and a small effect size was represented as $d = 0.20\text{-}0.49$ (Field, 2013).

Chapter 4: Results

A group of thirty female fastpitch softball players from an NCAA Division II university volunteered to participate; however, due to dropouts, twenty-eight participants completed the study (age: 19.75 $\pm$ 1.53 years; height: 165.42 $\pm$ 5.62cm; weight: 71.57 $\pm$ 14.00kg). Prior to data analysis, participants were excluded if they did not complete at least 80 percent of the resistance tube intervention they were assigned to. Treatment of data was performed on both the experimental and control group. In addition to not completing at least 80 percent of the additional training, participants were excluded from data analysis if they had resigned from the team prior to completing the training program. An attendance log was maintained to monitor training compliance during the eight-week long training program. The experimental group had an average compliance rate of 98.6% and the control group had an average compliance rate of 99.0%. Thus, 28 participants who completed the study (15 experimental and 13 control) were included in data analysis. SPSS (Version 24, 2015) was used for all statistical analyses.

Data Analysis

To determine if any statistical differences existed between or within the experimental and control groups, a two-way repeated measures analysis of variance (ANOVA) was conducted on pre- and post-test measurements of all dependent variables: anthropometric measurements, 1RM Chop Test, glenohumeral joint ROM in the internal and external direction, and peak and average overhead throwing velocity. A MANOVA was conducted on the changes from pre- to post-testing for each dependent variable. For all data analyses, significance was set at a p value of .05; effect size (d) was measured as d = 0.20-0.49 representing a small effect size, d = 0.50-0.79 representing a moderate effect size, and d $\geq$ 0.80 representing a large effect size. In addition to conducting a two-way repeated measures ANOVA and a MANOVA, descriptive statistics (mean

± standard deviation) were collected for all dependent variables for both experimental and control groups; these are shown in Table 4.1 and 4.2, respectively.

Table 4.1
Experimental Group (n = 15) Descriptive Statistics (Pre- & Post-Test)

Test	Mean	Average Change
Pre-Test Weight (kg)	70.01 ± 12.72	
Post-Test Weight (kg)	69.41 ± 12.24	-0.66 ± 1.59
Pre-Test % Body Fat	21.02 ± 4.02	
Post-Test % Body Fat	20.12 ± 4.22	-0.90 ± 0.97
Pre-Test Fat Mass (kg)	15.16 ± 5.63	
Post-Test Fat Mass (kg)	14.41 ± 5.66	-0.75 ± 0.72
Pre-Test LBM (kg)	54.92 ± 7.30	
Post-Test LBM (kg)	55.00 ± 6.84	+0.08 ± 1.35
Pre-Test 1RM Chop Test (kg)	27.22 ± 5.14	
Post-Test 1RM Chop Test (kg)	33.57 ± 6.59	+6.35 ± 3.75
Pre-Test Internal Rotation (degrees)	69.07 ± 16.34	
Post-Test Internal Rotation (degrees)	65.87 ± 8.48	-3.13 ± 19.84
Pre-Test External Rotation (degrees)	119.73 ± 12.27	
Post-Test External Rotation (degrees)	116.67 ± 12.19	-3.07 ± 12.76
Pre-Test Peak Throwing Velocity (mph)	53.27 ± 3.49	
Post-Test Peak Throwing Velocity (mph)	55.27 ± 2.94	+2.00 ± 2.39
Pre-Test Avg. Throwing Velocity (mph)	52.05 ± 3.37	
Post-Test Avg. Throwing Velocity (mph)	53.71 ± 2.92	+1.65 ± 1.83

+ = Increase
- = Decrease
* = Indicates significant change ($p < 0.05$)

Table 4.2
Control Group (n = 13) Descriptive Statistics (Pre- & Post-Test)

Test	Mean	Average Change
Pre-Test Weight (kg)	73.29 + 15.69	
Post-Test Weight (kg)	74.17 + 15.64	+0.87 ± 1.47
Pre-Test % Body Fat	22.42 + 4.69	
Post-Test % Body Fat	22.73 + 4.67	+0.31 ± 1.09
Pre-Test Fat Mass (kg)	17.05 + 6.92	
Post-Test Fat Mass (kg)	17.35 + 6.87	+0.30 ± 1.04
Pre-Test LBM (kg)	56.25 + 9.00	
Post-Test LBM (kg)	56.96 + 9.17	+0.71 ± 1.53
Pre-Test 1RM Chop Test (kg)	27.56 + 7.51	
Post-Test 1RM Chop Test (kg)	34.76 + 15.50	+4.89 ± 5.39
Pre-Test Internal Rotation (degrees)	70.00 + 17.05	
Post-Test Internal Rotation (degrees)	65.85 + 13.83	-4.15 ± 18.67
Pre-Test External Rotation (degrees)	124.31 + 14.31	
Post-Test External Rotation (degrees)	125.46 + 10.05	+1.15 ± 14.76
Pre-Test Peak Throwing Velocity (mph)	53.46 + 2.54	
Post-Test Peak Throwing Velocity (mph)	54.38 + 2.87	+0.92 ± 2.36
Pre-Test Avg. Throwing Velocity (mph)	52.03 + 2.73	
Post-Test Avg. Throwing Velocity (mph)	52.91 + 3.29	+0.91 ± 2.65

+ = Increase
- = Decrease
* = Indicates significant change ($p < 0.05$)

Findings

Analysis of both the two-way repeated measures ANOVA and MANOVA (Table 4.3 and 4.4, respectively) showed that statistically significant differences were found when comparing pre- to post-test measurements of the experimental group to the control group (group x time) within anthropometric measurements: weight (p = .013, d =0.07), body fat percentage (p = .005, d =0.51), and fat mass (p = .004, d =0.50). On average, the experimental group had a decrease in weight of 0.66 ± 1.59 kg, while the control group had an average increase of 0.87 ± 1.47 kg. Body fat percentage averages for the experimental group was a loss of 0.90 ± 0.97 percent, while the control group had an average gain of 0.31 ± 1.09 percent. The experimental group had an average decrease in fat mass of 0.75 ± 0.72 kg, while the control group had an average increase of 0.30 ± 1.04 kg.

Table 4.3
Two-Way Repeated Measures ANOVA Results

	F	*p*	*Effect Size (d)*
W Pre-test vs. Post-test (group as a whole)	0.13	.725	0.00
BF% Pre-test vs Post-test (group as a whole)	2.23	.147	0.04
FM Pre-test vs. Post-test (group as a whole)	1.80	.191	0.02
LBM Pre-test vs. Post-test (group as a whole)	2.12	.157	0.02
1RM Pre-test vs. Post-test (group as a whole)	17.48	.000*	0.34**
IR Pre-test vs. Post-test (group as a whole)	1.02	.322	0.13
ER Pre-test vs. Post-test (group as a whole)	.135	.716	0.04
PTV Pre-test vs. Post-test (group as a whole)	10.53	.003*	0.25**
ATV Pre-test vs. Post-test (group as a whole)	8.90	.006*	0.21**

W- Weight
BF% - Body Fat Percentage
FM – Fat Mass
LBM – Lean Body Mass
1RM – 1 Repetition Max
IR – Internal Rotation
ER – External Rotation
PTV – Peak Throwing Velocity
ATV – Average Throwing Velocity

* Indicates a significant value ($p < .05$)
** Indicates a small effect size (d = .2-.49)

Table 4.4

MANOVA Results: Change (Δ) Scores

	F	*p*	*Effect Size (r)*
ΔW Experimental Group vs. Control Group	7.04	.013*	0.07
ΔBF% Experimental Group vs. Control Group	9.64	.005*	0.51***
ΔFM Experimental Group vs. Control Group	10.00	.004*	0.50***
ΔLBM Experimental Group vs. Control Group	1.33	.260	0.21**
Δ1RM Experimental Group vs. Control Group	0.71	.406	0.16
ΔIR Experimental Group vs. Control Group	0.02	.890	0.03
ΔER Experimental Group vs. Control Group	0.66	.424	0.15
ΔPTV Experimental Group vs. Control Group	1.43	.243	0.22**
ΔATV Experimental Group vs. Control Group	0.77	.389	0.16

W- Weight
BF% - Body Fat Percentage
FM – Fat Mass
LBM – Lean Body Mass
1RM – 1 Repetition Max
IR – Internal Rotation
ER – External Rotation
PTV – Peak Throwing Velocity
ATV – Average Throwing Velocity

* Indicates a significant value ($p < .05$)
** Indicates a small effect size (d = .2-.49)
*** Indicates a moderate effect size (d = .5-.79)

Two-Way Repeated Measures ANOVA

Results from the two-way repeated measures ANOVA (Table 4.3) showed that statistically significant differences were found in the combined scores of both the experimental group and control group when comparing pre- and post-testing of the 1RM Chop Test, peak throwing velocity, and average throwing velocity ($p = .000$, $p = .003$, and $p = .006$, respectively). The effect sizes for 1RM, peak throwing velocity, and average throwing velocity (d =0.34, d =0.25, and d =0.21, respectively) indicate the training intervention had a small effect (d =0.20-0.49) on the listed variables.

Pre- to post-testing analysis of body composition (weight, body fat percentage, fat mass, and lean body mass), and internal rotation or external rotation of the glenohumeral joint did not yield significant results from the two-way repeated measures ANOVA. The *p* values and effect size of each are as followed: weight: $p = .725$, d = 0.00; body fat percentage: $p = .147$, d = 0.04;

fat mass: $p = .191$, d = 0.02; lean body mass: $p = .157$, d = 0.02; internal rotation: $p = .322$, d = 0.13; external rotation: $p = .716$, d = 0.04. The effect sizes associated with the previously noted dependent variables indicate that the training interventions had little effect (d < 0.20) on body composition, and internal and external rotation of the glenohumeral joint. The experimental group had a decrease in weight of 0.66 ± 1.59 kg, while the control group had an average increase of 0.87 ± 1.47 kg. Body fat percentage averages for the experimental group was a loss of 0.90 ± 0.97 percent, while the control group had an average gain of 0.31 ± 1.09 percent. The experimental group had an average decrease in fat mass of 0.75 ± 0.72 kg, while the control group had an average increase of 0.30 ± 1.04 kg. On average, the experimental group had a decrease of 3.13 ± 19.84 degrees in the direction of internal rotation of the glenohumeral joint and an average decrease of 3.07 ± 12.76 degrees in the direction of external rotation of the glenohumeral joint. The control group had an average decrease of 4.15 ± 18.87 degrees in the direction of internal rotation of the glenohumeral joint and an average increase of 1.15 ± 14.76 degrees in the direction of external rotation of the glenohumeral joint.

MANOVA

Although 1RM Chop test, peak throwing velocity, and average throwing velocity showed a significant difference from pre- to post-testing, a statistically significant difference was not seen between the experimental group and control group for these variables (1RM Chop Test: $p = .406$, d = 0.16; Peak Throwing Velocity: $p = .243$, d = 0.22; Average Throwing Velocity: $p = .389$, d = 0.16). Effect size for change scores between the experimental and control group was considered small with a d = 0.20-0.49, as shown in Table 4.4.

No significant differences were found between groups in internal rotation or external rotation of the glenohumeral joint ($p = .890$, d = 0.03; $p = .424$, d = 0.15, respectively). As mentioned earlier, the experimental group had a decrease of 3.13 ± 19.84 degrees in the direction of internal rotation of the glenohumeral joint and an average decrease of 3.07 ± 12.76 degrees in the direction of external rotation of the glenohumeral joint. The control group had an average decrease of 4.15 ± 18.67 degrees in the direction of internal rotation of the glenohumeral joint and an average increase of 1.15 ± 14.76 degrees in the direction of external rotation of the glenohumeral joint.

Summary

The results indicated that a significant difference was found when comparing pre- to post-test measurements of 1RM Chop Test, peak throwing velocity, and average throwing velocity in the combined scores of both the experimental group and control group ($p = .000$, $p = .003$, and $p = .006$, respectively). The experimental group had an average increase of 6.35 ± 3.75 kg, 2.00 ± 2.39 mph, and 1.65 ± 1.83 mph in the 1RM Chop Test, peak throwing velocity, and average throwing velocity, respectively. The control group had an average increase of 4.89 ± 5.39 kg, 0.92 ± 2.36 mph, and 0.91 ± 2.65 mph in the 1RM Chop Test, peak throwing velocity, and average throwing velocity, respectively. No significant difference was seen in internal rotation of the glenohumeral joint or external rotation of the glenohumeral joint from pre- to post-testing.

Although pre- to post-testing revealed a significant difference in 1RM Chop Test, peak throwing velocity, and average throwing velocity for all subjects combined, a significant difference was not viewed within these three variables when the experimental group was compared to the control group ($p = .406$, $p = .243$, and $p = .389$, respectively). No significant difference was seen between groups in glenohumeral joint ROM in the direction of internal rotation and external rotation, or lean body mass as well ($p = .890$, $p = 424$, and $p = .260$, respectively). However, a significant difference was seen in the change scores of the experimental group and control group in weight, body fat percentage, and fat mass ($p = .013$, $p = .005$, and $p = .004$, respectively). The experimental group decreased their weight by an average of 0.66 $\pm$ 1.59 kg, while the control group increased their weight by an average of 0.87 $\pm$ 1.47 kg. Body fat percentage averages for the experimental group was an average loss of 0.90 $\pm$ 0.97 percent, while the control group had an average gain of 0.31 $\pm$ 1.09 percent. An average decrease of 0.75 $\pm$ 0.72 kg was seen in fat mass for the experimental group, while the control group had an average increase of 0.30 $\pm$ 1.04 kg.

Chapter 5: Discussion

Introduction

The purpose of this study was to examine the effects of an eight-week long sport-specific resistance tube training intervention on overhead throwing velocity, upper body strength (via the 1RM Chop Test), and glenohumeral joint ROM. Both the experimental group and the control group performed a training intervention using resistance tubes – sport-specific training for the experimental group and non-sport-specific training for the control group. Sport-specific training targeted the muscles of the glenohumeral joint, while non-sport-specific training targeted the upper body as a whole. Some exercises in the control group's training may have utilized the muscles of the glenohumeral joint as supporting muscles; however, they were not the intended target of the exercise. Both training interventions had an equal exercise volume to control for training workload – each intervention performed four exercises each training session, for a total of twelve exercises in a single week. The tests used to measure the effects of the intervention included the peak and average throwing velocity of five throws measured using a SR-3300 Radar Gun, a 1RM Chop Test to measure upper body strength gains, and internal and external rotation measurements of the glenohumeral joint using a goniometer (Model G-300). Anthropometric measurements were also tested and included a seven-site skinfold test to measure body composition. The original hypotheses for the study were: the experimental group performing the sport-specific resistance tube training program would experience more of an increase in overhead throwing velocity compared to the control group; the experimental group would increase more in the 1RM Chop Test compared to the control group; more of an improvement in glenohumeral joint ROM would be seen in the experimental group compared to the control group.

The results, as presented in Tables 4.1 – 4.4, indicate that the combined scores of both the experimental group and the control group showed significant increases in the 1RM Chop Test, peak throwing velocity, and average throwing velocity from pre- to post-testing (p = .000, p = .003, and p = .006, respectively). The experimental group, which was performing the sport-specific resistance tube training exercises showed a 6.35 ± 3.75 kg increase in the 1RM Chop Test, 2.00 ± 2.36 mph increase in peak throwing velocity, and 1.65 ± 1.83 mph increase in average throwing velocity from pre- to post-test. The control group, which was performing a non-sport-specific resistance tube training program, showed a 4.89 ± 5.39 kg increase in the 1RM Chop Test, 0.92 ± 2.36 mph increase in peak throwing velocity, and 0.91 ± 2.65 mph increase in average throwing velocity from pre- to post-test. No statistical differences in the groups combined scores from pre- to post-testing were observed in weight, body fat percentage, fat mass, lean body mass, internal rotation of the glenohumeral joint, or external rotation of the glenohumeral joint.

Although statistically significant differences were observed in the combined pre- to post-test scores for both the experimental group and control group for the 1RM Chop Test, peak throwing velocity, and average throwing velocity from pre- to post-testing, these variables did not show a significant difference when comparing the experimental group to the control group (p = .796, p = .243, and p = .389, respectively), thus disproving the researcher's first two hypotheses. However, there were statistically significant differences between groups when comparing anthropometric measurements, specifically changes in weight, body fat percentage, and fat mass over the study period (p = .013, p = .005, p = .004, respectively). The experimental group showed a decrease in weight, body fat percentage and fat mass (loss of 0.66 ± 1.59 kg, 0.90 ± 0.97 %, and 0.75 ± 0.72 kg, respectively), while the control group showed an increase in weight, body fat percentage, and fat mass (gain of 0.87 $\pm$ 1.47 kg, 0.31 $\pm$ 1.09 %, and 0.30 $\pm$ 1.04 kg, respectively). Group comparisons also revealed that there was not a significant difference between the groups' change scores in both internal and external rotation of the glenohumeral joint (p = .890 and p = .424, respectively), thus disproving the researcher's final hypothesis.

Throwing Velocity

Significant differences were not seen in the experimental group compared to the control group for peak and average throwing velocity, thus no supporting the researcher's first hypothesis that a sport-specific resistance tube training program would have more of an improvement in peak and average throwing velocity compared to a non-sport-specific resistance tube training program. However, there was a significant increase from pre- to post-testing in both the experimental group and control group combined (peak: p = .003; average: p = .006). These values support the findings of Tirumala and Motimath (2014) that the implementation of a resistance tube training program will increase sport-specific velocities (overhead throwing velocity in the current study and kicking velocity in the Tirumala and Motimath, 2014, study) from pre- to post-testing measurements. However, the current study does not support the findings of Maddigan and colleagues (2014) that an experimental group performing overhead exercises with resistance bands would have a significant increase in overhead throwing velocity when compared to a control group. This may be due to Maddigan and colleagues' (2014) study having the experimental group perform an additional resistance tube training program while the control group did not perform any additional exercises. The increase in throwing velocity found in Maddigan and colleagues' (2014) study may be due to an increase in training volume and not due to the sport-specific resistance tube training program that targeted the muscles of the glenohumeral joint.

With effect sizes of d = 0.25 and d = 0.21 for peak and average throwing velocity, respectively, the results indicate that this specific resistance tube training program had a small effect on peak and average throwing velocity from pre- to post-testing. Although the values between groups for peak and average throwing velocity are not statistically significant, pre- to post-testing measures demonstrated a larger increase in both peak and average throwing velocity in the experimental group compared to the control group. The experimental group increased their peak and average throwing velocity by 1.08 mph (the experimental group's mean peak throwing velocity change minus the control group's mean peak throwing velocity change) and 0.74 mph (the experimental group's mean average throwing velocity change minus the control group's mean average throwing velocity change), respectively, more than the control group. Although not statistically significant, these findings support the findings of Escamilla and colleagues (2012), Kuklick and colleagues (2013), and Raeder and colleagues (2015) who all found that a training intervention targeting the muscles associated with an overhead throw will increase overhead throwing velocity by a range of 0.83 – 2.01 mph. The increases of 2.00 mph for peak throwing velocity and 1.65 mph for average throwing velocity found in the current study fall within this range. At the collegiate level, any increase in throwing velocity is viewed as significant in a practical sense. An increase in both peak and average throwing velocity could increase an athlete's chances of throwing a runner out at a base and improving the team's odds of winning the game (Escamilla et al., 2012; Kuklick et al., 2013).

Strength as Measured by the Chop Test

Statistical analysis revealed that there was no significant difference between the experimental group and control group in the 1RM Chop Test when comparing change scores. This does not support the researcher's second hypothesis that a sport-specific resistance tube training program would result in a greater improvement in strength, as measured by the Chop Test, compared to a non-sport-specific resistance tube training program. Both groups did show an increase in the combined scores from pre- to post-testing, indicating a significant difference from pre- to post-testing (p = .000). According to the research conducted by Palmer & Uhl (2011) and Palmer and colleagues (2015), an increase in the Chop Test occurred simultaneously with an increase in overhead throwing velocity. However, since both the experimental group and the control group increased both their peak and average throwing velocity from pre- to post-test in the current study, and both increased their Chop Test from pre- to post-test, the findings from the current study supports the findings from the studies by Palmer and colleagues (2011, 2015). An increase in the Chop Test seems to occur simultaneously with an increase in overhead throwing velocity (Palmer & Uhl, 2011; Palmer et al., 2015). However, in Palmer and colleagues' (2015) study correlation tests were performed and a significant correlation coefficient of 0.70 (p = 0.50) was found between throwing velocity and the Chop Test; the current study did not run correlation tests during data analysis, thus any "correlation" between the Chop Test and throwing velocity is speculation and future research should consider addressing these relationships.

With an effect size of d =0.34, the results of the current study indicate that a resistance tube training program has a small effect on upper body strength measured via the 1RM Chop Test from pre- to post-testing. However, the experimental group experienced a slightly greater increase than the control group: 1.46 kg more (the experimental group's mean 1RM change minus the control group's mean 1RM change). This may indicate that by specifically targeting the muscles of the glenohumeral joint, the experimental group's resistance tube training program may have increased the muscular strength of the glenohumeral joint, giving the participants a slight advantage in performing the Chop Test – a test that mimics the same motion and utilizes the same muscles as an overhead throw (Palmer & Uhl, 2011; Palmer et al., 2015). An increase in muscular strength in the glenohumeral joint may increase an individual's overhead throwing performance by improving stabilization of the joint and increasing the force production of the muscles (Baechle & Earle, 2016; Palmer & Uhl, 2011; Palmer et al., 2015).

Glenohumeral Joint ROM

Neither pre- to post-testing values nor group comparison values showed a significant difference in glenohumeral joint ROM in the directions of internal rotation and external rotation. The results do not support the researcher's third hypothesis that a sport-specific resistance tube training program would improve glenohumeral joint ROM more than a non-sport-specific resistance tube training program. Few studies have examined the effect of a resistance tube training program on glenohumeral joint ROM; however, the results of the current study agree with Gamma and colleagues' (2014) findings that different warm-up interventions will not significantly affect ROM of the glenohumeral joint in the directions of internal and external rotation. The warm-up exercises used in the study conducted by Gamma and colleagues (2014) were similar to the exercises utilized in the current study, specifically targeting the glenohumeral joint; however, the exercises were used as a form of warm-up and not as a form of training, so they were performed at a lower intensity than the exercises in the current study.

For the purpose of this study, an "improvement" in glenohumeral joint ROM was classified as a decrease in ROM; this is because softball players tend to have a larger ROM in the glenohumeral joint compared to the normal population due to the constant strain overhead throwing has on the joint (Gamma et al., 2014; Hibberd et al., 2014). This larger ROM in the glenohumeral joint compared to the normal population is necessary in overhead throwing athletes because it increases the flexibility of the joint and helps protect against overuse injuries. However, too much ROM can be just as dangerous as not enough ROM in overhead throwing athletes; ideally, an overhead throwing athlete should only have a glenohumeral joint ROM slightly larger than those of the normal population (Gamma et al., 2014; Hibberd et al., 2014). When laying in a supine position on the back, a normal individual should be able to externally rotate the arm to 90 degrees and internally rotate the arm to 45 degrees (parallel to the ground) (Gamma et al., 2014; Hibberd et al., 2014). An overhead throwing athlete should be able to go beyond that, about 100 degrees for external rotation and about 60 degrees for internal rotation, or slightly more (Gamma et al., 2014; Hibberd et al., 2014). Too much ROM can put the athlete at risk of injury due to a weak and unstable joint, so a decrease in the degree of ROM in softball players (improvement) could decrease their risk of these injuries (Hibberd et al., 2014). The experimental group showed a mean pre-test measurement of 69.07 $\pm$ 16.34 degrees in internal rotation and 119.73 $\pm$ 12.27 degrees in external rotation, while the control group had a mean pre-test measurement of 70.00 $\pm$ 17.05 degrees and 124.31 $\pm$ 14.31 degrees for internal and external rotation, respectively. The pre-test mean measurements for glenohumeral joint ROM showed that the participants in both groups had an excessive ROM and were at risk of shoulder injury due to instability.

Although no significant difference was observed, the experimental group did have a decrease of 3.13 $\pm$ 19.84 degrees in the direction of internal rotation and a decrease of 3.07 $\pm$ 12.76 degrees in the direction of external rotation. The control group also experienced a decrease of 4.15 $\pm$ 18.67 degrees in the direction of internal rotation; however, the control group experienced an increase of 1.15 $\pm$ 14.76 degrees in the direction of external rotation. This means that the exercises performed by the control group increased the ROM of the glenohumeral joint in the direction of external rotation and may have put the participant at a greater risk of injury due to the joint's muscles losing their elasticity. A large standard deviation within both the experimental group and the control group was found with these ROM measurements, and this might have prevented the statistics from being significant. If a larger population size or longer training intervention was implemented, the standard deviation might have been reduced and a significant difference may have been found between groups. It is also possible that a large standard deviation was found because of a biomechanical difference between infielders and outfielders. An outfielder must bring their arm completely back in order to generate as much force as they possibly can to throw the ball a great length; however, an infielder will actually shorten their throw by not bringing their arm completely back in order to quicken their throw to increase their chances of throwing an opposing runner out at a base. Since an outfield is constantly bringing their arm further back than an infielder, it is possible that an outfielder's ROM is larger than that of an infielder. Future research may benefit from comparing the glenohumeral joint ROM of an outfielder to that of an infielder, instead of just including an equal amount of each (outfield and infield) in each training group.

Both groups experienced an improvement in glenohumeral joint ROM in the direction of internal rotation; however, only the experimental group had an improvement in the direction of external rotation when comparing change scores (experimental group: -3.07 $\pm$ 12.76 degrees; control group: +1.15 $\pm$ 14.76 degrees). Although it was not significant, two-way repeated measures ANOVA group pairwise comparison (Appendix J) showed that external rotation was "trending" towards significance between the experimental group and control group (p = .096). This suggests that a sport-specific resistance tube training program may have an effect on improving glenohumeral joint ROM in the direction of external rotation compared to a control group if a larger population or longer intervention was utilized in the study. External rotation is responsible for the "wind-up" in a softball throw; i.e., it is where the athlete brings her arm back to generate the force needed to propel the softball forward as hard and far as she can (Kibler et al., 2013). By improving glenohumeral joint ROM in external rotation, the athlete will not have to bring her arm back as far to generate the force needed to throw the ball with maximal effort (Hibberd et al., 2014; Kibler et al., 2013; Powers & Howely, 2012).

Anthropometric Measurements

Although no hypotheses regarding anthropometric measurements were made for the study, it is still important to address each as a dependent variable that could change as a result of an eight-week long training program. Anthropometric measurements yielded no significant difference in the combined scores from pre- to post-testing within-subjects (weight: $p = .725$; body fat percentage: $p = .147$; fat mas: $p = .191$; and lean body mass: $p = .157$). This supports the findings of Palmer and colleagues (2015), Sunstrup and colleagues (2014), Van Den Tillaar and Marques (2011) that anthropometric measurements of weight, body fat percentage, fat mass, and lean body mass yielded no statistical differences between the experimental group and the control group within each study. However, statistical significance was viewed when comparing the change scores of the experimental group and the control group in weight, body fat percentage, and fat mass ($p = .013$, $p = .005$, and $p = .004$, respectively). The experimental group experienced a decrease in weight, body fat percentage, and fat mass while the control group experienced an increase in the three variables. When looking at the effects of a training program on body composition, it is ideal to see a loss in fat mass within participants, not an increase. The experimental group had a decrease in fat mass while the control group had an increase in fat mass. This may be because the exercises utilized by the experimental group targeted smaller muscles that are comprised mostly of type I muscle fibers (aerobic muscles fibers). These muscles are designed to last for a longer duration than type II muscle fibers by utilizing the breakdown of fat storage for energy to conserve glycogen stores (Baechle & Earle, 2016; Powers & Howely, 2012). This may have allowed the experimental group to use fat storage to replenish and conserve their bodies' glycogen stores. It is also possible that by completing the study during the team's competitive season, anthropometric measurements may have been affected; when the team is traveling, the athlete's choice in food is limited to where the team stops to eat, possibly making it difficult for an athlete to eat healthy when traveling. Regular in-season lifting can also affect the results of anthropometric measurements; although they are encouraged to give maximal effort while performing their workouts, it is possible that some of the participants did not give full effort, thus, not experiencing the same results as their fellow teammates.

An effect size of $d = 0.51$ in body fat percentage change and $d = 0.50$ in fat mass change between the experimental group and control group indicated that there was a moderate effect with the sport-specific resistance tube training program on these two dependent variables. This suggests that by participating in a resistance tube training program, an individual has a moderate chance of experiencing a decrease in fat mass. If a larger population or a longer training period was implemented, a large effect size ($d \geq 0.80$) might have been found. This could indicate that by participating in a resistance tube training program, an individual has a higher chance of decreasing their fat mass.

Though results indicated no significance in either combined pre- to post-test values or change scores in lean body mass, the control group experienced more of an increase in lean body mass than the experimental group – 0.63 kg more (the experimental group's mean lean body mass change minus the control group's mean lean body mass change). This variable did not yield significant results, and only a small effect size (d = 0.21) was found. This may indicate that by performing the non-sport-specific exercises that targeted the upper body as a whole and not the glenohumeral joint specifically like the experimental group, the exercises performed by the control group appeared to slightly increase the participants' muscle mass compared to the exercises performed by the experimental group. The muscles of the glenohumeral joint (i.e. the rotator cuff muscles) are small muscles that are responsible for stabilizing the joint. It is important to keep them strong to help in preventing injuries and to aid in force development in throwing athletes; however, they will not experience much muscle hypertrophy due to their small size (Baechle & Earle, 2016; Powers & Howley, 2012). This may have given the control group – whose exercises targeted larger muscle groups like the pectorals, latissimus dorsi, biceps, and triceps – an advantage in increasing their lean body mass (Baechle & Earle, 2016; Powers & Howley, 2012).

Summary

Although data analysis revealed statistics that did not support any of the researcher's three hypotheses, meaningful data was discovered. Those who participated in the sport-specific resistance tube training program (experimental group) experienced more of an improvement in mean values of peak throwing velocity, average throwing velocity, 1RM Chop test, and external rotation of the glenohumeral joint, than the control group performing the non-sport-specific exercises (1.08 mph, 0.74 mph, 1.46 kg, and -4.22 degrees, respectively). No significant differences were seen between groups; however, these small improvements in the experimental group compared to the control group may indicate that a resistance tube training program specifically targeting the muscles of the glenohumeral joint may have a slight advantage in improving overhead throwing velocity and glenohumeral joint health than a resistance tube training program that targets the upper body as a whole. At the collegiate level, any improvement (no matter how small) seen in overhead throwing velocity, upper body strength, and glenohumeral joint ROM should give an overhead throwing athlete an advantage over their opponents.

Chapter 6: Summary and Conclusion

Summary of Results

The purpose of this study was to compare the effects of a sport-specific resistance tube training program on overhead throwing velocity and glenohumeral joint ROM in NCAA division II softball players over an eight-week intervention. Specifically, this study investigated whether or not a sport-specific resistance training program would have more of an effect on peak and average throwing velocity, glenohumeral joint ROM in the direction of internal and external rotation, and upper body strength as measured by the 1RM Chop Test. The hypotheses that were tested included:

Hypothesis 1: The experimental group performing the sport-specific exercises with the resistance tubes would experience an improvement in both peak and average overhead throwing velocity compared to the control group.

Hypothesis 2: The experimental group performing the sport-specific exercises with the resistance tubes would experience a greater increase in strength in the Chop test compared to the control group.

Hypothesis 3: The experimental group performing the sport-specific exercises with the resistance tubes would experience an improvement in glenohumeral joint range of motion compared to the control group.

To investigate these hypotheses, all participants completed an eight-week long resistance tube training intervention in either an experimental group performing sport-specific exercises or a control group performing non-sport-specific exercises. Pre- and post-testing included anthropometric measurements, throwing velocity measurements (peak and average velocities of five overhead throws), 1RM Chop Test measurements following Baechle and Earle's (2016) protocol for a 1RM test, and glenohumeral joint ROM measurements in the direction of internal rotation and external rotation. Pre-testing was conducted one week prior to the start of the eight-week long training program, while post-testing was conducted one week after the completion of the eight-week long training program.

Anthropometric measurements were collected using a Seca digital medical scale, Model #220, and a seven-site skinfold measurement technique. Powers and Howley (2012) state that a seven-site skinfold measurement technique is a valid test and can be very accurate in calculating body composition with practice; to ensure reliability and validity, the same researcher conducted pre- and post-test measurements and was tested against a criterion supervising researcher. Pre- and post-test measurements of anthropometric measurements revealed a statistically significant difference between change scores of both the experimental group and the control group in weight, body fat percentage, and fat mass ($p = .013$, $p = .005$, $p = .004$, respectively). Participants in the experimental group experienced a decrease in these three variables (weight: -0.66 $\pm$ 1.59 kg; BF%: -0.90 $\pm$ 0.97 %; Fat mass: -0.75 $\pm$ 0.72 kg), while the control group experienced an increase (weight: 0.87 $\pm$ 1.47 kg; BF%: 0.31 $\pm$ 1.09 %; Fat mass: 0.30 $\pm$ 1.04 kg). These findings indicate that those participating in a sport-specific resistance tube training program have more of a decrease in body fat compared to a non-sport-specific resistance tube training program.

Throwing velocity measurements were collected using a SR-3300 Sports Radar Speed Gun, which has been deemed valid and reliable in measuring throwing velocity (Escamilla et al., 2012; McEvoy & Newton, 1998; Palmer et al., 2015; Prokopy et al., 2008; Van Den Tillaar & Marques, 2011). Average throwing velocity was calculated as the mean of the five overhead throws each participant attempted, while peak throwing velocity was calculated as the highest of the five throws. Statistical analysis revealed that significant differences were found in peak and average throwing velocity when comparing pre-test measurements to post-test measurements for all participants combined ($p = .003$, $p = .006$, respectively). The experimental group increased peak throwing velocity by 2.00 mph and average throwing velocity by 1.65 mph, while the control group increased peak throwing velocity by 0.92 mph and average throwing velocity by 0.91 mph. However, a significant difference was not seen when the experimental group was compared to the control group for either variable. This does not support the researcher's hypothesis that the experimental group performing the sport-specific exercises would experience more of an improvement in both peak and average overhead throwing velocity compared to the control group.

The 1RM Chop Test was chosen to measure any changes in upper body strength post-intervention. This test has been used in past research and has been shown to be a reliable and valid test in testing strength gains that correlate with throwing velocity gains (Palmer & Uhl, 2011; Palmer et al., 2015). A significant difference in the 1RM Chop Test was seen when comparing combined pre- to post-test measurements for both the experimental group and control group ($p = .000$). However, an effect size of d =0.34 was shown for pre- and post-test measurements for the Chop Test, indicating that there is a small effect between a resistance tube training program and the 1RM Chop Test. No significant difference was seen when group means were compared, thus not supporting the researcher's second hypothesis that the experimental group performing the sport-specific exercises would experience a greater increase in strength in the Chop Test compared to the control group.

Glenohumeral joint ROM was measured in the directions of internal rotation and external rotation. These directions of rotation were chosen because they are the most predominant rotations of the glenohumeral joint found in an overhead throw (Gamma et al., 2014; Hibberd et al., 2014). Both directions was measured using a goniometer (Model G-300), with similar models being used in past research (Edouard et al., 2013; Gamma et al., 2014; Hibberd et al., 2014; In-Gui et al., 2015). No significant difference was found in either the internal rotation direction or external rotation direction when comparing pre- to post-testing values or when comparing the experimental group to the control group. This also does not support the researcher's third hypothesis that the experimental group would experience an improvement in glenohumeral joint ROM compared to the control group.

Both the experimental group and control group experienced increases in throwing velocity, 1RM Chop Test, and improvement in glenohumeral joint ROM in the direction of internal rotation. However, mean changes from pre- to post-testing showed that the experimental group tended to experience a slightly greater improvement than the control group in throwing velocity, 1RM Chop Test, and glenohumeral joint ROM in the direction of external rotation. These findings suggest that although there may be a slight advantage to performing sport-specific exercises targeting the glenohumeral joint, there was no statistically significant difference between performing sport-specific resistance tube exercises and non-sport-specific exercises on throwing velocity, 1RM Chop Test strength, or glenohumeral joint ROM over an eight-week long intervention.

Practical Applications

The results show that there is no significant difference between the experimental group and the control group values in throwing velocity, 1RM Chop Test, or glenohumeral joint ROM. However, statistical analysis revealed that there were significant differences when comparing pre-test values to post-test values in throwing velocity, 1RM Chop Test, and glenohumeral joint

ROM for the groups combined. Mean changes showed that, on average, those who participated in the experimental group experienced greater changes in peak and average throwing velocity, 1RM Chop Test, and glenohumeral joint ROM in the external rotation compared to the control group. Although the statistics state it is not significant, participating in a resistance tube training program that targets the muscles of the glenohumeral joint may give a slight but meaningful advantage in increasing throwing velocity, 1RM Chop Test, and improving glenohumeral ROM. At the collegiate level, any increase in overhead throwing velocity is going to be viewed as beneficial, even though it may not be statistically significant. With softball players reaching similar sprinting speeds as baseball players, increasing throwing velocity will increase a defensive player's chances of throwing the opposing runner out at a base, thus, increasing the team's odds of winning (McEvoy & Newton, 1998). A strength and conditioning coach looking to develop a program for female softball players may want to consider incorporating these sport-specific resistance tube exercises, if not for the increase in throwing velocity, then for improving glenohumeral joint ROM.

Although it was not a statistically significant improvement, the experimental group experienced more of a decrease in the direction of external rotation of the glenohumeral joint. External rotation of the glenohumeral joint is what is responsible for the "wind-up" (or arm back) in an overhead throw, which is where the force is produced to complete the throw. Too much range of motion can be as bad as too little; it causes the joint to become unstable and increase the risk of injury (Hibberd et al., 2014; Powers & Howely, 2012). Too much ROM also forces the individual to have to bring her arm further back in order to produce maximal force production; muscles are very elastic, in the sense that they "snap" back into shape after an initial stretch (Powers & Howely, 2012). However, when exposed to a consistent movement that stretches the muscles of the joint, the muscles slowly lose their elasticity and may not have the ability to return to their normal length; this will increase ROM in the joint, but at the expense of force production (Powers & Howely, 2012). By strengthening the muscles of the glenohumeral joint and returning them to their normal lengths, the joint becomes much more stable, decreasing the risk of injury (Hibberd et al., 2014; Powers & Howely, 2012). It will also reduce the strain placed on the glenohumeral joint during an overhead throw because the individual will not have to reach her arm further back to produce the proper amount of force to throw the ball with high velocity and accuracy (Hibberd et al., 2014; Powers & Howely, 2012).

Utilizing resistance tubes in a strength program also allows the freedom of affordability and portability for a softball team. A team that does not have a large budget to pay for weight equipment would have the ability to purchase multiple resistance tube sets for a fraction of the price of weight equipment, while also receiving the same benefits of traditional weight equipment (Escamilla et al., 2012; Sundstrup et al., 2014). Resistance tubes also do not need a lot of room for storage. A team could store the resistance tube sets in their locker room, at their field (if they have a place to store them there), or even assign a set to each member of the team and have them store that set in their softball bag. These resistance tubes could also be taken with a team when they travel; this would allow the team to use the resistance tubes during their warm-up before a game to help activate the muscles of the glenohumeral joint (Escamilla et al., 2012; Gamma et al., 2014; Sundstrup et al., 2014).

Recommendations for Future Research

To date, minimal research has examined the effects of a resistance tube (or band) training program solely on female softball players. The research that has been conducted has been on male baseball players, a combination of both male baseball players and female softball players, or females of other overhead throwing sports (Dohoney et al., 2002; Escamilla et al., 2012; Kuklick et al., 2013; Raeder et al., 2015; Van Den Tillaar & Cabri, 2012; Zinner et al., 2015). The current study compared a sport-specific resistance tube training program to a non-sport-specific resistance tube training program, like the training programs conducted in the previous research; however, the current study was conducted solely on NCAA division II female softball players. No significant differences ($p > 0.05$) were found in the current study between the sport-specific training group and the non-sport-specific training group in throwing velocity, strength as measured by the 1RM Chop Test, or glenohumeral joint ROM. However, significant differences between pre- and post-testing in peak and average throwing velocity, and 1RM Chop Test were found within all subjects combined, and the experimental group experienced slightly higher mean increases than the control group.

The current study was conducted using NCAA Division II softball players at one university. There is a reasonable chance that results could differ in future research if a larger population was studied (i.e., multiple universities), or a different competitive level was chosen (i.e., high school, junior college, DI, DIII, NAIA, professional, etc.). Participants in the current study were also required to have at least five years of experience playing competitive softball. By reducing the experience required to participate, more subjects could be obtained; however, with an experience requirement set lower than five years, future research could run the risk of the participants' throwing arm not being conditioned to the overhead throwing motion. This could skew the results since the participants with less than five years of experience may not have reached their peak throwing velocity or peak strength just yet. By simply participating in a training program, such as in the current study, the participants with less playing experience may have an increase in the previously mentioned variables because of an increase in exercise volume. Pitchers were also excluded from the current study; although they do not throw overhead very often, they may still be required to throw overhead during competition. Including pitchers in the study may have yielded different results, and should be addressed in future research.

Biomechanical analysis using slow motion cameras may also give future researchers a better understanding of glenohumeral joint ROM. Instead of passively rotating the shoulder in either the direction of internal or external rotation, future researchers could video record the athletes performing an overhead throw using high resolution cameras and then analyze the ROM of the glenohumeral joint when the athlete is actually performing the throw. The joint angle can be calculated using the appropriate software by analyzing a freeze-frame of the video when the arm to completely back. This would allow the researchers to gather applicable data that can easily be applied to the movements performed during actual competition.

Future research might see more statistical significance between groups if a training intervention longer than eight weeks was implemented. Exposing the participants to the exercises for a longer duration (i.e., 12 weeks or more) could give the muscles of the glenohumeral joint more time to adapt and increase muscular strength. The current study was also conducted during the softball team's competitive season; this could have skewed results based on the number of throws everyone has during practice and competition. Maintaining a schedule became difficult once the team began traveling, and resulted in many make-up sessions in the current study. It may be beneficial for future research to conduct the study during the team's off-season where the team's schedule could be adjusted to work with the training intervention. This would give the head coach the ability to modify the team workout schedule without the fear of it affecting an upcoming game because there are no games in the off-season.

Conclusion

The results of this study revealed that there was no significant difference between a sport-specific resistance tube training program targeting the muscles of the glenohumeral joint and a non-sport-specific resistance tube training program targeting the upper body as a whole on overhead throwing velocity, strength as measured by the 1RM Chop Test, and glenohumeral joint ROM. This does not support the researcher's three hypotheses that a sport-specific resistance tube training program would have more of an effect on: 1) overhead throwing velocity, 2) upper body strength via the 1RM Chop Test, and 3) glenohumeral joint ROM compared to the control group performing non-sport-specific resistance tube exercises. However, a significant difference was seen in the anthropometric measurements of weight, body fat percentage, and fat mass when comparing the change scores of both the experimental group and the control group. The experimental group saw an average loss of 0.66 $\pm$ 1.59 kg, 0.90 $\pm$ 0.97 %, and 0.75 $\pm$ 0.72 kg in weight, body fat percentage, and fat mass, respectively. The control group had an average gain of 0.87 $\pm$ 1.47 kg, 0.31 $\pm$ 1.09 %, and 0.30 $\pm$ 1.04 kg, in weight, body fat percentage, and fat mass, respectively. This indicates that those participating in a sport-specific resistance tube training program tend to have more of a decrease in the amount of fat mass than a non-sport-specific resistance tube training program.

Although no significant differences were seen between groups in overhead throwing velocity, 1RM Chop Test, or glenohumeral joint ROM, practical significance could be seen. At the collegiate level, any increase in these variables should give an overhead throwing athlete an advantage over their opponents, increasing their chances of winning the game or competition. The experimental group improved an average of 1.08 mph, 0.74 mph, 1.46 kg, and -4.22 degrees more than the control group in peak throwing velocity, average throwing velocity, 1RM Chop

Test, and external rotation of the glenohumeral joint, respectively. It would appear that including a sport-specific resistance tube training program that targets the muscles of the glenohumeral joint in a softball player's strength training program would give the player a slight, but meaningful advantage over her opponents.

The results of the current study may have been limited by completing the study during the team's competitive season and only using participants from a single Division II collegiate team. Future research may want to widen the population size by including multiple teams from multiple performance levels (i.e., high school, junior college, Division I and III, and NAIA). Future research may also want to study the effects of a longer training intervention; exposing the participants to the exercises for a longer period of time may result in more significant differences between groups. It is also recommended that future research conduct the study during the team(s) off-season; a stricter training schedule can be implemented and the researcher would be able to work more closely with the head coach to make sure the team's normal training did not interfere with the study's training intervention.

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Appendix A: Institutional Review Board Consent Form

Institutional Review Board Consent Form

Adams State University

Request to obtain approval for the use of human participants – expedited review

Date: December 5th, 2016

To: Adams State University

Request to obtain approval for the use of human participants – expedited review

Date: December 5th, 2016

To: Beth Bonnstetter

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Responsible Faculty Member

Chair of Thesis Committee: Tracey Robinson, Ph.D.

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Phone: (719) 587-7663

Subject: The Effects of a Sport-Specific Upper Body Resistance Tube Training Program on Overhead Throwing Velocity and Glenohumeral Joint Range of Motion in NCAA Division II Softball Players

Research Assistants: Possible senior undergraduate students, and head strength and conditioning coach, Matt Gersick.

Title of the Research: The Effects of a Sport-Specific Upper Body Resistance Tube Training Program on Overhead Throwing Velocity and Glenohumeral Joint Range of Motion in NCAA Division II Softball Players

Objectives of the Research: Fastpitch softball is a sport played worldwide, with millions of participants. There are a variety of different levels including little league, club, collegiate, and professional. Many studies have investigated the effects of resistance training programs on overhead throwing velocity in high school and collegiate level male baseball players and other overhead throwing sports, such as water polo and team handball, and were able to show increases in velocities (Escamilla et al., 2012; Kuklick et al., 2013; Raeder et al., 2015; Van Den Tillaar & Cabri, 2012; and Zinner et al., 2015). The research on collegiate fastpitch female softball players is very limited and must be expanded on. The purpose of this study is to identify if an upper body resistance tube training program produces an increase in the overhead throwing velocity and glenohumeral joint range of motion of Division II collegiate female softball players. It is necessary to identify the specific exercises that contribute to an increase in overhead throwing velocity and glenohumeral joint range of motion.

Benefits

The benefits of participation in this study may include, but are not limited to, the following: increased overhead throwing velocity, improved glenohumeral joint range of motion, and increases in upper body strength and power production. Identifying specific exercises that cause an increase in upper body strength and power production to produce an increase in overhead throwing velocity will also be beneficial. Many exercises have already been shown to produce an increase in overhead throwing velocities in males and other overhead throwing sports other than softball. It is crucial to determine exercises and improve knowledge that will potentially improve performance for the female, fastpitch softball population.

Risks and Discomforts

There are possible risks associated with the study that include the potential for injury to the glenohumeral joints, upper back, and upper and lower arms, that are associated with any lifting program. To minimize the potential for injury, the exercises will be instructed and supervised by the primary researcher and Matt Gersick (Head Strength and Conditioning Coach at the university). Every professional effort will be made to minimize any risks involved in this study. Minimal discomfort and/or bruising can occur during pre- and post-testing skinfold measurements to determine body composition (percent body fat). Participants may also experience muscle soreness due to the training programs. The risks of participating in a resistance training program are less than that of playing the actual sport.

Methods of Procedures

Thirty participants will be randomly selected from a group of forty-five fastpitch Division II softball players from the university women's softball team. Participants will be divided equally into two groups – an experimental group and a control group. Group one will be identified as the experimental group, performing the regular in-season strength and conditioning program, as well as a sport-specific resistance tube training program. Group two will be identified as the control group, performing the regular in-season strength and conditioning program, as well as a non-sport-specific resistance tube training program. The control group's training program is designed to assure an equal volume of training for both groups. Both eight-week long training programs have been developed by the researcher and the head strength and conditioning coach. Each week will consist of three training days (Mondays, Wednesdays, and Fridays), with one day of rest in between. Each training session will last a maximum of 45 minutes. Each training session will begin with five minutes of dynamic warm-up, to increase quality of exercise and muscle blood flow. No deception will be involved in the study.

Specific pre/post laboratory tests:

All participants will be asked to sign a consent form to participate in this study. After consent has been given, participants will be asked to complete a short demographic and history survey. Participants will complete pre- and post-test anthropometric measures including weight, height, and body composition (skinfold measurements via skinfold calipers).

Pre- and post-tests of glenohumeral joint range of motion will be measured in Plachy Hall located on the university campus. Participants will be instructed to lay flat on their back on a table and relax their upper body. Another researcher – a senior undergraduate student – will place one hand on top of the participant's glenohumeral joint, and then passively rotate the participant's arm externally until resistance is felt and the arm cannot rotate any further or verbal instruction to stop is given by the participant. The primary researcher will then use a goniometer to measure the degree of rotation of the glenohumeral joint. The process will be repeated for internal rotation of the glenohumeral joint.

Pre- and post-tests of overhead throwing velocity will be measured in the Athletic Field House at the university. Participants will perform a ten-minute self-regulated throwing warm-up with a partner. The participant will then be instructed to take five warm-up throws by throwing the designated softball at the designated target. This warm-up is designed to familiarize the participant with the testing station and to reduce any pre-test anxiety. Participants will then be instructed to maximally throw an additional five balls into the target to measure overhead throwing velocity. Participants are not permitted to view their overhead throwing velocity results. Ten seconds of rest will be allowed between throws. The participants must throw the ball accurately into the target to allow the SR-3300 radar gun to get an accurate reading. The SR-3300 radar gun is a type of radar gun that uses the Doppler Effect to measure the velocity of a moving object passing stationary objects, and will be used to measure overhead throwing velocity.

Pre- and post-testing protocol for a 1RM of a Chop Test will be taken from Baechle and Earle (2016): Participants will be instructed to warm-up with light resistance that easily allows five to ten repetitions of a "chop"; a rest of one minute will be allowed. Participants will then estimate a load that is near their predicted 1RM and perform an additional three to five repetitions. Since the test is being conducted on a cable machine, weight will be increased by one plate (five pounds) and one repetition will be completed, with a three minute rest between sets. The weight will continue to be increased by one plate until failure occurs. Once failure occurs, the participant will drop the weight by one plate and will attempt another repetition, and the weight will be recorded as their 1RM. To reduce the risk for injury the pre- and post-testing sessions will be monitored by a certified strength and conditioning specialist.

Research Design: This is an independent research for a Master's thesis. Data will be analyzed using SPSS statistical analysis software. The independent variables in this study will be the treatment groups (experimental and control resistance tube training programs). The dependent variables will be the peak and average overhead throwing velocity, glenohumeral joint range of motion, 1RM Chop Test, and anthropometric measurements.

The Setting: The study will take place at a Division II university. All participants will complete pre- and post-test measures of overhead throwing velocity in the Athletic Field House. Anthropometric measures as well as glenohumeral joint range of motion measures will also be taken in Plachy Hall on the university campus. The 1RM Chop test will be performed in the university weight room. Training sessions will be conducted on the university softball field forty-five minutes prior to the start of the team's regular in-season practice. If weather does not permit the training program to be conducted at the softball field, the exercises will be completed in the Athletic Field House on the university campus.

Participants: A group of thirty female fastpitch softball players from an NCAA Division II university women's softball team will volunteer to participate in the study. The university head softball coach has given permission for the team to participate, if they choose, in the eight-week training program. The participants' ages will range from 18 – 23 years old. Pitchers will be excluded from the study due to the fact that they throw the ball underhand for the majority of competition. Those with less than five years of softball experience will be excluded from the study; this is to ensure that the participants' arms are well conditioned in overhead throwing.

Protection Measures

Participation is voluntary and will be held confidential. Participants may choose not to answer any questions they do not want to answer and/or may withdraw from participation at any time, without penalty. Names will not be used in the study; participants will be assigned a number and group data will be reported. Data will be locked under a password protected computer for one year in which the researcher only has the password. If research is used in public forum, data will be reported as a group without individual or school identification.

Consent: Participants will be asked to read over and sign the consent form before any testing begins. The informed consent is attached separately.

Changes: If any changes are made to the research I will contact the IRB immediately and fill out the needed paperwork.

1/17/17
1/17/17

Name and Signature of Department Chair Appropriate Person

Date

Name and Signature of IRB chair

1-17-17
Date

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...STITUTIONAL REVIEW BO...
...proved on: 1-17-17
...: 1-17-18

The Effects of a Sport-Specific Upper Body Resistance Tube Training Program on Overhead Throwing Velocity and Glenohumeral Joint Range of Motion in NCAA Division II Softball Players

Erika Ecsedy

Adams State University

Human Performance and Physical Education

Purpose of Research

The purpose of this study is to identify if an upper body resistance tube training program produces an increase in the overhead throwing velocity and glenohumeral joint range of motion in Division II collegiate fastpitch softball players. The secondary purpose of this study is to identify the specific exercises that contribute to an increase in overhead throwing velocity and glenohumeral joint range of motion. You have been identified by the researcher as a potential volunteer for this study because you met the criteria of being a Division II, collegiate softball player.

Procedures

Participants, will be randomly assigned to one of two groups: group one and group two (both will complete their regular in-season lifting with additional resistance tube exercises). Each training session will last a maximum of 45 minutes. Randomization of the two groups will be performed equally, based on collegiate softball experience, age, and position.

Training Program:

The eight (8) week training program will be performed at the university softball field under the supervision of Erika Ecsedy (Primary Researcher) and Matt Gersick (Head Strength and Conditioning Coach). Both additional resistance tube programs will be performed the same day, prior to the start of the regular, in-season practice session.

If you are randomly selected to participate in group one, you will perform your regular, in-season lifting program two days a week (Tuesdays and Thursdays), as well as a resistance tube training program three times a week (Mondays, Wednesdays, and Fridays). Exercises for group one include: bilateral shoulder raises, internal shoulder rotation, external shoulder rotation, resisted shoulder flexion, resisted shoulder extension, resisted shoulder pinch, 90/90 internal shoulder rotation, 90/90 external shoulder rotation, overhead pulls, straight fly, overhead fly, and overhead-behind the head fly.

If you are randomly selected to participate in group two, you will perform your regular, in-season lifting program two days a week (Tuesdays and Thursdays), as well as additional resistance tube exercise three times a week (Mondays, Wednesdays, and Fridays). Exercises for group two include: bicep curls, triceps pull-downs, triceps extensions, rows, chest press, incline chest press, push-ups, latissimus pull-downs, resistance tube twist, rotational chop, and resistance tube pull through.

Written explanations and pictorial representations of each exercise that will be utilized in the study is attached separately, but demonstration will also be provided by the researcher to ensure proper form.

Benefits

The potential benefits from participating in this study include, but are not limited to: increased overhead throwing velocity, improved glenohumeral joint range of motion, and an increase in upper body strength and power production.

Risks and Discomforts

There are risks associated with the study that include the potential for injury, with any lifting program. Injuries most often occur within a lifting program due to improper progression, improper loads, or poor technique. Every effort will be made to minimize the risk of injury throughout this study by performing the program under the supervision of certified professionals, teaching and encouraging proper form, and by having the training programs written by individuals with years of experience with softball and resistance training. As a participant, to minimize your individual potential for injury, you will be asked to perform exercises to the best of your ability while being supervised by certified professionals. You may also experience the discomfort of muscle soreness, which is common with any new training program. In general, the risks associated with a resistance training program are less than that of playing the actual sport of softball.

Confidentiality

The researcher will not identify me by name in any reports using information obtained from this study. Any use of data and records will be subject to standard data use policies, which protect the anonymity of individuals. Data will be locked under a password protected computer for one year in which the researcher only has the password. Consent forms will be stored in a locked file in the Thesis Chair's office.

I understand that this study will be reviewed and approved by the Institutional Review Board (IRB) for Studies Involving Human Subjects at Adams State University. I understand that I can contact the Primary Researcher, and/or the Thesis Chair at any time with questions or concerns regarding the study.

Primary Researcher
Erika Ecsedy
ecsedyen@grizzlies.adams.edu
(661) 361 – 4542

Thesis Chair
Dr. Tracey Robinson
tlrobins@adams.edu
(719) 587 – 7663

Human Subject Statement

If you have any questions regarding your rights as a participant in this research and/or concerns about the study, or if you feel under any pressure to enroll or to continue to participate in this study, you may contact Beth Bonnstetter with the Adams State University Institutional Review Board (which is a group of people who review the research studies to protect participants' rights).

IRB Chair
Beth Bonnstetter
bonnstetter@adams.edu
(719) 587 – 7494

A copy of this consent form will be given to you to keep.

I hereby voluntarily give consent to engage in a resistance tube training program to see the effects on overhead throwing velocity and glenohumeral joint range of motion. I understand that the training program will involve resistance training and the study is designed to gather information about the effects of an eight-week training program on throwing velocity and glenohumeral joint range of motion. I understand that during the eight weeks of training and testing I will be encouraged to work at maximum effort. I understand that I will be one of approximately 30 participants in the study. Lastly, I understand that I may choose to withdraw from the study, at any time, with no penalty. I have had the opportunity to read this consent form and I understand what participation in this study involves. Any questions which may have occurred to me concerning this informed consent have been answered to my satisfaction.

______________________________ ______________________

Participant's Signature   Date

____

Participant's Name (Printed)

______________________________ ______________________

Researcher's Signature   Date

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1-17-18

Appendix B: Participant Demographic Questionnaire

Please answer all questions to the best of your knowledge:

1. Age: ____________________________
2. Eligibility Year: _______________________________
3. Do you throw using your right or left arm? RIGHT / LEFT
4. Have you ever suffered an injury to your throwing arm? YES / NO

   If YES, what part of the arm (i.e. forearm, shoulder, etc.), how long ago, and how long until you could return to playing?

   ____

   ____

5. How many years have you participated in Fastpitch softball? ______________________
6. What position(s) do you play? (List all if more than one)

   ____

   ____

7. How many hours a week do you spend at defensive practice? ______________________
8. Do you throw on your own outside of official team practice? YES / NO

   If YES, how many extra hours a week? ____

9. Do you take part in additional exercise outside of your sport or the regular training you are required to participate in? (i.e. extra weights, running on your own, etc.) YES / NO

   If YES, what do you do and how many hours a week for each activity?

   ____

   ____

   ____

Appendix C: Data Collection Sheet

Data Form

Name ____________________________ Age: __________ Class: ___________

I.D. # ____________________________

Height: ______________ ft. Weight: Pre-Test ___________lbs. Post-Test ___________lbs.

Skinfold Measurements:

Pre-Test:	___________ **date**	**Post-Test:**	__________ **date**
Chest:	___________mm	Chest	__________mm
Axilla:	___________mm	Axilla:	__________mm
Triceps:	___________mm	Triceps:	__________mm
Subscapula:	___________mm	Subscapula:	__________mm
Suprailiac:	___________mm	Suprailiac:	__________mm
Abdomen:	___________mm	Abdomen:	__________mm
Thigh:	___________mm	Thigh:	__________mm
% Body Fat:	___________	% Body Fat:	___________
LBM:	___________lbs.	LBM:	___________lbs.
Fat Mass:	___________lbs.	Fat Mass:	___________lbs.

1RM Chop Test:

Pre-Test: _______________ **date**	**Post-Test:** _______________ **date**
_______________ lbs.	_______________ lbs.

Glenohumeral Joint ROM:

Pre-Test:	_______________ **date**	**Post-Test:**	_______________ **date**
Internal:	_______________ degrees	Internal:	_______________ degrees
External:	_______________ degrees	External:	_______________ degrees

Overhead Throwing Velocity:

Pre-Test: _______________ date

Throw	Velocity (mph)
1.	
2.	
3.	
4.	
5.	
Average:	
Peak:	

Post-Test: _______________ date

Throw	Velocity (mph)
1.	
2.	
3.	
4.	
5.	
Average:	
Peak:	

Additional Notes:

____

____

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____

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____

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Appendix D: Warm-Up Protocol

All exercises were performed once and then followed by a second set. One minute of rest was allowed between each set.

Exercise	Repetitions	Sets
Arm Circles (Forward)	10	2
Arm Circles (Backward)	10	2
Arm Swings (right arm on top)	10	2
Arm Swings (left arm on top)	10	2
Alternating Toe Touches	10 per side	2
Trunk Rotation	10 per side	2

Appendix E: 8-Week Experimental Training Program

The following exercises were performed in the order listed in the training program. All sets and repetitions of the exercises were completed before continuing on to the next listed exercise. Exercises were required to be performed by both the left and right arm, regardless of which the participant deemed as their dominant throwing arm. A thirty-second rest was implemented between each set.

Red* - 6-8 lbs. of resistance
Blue** - 9-11 lbs. of resistance
Green*** - 12-14 lbs. of resistance

Week 1	Exercise	Sets	Reps	Resistance
Day 1	Internal Rotation	2	10 per arm	Red*
	External Rotation	2	10 per arm	Red*
	Bilateral Shoulder Raises	2	10	Red*
	Resisted Shoulder Pinch	2	10	Red*
Day 2	Straight Fly	2	10	Red*
	Overhead Fly	2	10	Red*
	Overhead-Behind the Head Fly	2	10	Red*
	Overhead Pull	2	10	Red*
Day 3	Resisted Flexion	2	10 per	Red*
	Resisted Extension	2	10 per	Red*
	90/90 Internal Rotation	2	10 per	Red*
	90/90 External Rotation	2	10 per	Red*

Week 2	Exercise	Sets	Reps	Resistance
Day 1	Internal Rotation	2	10 per	Red*
	External Rotation	2	10 per	Red*
	Bilateral Shoulder Raises	2	10	Red*
	Resisted Shoulder Pinch	2	10	Red*
Day 2	Straight Fly	2	10	Red*
	Overhead Fly	2	10	Red*
	Overhead-Behind the Head Fly	2	10	Red*
	Overhead Pull	2	10	Red*
Day 3	Resisted Flexion	2	10 per	Red*
	Resisted Extension	2	10 per	Red*
	90/90 Internal Rotation	2	10 per	Red*
	90/90 External Rotation	2	10 per	Red*

Week 3	Exercise	Sets	Reps	Resistance
Day 1	Internal Rotation	3	10 per	Blue**
	External Rotation	3	10 per	Blue**
	Bilateral Shoulder Raises	3	10	Blue**
	Resisted Shoulder Pinch	3	10	Blue**
Day 2	Straight Fly	3	10	Blue**
	Overhead Fly	3	10	Blue**
	Overhead-Behind the Head Fly	3	10	Blue**
	Overhead Pull	3	10	Blue**
Day 3	Resisted Flexion	3	10 per	Blue**
	Resisted Extension	3	10 per	Blue**
	90/90 Internal Rotation	3	10 per	Blue**
	90/90 External Rotation	3	10 per	Blue**

Week 4	Exercise	Sets	Reps	Resistance
Day 1	Internal Rotation	3	10 per	Blue**
	External Rotation	3	10 per	Blue**
	Bilateral Shoulder Raises	3	10	Blue**
	Resisted Shoulder Pinch	3	10	Blue**
Day 2	Straight Fly	3	10	Blue**
	Overhead Fly	3	10	Blue**
	Overhead-Behind the Head Fly	3	10	Blue**
	Overhead Pull	3	10	Blue**
Day 3	Resisted Flexion	3	10 per	Blue**
	Resisted Extension	3	10 per	Blue**
	90/90 Internal Rotation	3	10 per	Blue**
	90/90 External Rotation	3	10 per	Blue**

Week 5	Exercise	Sets	Reps	Resistance
Day 1	Internal Rotation	3	10 per	Blue**
	External Rotation	3	10 per	Blue**
	Bilateral Shoulder Raises	3	10	Blue**
	Resisted Shoulder Pinch	3	10	Blue**
Day 2	Straight Fly	3	10	Blue**
	Overhead Fly	3	10	Blue**
	Overhead-Behind the Head Fly	3	10	Blue**
	Overhead Pull	3	10	Blue**
Day 3	Resisted Flexion	3	10 per	Blue**
	Resisted Extension	3	10 per	Blue**
	90/90 Internal Rotation	3	10 per	Blue**
	90/90 External Rotation	3	10 per	Blue**

Week 6	Exercise	Sets	Reps	Resistance
Day 1	Internal Rotation	3	15 per	Green***
	External Rotation	3	15 per	Green***
	Bilateral Shoulder Raises	3	15	Green***
	Resisted Shoulder Pinch	3	15	Green***
Day 2	Straight Fly	3	15	Green***
	Overhead Fly	3	15	Green***
	Overhead-Behind the Head Fly	3	15	Green***
	Overhead Pull	3	15	Green***
Day 3	Resisted Flexion	3	15 per	Green***
	Resisted Extension	3	15 per	Green***
	90/90 Internal Rotation	3	15 per	Green***
	90/90 External Rotation	3	15 per	Green***

Week 7	Exercise	Sets	Reps	Resistance
Day 1	Internal Rotation	3	15 per	Green***
	External Rotation	3	15 per	Green***
	Bilateral Shoulder Raises	3	15	Green***
	Resisted Shoulder Pinch	3	15	Green***
Day 2	Straight Fly	3	15	Green***
	Overhead Fly	3	15	Green***
	Overhead-Behind the Head Fly	3	15	Green***
	Overhead Pull	3	15	Green***
Day 3	Resisted Flexion	3	15 per	Green***
	Resisted Extension	3	15 per	Green***
	90/90 Internal Rotation	3	15 per	Green***
	90/90 External Rotation	3	15 per	Green***

Week 8	Exercise	Sets	Reps	Resistance
Day 1	Internal Rotation	3	15 per	Green***
	External Rotation	3	15 per	Green***
	Bilateral Shoulder Raises	3	15	Green***
	Resisted Shoulder Pinch	3	15	Green***
Day 2	Straight Fly	3	15	Green***
	Overhead Fly	3	15	Green***
	Overhead-Behind the Head Fly	3	15	Green***
	Overhead Pull	3	15	Green***
Day 3	Resisted Flexion	3	15 per	Green***
	Resisted Extension	3	15 per	Green***
	90/90 Internal Rotation	3	15 per	Green***
	90/90 External Rotation	3	15 per	Green***

Appendix F: 8-Week Control Training Program

The following exercises were performed in the order listed in the training program. All sets and repetitions of the exercises were completed before continuing on to the next listed exercise. Exercises were required to be performed by both the left and right arm, regardless of which the participant deemed as their dominant throwing arm. A thirty-second rest was implemented between each set.

Red* - 6-8 lbs. of resistance
Blue** - 9-11 lbs. of resistance
Green*** - 12-14 lbs. of resistance

Week 1	Exercise	Sets	Reps	Resistance
Day 1	Bicep Curl	2	10 per	Red*
	Triceps Pull-Down	2	10 per	Red*
	Chest Press	2	10	Red*
	Wrist Flexion	2	10 per	Red*
Day 2	Row	2	10	Red*
	Latissimus Pull-Down	2	10	Red*
	Resistance Tube Pull Through	2	10	Red*
	Rotational Chop (Low to High)	2	10 per	Red*
Day3	Triceps Extension	2	10 per	Red*
	Resisted Push-Ups	2	10	Red*
	Resistance Tube Twist	2	10 per	Red*
	Incline Chest Press	2	10	Red*

Week 2	Exercise	Sets	Reps	Resistance
Day 1	Bicep Curl	2	10 per	Red*
	Triceps Pull-Down	2	10 per	Red*
	Chest Press	2	10	Red*
	Wrist Flexion	2	10 per	Red*
Day 2	Row	2	10	Red*
	Latissimus Pull-Down	2	10	Red*
	Resistance Tube Pull Through	2	10	Red*
	Rotational Chop (Low to High)	2	10 per	Red*
Day3	Triceps Extension	2	10 per	Red*
	Resisted Push-Ups	2	10	Red*
	Resistance Tube Twist	2	10 per	Red*
	Incline Chest Press	2	10	Red*

Week 3	Exercise	Sets	Reps	Resistance
Day 1	Bicep Curl	3	10 per	Blue**
	Triceps Pull-Down	3	10 per	Blue**
	Chest Press	3	10	Blue**
	Wrist Flexion	3	10 per	Blue**
Day 2	Row	3	10	Blue**
	Latissimus Pull-Down	3	10	Blue**
	Resistance Tube Pull Through	3	10	Blue**
	Rotational Chop (Low to High)	3	10 per	Blue**
Day3	Triceps Extension	3	10 per	Blue**
	Resisted Push-Ups	3	10	Blue**
	Resistance Tube Twist	3	10 per	Blue**
	Incline Chest Press	3	10	Blue**

Week 4	Exercise	Sets	Reps	Resistance
Day 1	Bicep Curl	3	10 per	Blue**
	Triceps Pull-Down	3	10 per	Blue**
	Chest Press	3	10	Blue**
	Wrist Flexion	3	10 per	Blue**
Day 2	Row	3	10	Blue**
	Latissimus Pull-Down	3	10	Blue**
	Resistance Tube Pull Through	3	10	Blue**
	Rotational Chop (Low to High)	3	10 per	Blue**
Day3	Triceps Extension	3	10 per	Blue**
	Resisted Push-Ups	3	10	Blue**
	Resistance Tube Twist	3	10 per	Blue**
	Incline Chest Press	3	10	Blue**

Week 5	Exercise	Sets	Reps	Resistance
Day 1	Bicep Curl	3	10 per	Blue**
	Triceps Pull-Down	3	10 per	Blue**
	Chest Press	3	10	Blue**
	Wrist Flexion	3	10 per	Blue**
Day 2	Row	3	10	Blue**
	Latissimus Pull-Down	3	10	Blue**
	Resistance Tube Pull Through	3	10	Blue**
	Rotational Chop (Low to High)	3	10 per	Blue**
Day3	Triceps Extension	3	10 per	Blue**
	Resisted Push-Ups	3	10	Blue**
	Resistance Tube Twist	3	10 per	Blue**
	Incline Chest Press	3	10	Blue**

Week 6	Exercise	Sets	Reps	Resistance
Day 1	Bicep Curl	3	15 per	Green***
	Triceps Pull-Down	3	15 per	Green***
	Chest Press	3	15	Green***
	Wrist Flexion	3	15 per	Green***
Day 2	Row	3	15	Green***
	Latissimus Pull-Down	3	15	Green***
	Resistance Tube Pull Through	3	15	Green***
	Rotational Chop (Low to High)	3	15 per	Green***
Day3	Triceps Extension	3	15 per	Green***
	Resisted Push-Ups	3	15	Green***
	Resistance Tube Twist	3	15 per	Green***
	Incline Chest Press	3	15	Green***

Week 7	Exercise	Sets	Reps	Resistance
Day 1	Bicep Curl	3	15 per	Green***
	Triceps Pull-Down	3	15 per	Green***
	Chest Press	3	15	Green***
	Wrist Flexion	3	15 per	Green***
Day 2	Row	3	15	Green***
	Latissimus Pull-Down	3	15	Green***
	Resistance Tube Pull Through	3	15	Green***
	Rotational Chop (Low to High)	3	15 per	Green***
Day3	Triceps Extension	3	15 per	Green***
	Resisted Push-Ups	3	15	Green***
	Resistance Tube Twist	3	15 per	Green***
	Incline Chest Press	3	15	Green***

Week 8	**Exercise**	**Sets**	**Reps**	**Resistance**
Day 1	Bicep Curl	3	15 per	Green***
	Triceps Pull-Down	3	15 per	Green***
	Chest Press	3	15	Green***
	Wrist Flexion	3	15 per	Green***
Day 2	Row	3	15	Green***
	Latissimus Pull-Down	3	15	Green***
	Resistance Tube Pull Through	3	15	Green***
	Rotational Chop (Low to High)	3	15 per	Green***
Day3	Triceps Extension	3	15 per	Green***
	Resisted Push-Ups	3	15	Green***
	Resistance Tube Twist	3	15 per	Green***
	Incline Chest Press	3	15	Green***

Appendix G: Regular In-Season Weight-Lifting Program

The following training program was developed by the Head Strength and Conditioning coach at the university for the university's women's softball team's in-season training schedule.

*ROM – range of motion
**BW – body weight
***AMAP – as much [weight] as possible

Week 1	Exercises	Sets	Reps	Emphasis
Day 1	Trap Bar Jump	3	5	Explosive
	Medicine Ball Seated Jump	3	6	Explosive
	Dumbbell 3-Way Lunge	3	3 per	ROM*
	Bodyweight Power Step-Up	3	4 per	Explosive
	Dumbbell 1-Arm Row	3	12 per	AMAP***
	Trap Bar RDL	3	10	AMAP***
	Band Ankle Flexion	3	15 per	Control
	Dumbbell Single Leg Hip Extension	3	6 per	Control
	Medicine Ball Sit-Up & Throw w/ Partner	3	6	Explosive
	Plate Sit-Up & Twist	3	12 per	Control
	Plank & Shoulder Tap	3	12 per	Control

Week 2	Exercises	Sets	Reps	Emphasis
Day 1	Front Squat	3	3	ROM*
	Plate Jump	3	6	Explosive
	Dumbbell Bench Press	3	8	Control
	Clap Push-Up	3	6	Explosive
	Chin-up	3	6 to 8	BW**
	Barbell RDL	3	6 to 8	AMAP***
	Dumbbell Heel Raises	3	12 to 15	AMAP***
	V-Up	3	15	BW**
	Medicine Ball Side Throw	3	8 per	Control
Day 2	Dumbbell Squat Jump	3	3	Explosive
	BW Lateral Hop	3	6 per	BW**
	Dumbbell Step-Up & Reverse Lunge	3	4 per	AMAP***
	Barbell Bent Over Row	3	12	AMAP***
	P/C Attack	3	6 to 8 per	5-15 lbs
	Dumbbell Hamstring Walkout	3	6	BW**
	Alternating V-Up	3	10 per	BW**
	3-Way Plank	30s/30s/60s		

Week 3	Exercises	Sets	Reps	Emphasis
Day 1	Back Squat	3	6, 4, 2	ROM*
	Plate Jump	3	8	Explosive
	Dumbbell Incline Press	3	6	Control
	Clap Push-Up	3	8	Explosive
	Barbell RDL	3	4 to 6	AMAP***
	Dumbbell Heel Raise	3	12	AMAP***
	Plate Sit-Up	3	15	25 lbs
	Russian Twist	3	12 per	BW**
	I, Y, T, W	3	15s per	BW**
Day 2	Trap Bar Jump	5	3	Explosive
	Trap Bar Deadlift	5	3	ROM*
	Dumbbell Power Step-Up	3	4 to 6 per	Explosive
	Bench Press	5	3	ROM*
	Dumbbell 1-Arm Row	4	6 to 8 per	Heavy
	Side Lying Extensions	4	8 to 10 per	Control
	Seated Medicine Ball Side Throw	3	8 per	Explosive

Week 4	Exercises	Sets	Reps	Emphasis
Day 1	Front Squat	3	6, 4, 2	ROM*
	Dumbbell Split Squat Jump	3	5 per	Explosive
	Dumbbell Bench Press	3	6	Control
	Medicine Ball Throw	3	8	Explosive
	Pull-up	3	4 to 6	BW**
	Dumbbell Single Leg RDL	3	6 per	ROM*
	Dumbbell Heel Raise	3	10 to 12	Control
	Dumbbell Suitcase Deadlift	3	6	Control
	V-Up	3	12	BW**
	3-Way Plank	3	70s/40s/40s	BW**
Day 2	Dumbbell Squat Jump	3	6, 4, 2	Explosive
	BW Lateral Jump	3	8 per	Explosive
	Dumbbell Step-Up & Back Lunge	3	5 per	Control
	P/C Attack	3	6	Control
	Glute/Hamstring Raise	3	8	Control
	Band Ankle Flexion	3	12 per	ROM*
	Medicine Ball Side Throw	3	12 per	Explosive
	Back Extension	3	12	BW**

Week 5	Exercises	Sets	Reps	Emphasis
Day 1	Trap Bar Jump	5	3	Explosive
	Back Squat	5	5	Heavy
	Barbell Row	5	12	AMAP***
	Plate Overhead Bulgarian Split Squat	4	8 per	AMAP***
	Glute/Hamstring Cuban Press	4	12	5-15 lbs
	Chin-Up or Pulldowns	4	12	AMAP***
Day 2	Dumbbell Squat Jump	5	3	20-30 lbs
	Trap Bar Deadlift	5	5	Heavy
	Bench Press	5	5	Heavy
	Dumbbell Single Leg RDL & Overhead Press	5	10 per	AMAP***
	Seated Medicine Ball Partner Throw	4	8 per	Light
	Split Squat Hitter's Throw	4	8 per	Light
	Medicine Ball Russian Twist	2	15 per	Light
	Glute/Hamstring Partner Throw	2	12	Light

Week 6	Exercises	Sets	Reps	Emphasis
Day 1	Trap Bar Jump	5	4	Explosive
	Back Squat	5	4	ROM*
	Barbell Bent Over Row	5	10	AMAP***
	Plate Overhead Bulgarian Split Squat	4	7 per	AMAP***
	Glute/Hamstring Cuban Press	4	10	5-15 lbs
	Chin-Up or Pulldown	4	10	AMAP***
Day 2	Dumbbell Squat Jump	5	4	30-40 lbs
	Trap Bar Deadlift	5	4	Heavy
	Bench Press	5	4	Heavy
	Dumbbell Single Leg & Overhead Press	5	8 per	AMAP***
	Seated Medicine Partner Throw	4	8	10-15 lbs
	Split Squat Hitter's Throw	4	8 per	6-12 lbs

Week 7	Exercises	Sets	Reps	Emphasis
Day 1	Trap Bar Jump	5	5	Explosive
	Back Squat	5	3	Heavy
	Barbell Bent Over Row	5	8	AMAP***
	Plate Overhead Bulgarian Split Squat	5	8	AMAP***
	Glute/Hamstring Cuban Press	4	8	5-15 lbs
	Chin-Up or Pulldown	4	8	AMAP***
	Plate Sit-Up & Twist	2	15	15-25 lbs
	3-way Plank	2	40s/30s/30s	BW**
Day 2	Dumbbell Squat Jump	5	5	35-45 lbs
	Trap Bar Deadlift	5	3	Heavy
	Bench Press	5	3	Heavy
	Dumbbell Single Leg RDL & Press	5	6 per	AMAP***
	Seated Medicine Ball Partner Throw	4	6	8-15 lbs
	Split Squat Hitter's Throw	4	6 per	8-15 lbs
	Medicine Ball Russian Twist	2	15 per	12-15 lbs
	P/C Attack	2	15 per	10-25 lbs

Week 8	Exercises	Sets	Reps	Emphasis
Day 1	Trap Bar Jump	5	6	Explosive
	Back Squat	5	2	Heavy
	Barbell Bent Over Row	5	6	AMAP***
	Plate Overhead Bulgarian Split Squat	4	5 per	AMAP***
	Glute/Hamstring Cuban Press	4	6	Moderate
	Chin-Up or Pulldown	4	6	AMAP***
Day 2	Dumbbell Squat Jump	5	6	Explosive
	Trap Bar Deadlift	5	2	Heavy
	Bench Press	5	2	Heavy
	Dumbbell Single Leg RDL	5	5	AMAP***
	Seated Medicine Ball Partner Throw	4	6	Light
	Split Squat Hitter's Throw	4	6 per	Light

Appendix H: Exercises for Experimental Group

The following is a visual aid and explanation of each exercise the experimental group performed. These were sport-specific exercises that targeted the primary muscles used in an overhead throw, primarily the rotator cuff muscles. The resistance tube was connected to the chain-link fence on the Adams State University softball field unless otherwise specified.

Bilateral Shoulder Raises

Holding the resistance tube in both hands, the participant bends both elbows to 90 degrees with forearms forward and placed at their sides. Pushing the scapuli together, the participant was instructed to rotate arms up and out away from the body. They then slowly lowered their arms back to the starting position.

Internal Shoulder Rotation

The participant was instructed to hold the resistance tube in one hand with their elbow at their side, bent at 90 degrees with forearm out in front of their body. They then slowly rotated their forearm in across their body, pulling against the resistance tube. They were then instructed to slowly rotate their forearm back out to the starting position.

External Shoulder Rotation

Holding the resistance tube in one hand with their elbow at their side, bent at 90 degrees and forearm out in front of their body, the participant was instructed to slowly rotate their forearm out, away from their body, pulling against the resistance tube. They then slowly rotated the forearm back towards the body to the starting position.

Resisted Shoulder Flexion

The participant was instructed to hold the resistance tube in one hand at their side. They were to pull forward and up with a straight elbow against the resistance tube until their arm was slightly above parallel with the ground. They were then instructed to slowly return their arm to the starting position.

Resisted Shoulder Extension

The participant was instructed to hold the resistance tube in one hand with their arm forward. With their elbow straight, they were to pull down and back against the resistance tube until their arm passed the side of their body slightly. They were then instructed to slowly return their arm to the starting position.

Resisted Shoulder Pinch

With the resistance tube anchored in the middle, allowing for two equal sides, the participant was instructed to hold one side of the resistance tube in each hand. With elbows at their sides and bent at 90 degrees and forearms forward, they were to pinch the scapuli together while pulling against the resistance tube. They were then instructed to release muscular contraction and return to the starting position.

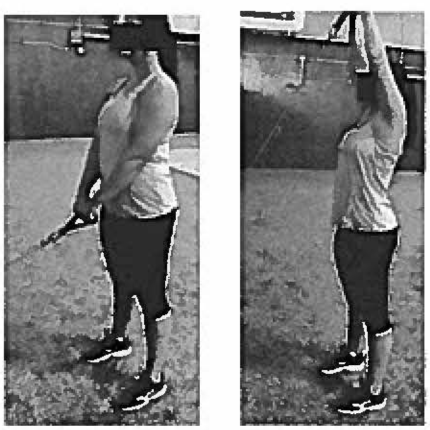
90/90 Internal Shoulder Rotation

Participants were told to hold the resistance tube in one hand and face away from the resistance tube's anchor. They were instructed to bend their elbow to 90 degrees, raise their forearm up, and move arm up and out to the side. With their palm facing forward, they then pulled their forearm down slowly until their hand was level with their elbow. They then slowly returned their forearm to the starting position.

90/90 External Shoulder Rotation

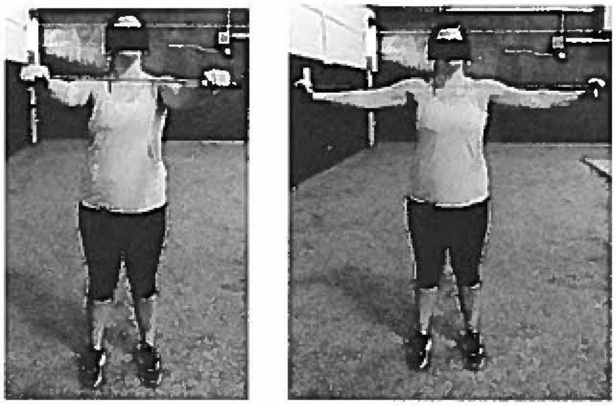
Participants were told to hold the resistance tube in one hand and face the resistance tube's anchor. They were instructed to bend their elbow to 90 degrees, place their forearm forward, and raise their arm up and out to their side. With their palm facing down, they then pulled their forearm up slowly to a vertical position. They then slowly returned their forearm to the starting position.

Overhead Pulls



Facing the resistance tube's anchor while holding the resistance tube in both hands the participant was instructed to start with arms hanging in front of their body. With straight arms, they then pulled up against the resistance tubes until their arms were above their head. They then slowly lowered their arms back to the starting position.

Straight Fly



The participant was instructed to hold each side of the resistance tube in each hand and lift their arms until they were parallel to the ground. Keeping their elbows straight, they then slowly pulled their arms away from center, stretching the resistance tube until their arms were perpendicular to their sides. They then slowly moved their arms back to the starting position.

Overhead Fly

The participant was instructed to hold each side of the resistance tube in each hand and lift their arms straight above their head. Keeping their elbows straight, they then slowly lowered their arms and stretched the resistance tube until their arms were perpendicular with their sides. They then slowly raised their arms until they were back to the starting position.

Overhead-Behind the Head Fly

The participant was instructed to hold each side of the resistance tube in each hand and lift their arms straight above their head. Keeping their elbows straight, they then slowly lowered their arms and stretched the resistance tube until their arms were perpendicular with sides and the resistance tube was behind their head. They then slowly raised their arms until they were back to the starting position.

Appendix I: Exercises for Control Group

The following is a visual aid and explanation of each exercise the control group performed. These exercises were described as being non sport-specific; they do not target the specific rotator cuff muscles responsible for the overhead throwing motion, but just the upper body in general. The resistance tube was connected to the chain-link fence on the Adams State University softball field unless otherwise specified.

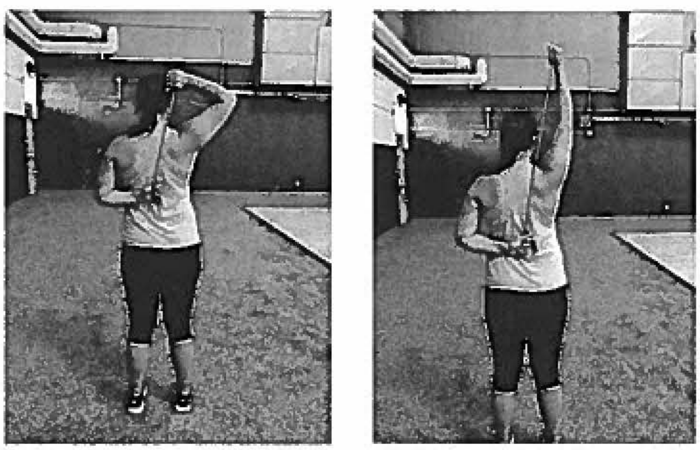
Bicep Curl

Standing with one end of the resistance tube in their hand and the other under their foot, the participant was instructed to start with their arm at their side and their elbow straight. Keeping their elbow at their side, they then slowly pulled up with their forearm against the resistance tube until their hands were to their chest. They were then instructed to slowly return their forearm to the starting position.

Triceps Pull-Down

With the resistance tube anchored above the participant's head, the participant held the resistance tube in one hand. Their elbow was at their side and bent until their hand was close to their chest. They were then instructed to keep their elbow at their side, but pull down with their forearm until the elbow was straight. They then slowly raised their forearm to return to the starting position.

Triceps Extension



Holding each end of the resistance tube, the participant was instructed to place one arm behind their back and the other above their head, both with bent elbows. Keeping the elbow behind their back bent and in a fixed position, the participant slowly extended their arm they had above their head until the elbow was straight. They then lowered their arm back to the starting position.

Row

Positioning the resistance tube's anchor in the middle of the tube to allow for two equal sides, the participant was instructed to sit on the ground and extend their arms in front of them. They then pulled against the resistance tube by bending both their elbows and pulling back at the same time. They then slowly extended their arms back out and returned to the starting position.

Chest Press

Positioning the resistance tube's anchor in the middle of the tube to allow for two equal sides, the participant was instructed to hold each end of the resistance tube in each hand and face away from the anchor. Starting with their elbows bent, their arms raised, and their forearms forward, the participant then extended both of their arms forward until fully extended. They then slowly returned their arms to the starting position.

Incline Chest Press

Positioning the resistance tube's anchor in the middle of the tube to allow for two equal sides and slightly lower than the participant's mid-back, the participant was instructed to hold each end of the resistance tube in each hand and face away from the anchor. Starting with their elbows bent and to the side, their forearms forward, the participant extended their arms upward and forward. They then slowly returned their arms to the starting position.

Resisted Push-Up

With each end of the resistance tube in each hand and the resistance tube behind the participant's back, the participant was instructed to lay on the ground and get into a push-up position. The participant then slowly lowered their chest towards the ground by bending their elbows to 90 degrees. They then extended their elbows and returned back to the starting position.

Latissimus Pull-Down

Positioning the resistance tube's anchor in the middle of the tube to allow for two equal sides, the participant was instructed to hold each end of the resistance tube in each hand and face the anchor. The participant's arms should be fully extended forward and slightly raised above parallel with the ground. They then pull against the resistance tube by bending their elbows and pulling back simultaneously, but keeping their arms up. They were then instructed to slowly extend their arms back to the starting position.

Resistance Tube Twist

Holding one end of the resistance tube in both hands, the participant was instructed to stand with the resistance tube to the side of them. They were then instructed to rotate their torso to their opposite side where the resistance band was not, while keeping their elbows in a locked position. They then rotated their torso back to the starting position.

Rotational Chop (Low to High)

Holding one end of the resistance tube in both hands and the resistance tube anchored low, the participant was instructed to stand with the resistance tube to the side of them and bend at their hips. They then rotated their torso to their opposite side where the resistance band was not, while reaching up with their extended arms simultaneously. They were then instructed to rotate their torso back to the starting position.

Resistance Tube Pull Through

Holding one end of the resistance tube in both hands and the resistance tube anchored low, the participant was instructed to stand facing away from the anchor and the resistance tube between their legs. The participant was instructed to start in a slightly bent position, bending at their hips. Keeping their arms fully extended, they then pulled against the resistance tube by extending their hips and standing straight up. To return to the starting position, the participant slowly lowered their body back down by bending at their hips.

Appendix J: SPSS Output File

Descriptive Statistics

Participant Descriptive Statistics					
	N	Minimum	Maximum	Mean	Std. Deviation
Age_years	28	18.00	23.00	19.7500	1.53055
Height_cm	28	157.48	177.80	165.4175	5.62280
Valid N (listwise)	28				

Between-Subjects Factors			
		Value Label	N
Group	1	Experimental	15
	2	Control	13

Group Descriptive Statistics				
	Group	Mean	Std. Deviation	N
Pre_Weight	Experimental	70.0767	12.71816	15
	Control	73.2946	15.69493	13
	Total	71.5707	14.00081	28
Post_Weight	Experimental	69.4120	12.24074	15
	Control	74.1654	15.64294	13
	Total	71.6189	13.86639	28
Pre_Fat_Percentage	Experimental	21.0167	4.02254	15
	Control	22.4169	4.69208	13
	Total	21.6668	4.32210	28
Post_Fat_Percentage	Experimental	20.1207	4.22396	15
	Control	22.7308	4.66662	13
	Total	21.3325	4.54834	28
Pre_LBM	Experimental	54.9180	7.29857	15
	Control	56.2477	8.99747	13
	Total	55.5354	8.00355	28
Post_LBM	Experimental	55.0007	6.84144	15
	Control	56.9577	9.16648	13
	Total	55.9093	7.91211	28

Pre_Fat_Mass	Experimental	15.1600	5.62507	15
	Control	17.0469	6.92349	13
	Total	16.0361	6.21525	28
Post_Fat_Mass	Experimental	14.4067	5.65997	15
	Control	17.3515	6.87101	13
	Total	15.7739	6.31113	28
Pre_1RM	Experimental	27.2173	5.14410	15
	Control	27.5646	7.51415	13
	Total	27.3786	6.23269	28
Post_1RM	Experimental	33.5667	6.59288	15
	Control	34.7585	15.50141	13
	Total	34.1200	11.38866	28
Pre_Internal_Rotation	Experimental	69.0667	16.34217	15
	Control	70.0000	17.04895	13
	Total	69.5000	16.36731	28
Post_Internal_Rotation	Experimental	65.87	8.476	15
	Control	65.85	13.825	13
	Total	65.86	11.054	28
Pre_External_Rotation	Experimental	119.7333	12.27347	15
	Control	124.3077	14.30842	13
	Total	121.8571	13.20974	28
Post_External_Rotation	Experimental	116.67	12.193	15
	Control	125.46	10.047	13
	Total	120.75	11.912	28
Pre_Peak_Velocity	Experimental	53.27	3.494	15
	Control	53.46	2.537	13
	Total	53.36	3.033	28
Post_Peak_Velocity	Experimental	55.27	2.939	15
	Control	54.38	2.873	13
	Total	54.86	2.889	28
Pre_Average_Velocity	Experimental	52.0533	3.36831	15
	Control	52.0308	2.72623	13
	Total	52.0429	3.03088	28
Post_Average_Velocity	Experimental	53.7067	2.91877	15
	Control	52.9077	3.29000	13
	Total	53.3357	3.06476	28

Change Descriptive Statistics				
	Group	Mean	Std. Deviation	N
Change_Weight	Experimental	-.6647	1.57811	15
	Control	.8708	1.46584	13
	Total	.0482	1.68950	28
Change_Fat_Percentage	Experimental	-.8960	.97353	15
	Control	.3138	1.08856	13
	Total	-.3343	1.18137	28
Change_LBM	Experimental	.0827	1.35196	15
	Control	.7100	1.52918	13
	Total	.3739	1.44518	28
Change_Fat_Mass	Experimental	-.7533	.71889	15
	Control	.3046	1.04178	13
	Total	-.2621	1.01933	28
Change_1RM	Experimental	6.3513	3.75499	15
	Control	4.8862	5.38745	13
	Total	5.6711	4.55682	28
Change_Internal_Rotation	Experimental	-3.1333	19.83815	15
	Control	-4.1538	18.67193	13
	Total	-3.6071	18.95480	28
Change_External_Rotation	Experimental	-3.0667	12.76416	15
	Control	1.1538	14.76395	13
	Total	-1.1071	13.63639	28
Change_Peak_Velocity	Experimental	2.0000	2.39046	15
	Control	.9231	2.36155	13
	Total	1.5000	2.39598	28
Change_Average_Velocity	Experimental	1.6533	1.83220	15
	Control	.9077	2.65030	13
	Total	1.3071	2.23738	28

Two-Way Repeated Measures ANOVA Results

Tests of Within-Subjects Contrasts

Source	Measure	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[a]
Time	Weight	.148	1	.148	.127	.725	.005	.127	.064
	Fat_Percentage	1.180	1	1.180	2.232	.147	.079	2.232	.302
	LBM	2.188	1	2.188	2.121	.157	.075	2.121	.289
	Fat_Mass	.701	1	.701	1.800	.191	.065	1.800	.253
	One_RM	638.687	1	638.687	17.479	.000	.402	17.479	.980
	Internal_Rotation	188.311	1	188.311	1.019	.322	.038	1.019	.163
	External_Rotation	12.741	1	12.741	.135	.716	.005	.135	.065
	Peak_Velocity	29.753	1	29.753	10.530	.003	.288	10.530	.878
	Average_Velocity	22.293	1	22.293	8.901	.006	.255	8.901	.819
time * Group	Weight	8.209	1	8.209	7.039	.013	.213	7.039	.724
	Fat_Percentae	5.097	1	5.097	9.642	.005	.271	9.642	.848
	LBM	1.370	1	1.370	1.328	.260	.049	1.328	.199
	Fat_Mass	3.897	1	3.897	10.004	.004	.278	10.004	.861
	One_RM	2.483	1	2.483	.068	.796	.003	.068	.057
	Internal_Rotation	3.168	1	3.168	.017	.897	.001	.017	.052
	Exernal_Rotation	62.026	1	62.026	.659	.424	.025	.659	.122
	Peak_Velocity	4.038	1	4.038	1.429	.243	.052	1.429	.210
	Average_Velocity	2.099	1	2.099	.838	.368	.031	.838	.143
Error (time)	Weight	30.325	26	1.166					
	Fat_Percentage	13.744	26	.529					
	LBM	26.825	26	1.032					
	Fat_Mass	10.130	26	.390					
	One_RM	950.047	26	36.540					
	Internal_Rotation	4805.046	26	184.809					
	External_Rotation	2448.313	26	94.166					
	Peak_Velocity	73.462	26	2.825					
	Average_Velocity	65.120	26	2.505					

(Time was assumed linear)

a. Computed using alpha = .05

Levene's Test of Equality of Error Variances[a]				
	F	df1	df2	Sig.
Pre_Weight	.932	1	26	.343
Post_Weight	1.108	1	26	.302
Pre_Fat_Percentage	.551	1	26	.465
Post_Fat_Percentage	.157	1	26	.695
Pre_LBM	1.277	1	26	.269
Post_LBM	1.782	1	26	.194
Pre_Fat_Mass	.555	1	26	.463
Post_Fat_Mass	.597	1	26	.447
Pre_1RM	2.699	1	26	.112
Post_1RM	.827	1	26	.371
Pre_Internal_Rotation	.451	1	26	.508
Post_Internal_Rotation	2.667	1	26	.114
Pre_External_Rotation	.647	1	26	.429
Post_External_Rotation	.152	1	26	.700
Pre_Peak_Velocity	3.144	1	26	.088
Post_Peak_Velocity	.201	1	26	.658
Pre_Average_Velocity	2.048	1	26	.164
Post_Average_Velocity	.045	1	26	.833

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + Group

Within Subjects Design: Time

Group Pairwise Comparisons

Measure	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
						Lower Bound	Upper Bound
Weight	Experimental	Control	-3.986	5.313	.460	-14.908	6.936
	Control	Experimental	3.986	5.313	.460	-6.936	14.908
Fat_Percentage	Experimental	Control	-2.005	1.652	.236	-5.401	1.390
	Control	Experimental	2.005	1.652	.236	-1.390	5.401
LBM	Experimental	Control	-1.643	3.043	.594	-7.899	4.612
	Control	Experimental	1.643	3.043	.594	-4.612	7.899
Fat_Mass	Experimental	Control	-2.416	2.364	.316	-7.274	2.442
	Control	Experimental	2.416	2.364	.316	-2.442	7.274
One_RM	Experimental	Control	-.770	3.149	.809	-7.241	5.702
	Control	Experimental	.770	3.149	.809	-5.702	7.241
Internal_Rotation	Experimental	Control	-.456	3.975	.909	-8.627	7.714
	Control	Experimental	.456	3.975	.909	-7.714	8.627
External_Rotation	Experimental	Control	-6.685	3.865	.096	-14.629	1.260
	Control	Experimental	6.685	3.865	.096	-1.260	14.629
Peak_Velocity	Experimental	Control	.344	1.044	.745	-1.802	2.490
	Control	Experimental	-.344	1.044	.745	-2.490	1.802
Average_Velocity	Experimental	Control	.411	1.092	.710	-1.834	2.656
	Control	Experimental	-.411	1.092	.710	-2.656	1.834

Based on estimated marginal means

a. Adjustment for multiple comparisons: Bonferroni.

Time Pairwise Comparisons							
Measure	(I) Time	(J) Time	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
Weight	1	2	-.103	.289	.725	-.698	.492
	2	1	.103	.289	.725	-.492	.698
Fat_Percentage	1	2	.291	.195	.147	-.109	.692
	2	1	-.291	.195	.147	-.692	.109
LBM	1	2	-.396	.272	.157	-.956	.163
	2	1	.396	.272	.157	-.163	.956
Fat_Mass	1	2	.224	.167	.191	-.119	.568
	2	1	-.224	.167	.191	-.568	.119
One_RM	1	2	-6.772*	1.620	.000	-10.101	-3.442
	2	1	6.772*	1.620	.000	3.442	10.101
Internal_Rotation	1	2	3.677	3.643	.322	-3.811	11.164
	2	1	-3.677	3.643	.322	-11.164	3.811
External_Rotation	1	2	.956	2.600	.716	-4.388	6.301
	2	1	-.956	2.600	.716	-6.301	4.388
Peak_Velocity	1	2	-1.462*	.450	.003	-2.387	-.536
	2	1	1.462*	.450	.003	.536	2.387
Average_Velocity	1	2	-1.265*	.424	.006	-2.137	-.393
	2	1	1.265*	.424	.006	.393	2.137

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.

Multivariate[a,b]									
Within Subjects Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared	Noncent. Parameter	Observed Power[d]
Time	Pillai's Trace	.619	3.254[c]	9.000	18.000	.016	.619	29.285	.886
	Wilks' Lambda	.381	3.254[c]	9.000	18.000	.016	.619	29.285	.886
	Hotelling's Trace	1.627	3.254[c]	9.000	18.000	.016	.619	29.285	.886
	Roy's Largest Root	1.627	3.254[c]	9.000	18.000	.016	.619	29.285	.886
Time * Group	Pillai's Trace	.451	1.642[c]	9.000	18.000	.177	.451	14.776	.553
	Wilks' Lambda	.549	1.642[c]	9.000	18.000	.177	.451	14.776	.553
	Hotelling's Trace	.821	1.642[c]	9.000	18.000	.177	.451	14.776	.553
	Roy's Largest Root	.821	1.642[c]	9.000	18.000	.177	.451	14.776	.553

a. Design: Intercept + Group

Within Subjects Design: Time

b. Tests are based on averaged variables.

c. Exact statistic

d. Computed using alpha = .05

MANOVA Results

Tests of Between-Subjects Effects							
Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	Change_Weight	16.419[a]	1	16.419	7.039	.013	.213
	Change_Fat_Percentage	10.194[b]	1	10.194	9.642	.005	.271
	Change_LBM	2.741[c]	1	2.741	1.328	.260	.049
	Change_Fat_Mass	7.795[d]	1	7.795	10.004	.004	.278
	Change_1RM	14.951[e]	1	14.951	.712	.406	.027
	Change_Internal_Rotation	7.253[f]	1	7.253	.019	.890	.001
	Change_External_Rotation	124.053[g]	1	124.053	.659	.424	.025
	Change_Peak_Velocity	8.077[h]	1	8.077	1.429	.243	.052
	Change_Average_Velocity	3.872[i]	1	3.872	.767	.389	.029
Intercept	Change_Weight	.296	1	.296	.127	.725	.005
	Change_Fat_Percentage	2.360	1	2.360	2.232	.147	.079
	Change_LBM	4.376	1	4.376	2.121	.157	.075
	Change_Fat_Mass	1.402	1	1.402	1.800	.191	.065
	Change_1RM	879.458	1	879.458	41.902	.000	.617
	Change_Internal_Rotation	369.824	1	369.824	.992	.328	.037
	Change_External_Rotation	25.482	1	25.482	.135	.716	.005
	Change_Peak_Velocity	59.505	1	59.505	10.530	.003	.288
	Change_Average_Velocity	45.678	1	45.678	9.046	.006	.258
Group	Change_Weight	16.419	1	16.419	7.039	.013	.213
	Change_Fat_Percentage	10.194	1	10.194	9.642	.005	.271
	Change_LBM	2.741	1	2.741	1.328	.260	.049
	Change_Fat_Mass	7.795	1	7.795	10.004	.004	.278
	Change_1RM	14.951	1	14.951	.712	.406	.027
	Change_Internal_Rotation	7.253	1	7.253	.019	.890	.001
	Change_External_Rotation	124.053	1	124.053	.659	.424	.025
	Change_Peak_Velocity	8.077	1	8.077	1.429	.243	.052
	Change_Average_Velocity	3.872	1	3.872	.767	.389	.029
Error	Change_Weight	60.650	26	2.333			
	Change_Fat_Percentage	27.488	26	1.057			
	Change_LBM	53.650	26	2.063			
	Change_Fat_Mass	20.259	26	.779			
	Change_1RM	545.695	26	20.988			
	Change_Internal_Rotation	9693.426	26	372.824			

	Change_External_Rotation	4896.626	26	188.332			
	Change_Peak_Velocity	146.923	26	5.651			
	Change_Average_Velocity	131.287	26	5.049			
Total	Change_Weight	77.134	28				
	Change_Fat_Percentage	40.811	28				
	Change_LBM	60.306	28				
	Change_Fat_Mass	29.978	28				
	Change_1RM	1461.155	28				
	Change_Internal_Rotation	10065.00	28				
	Change_External_Rotation	5055.000	28				
	Change_Peak_Velocity	218.000	28				
	Change_Average_Velocity	183.000	28				
Corrected Total	Change_Weight	77.069	27				
	Change_Fat_Percentage	37.682	27				
	Change_LBM	56.391	27				
	Change_Fat_Mass	28.054	27				
	Change_1RM	560.645	27				
	Change_Internal_Rotation	9700.679	27				
	Change_External_Rotation	5020.679	27				
	Change_Peak_Velocity	155.000	27				
	Change_Average_Velocity	135.159	27				

a. R Squared =.213 (Adjusted R Squared =.183)

b. R Squared =.271 (Adjusted R Squared =.242)

c. R Squared =.049 (Adjusted R Squared =.012)

d. R Squared =.278 (Adjusted R Squared =.250)

e. R Squared =.027 (Adjusted R Squared =-.011)

f. R Squared =.001 (Adjusted R Squared =-.038)

g. R Squared =.025 (Adjusted R Squared =-.013)

h. R Squared =.052 (Adjusted R Squared =.016)

i. R Squared =.029 (Adjusted R Squared =-.009)

Levene's Test of Equality of Error Variances[a]

	F	df1	df2	Sig.
Change_Weight	.003	1	26	.956
Change_Fat_Percentage	.945	1	26	.340
Change_LBM	.182	1	26	.673
Change_Fat_Mass	2.063	1	26	.163
Change_1RM	.646	1	26	.429
Change_Internal_Rotation	.049	1	26	.827
Change_External_Rotation	.506	1	26	.483
Change_Peak_Velocity	.015	1	26	.903
Change_Average_Velocity	2.106	1	26	.159

Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

a. Design: Intercept + Group

Multivariate Tests[a]

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Intercept	Pillai's Trace	.773	6.796[b]	9.000	18.000	.000	.773
	Wilks' Lambda	.227	6.796[b]	9.000	18.000	.000	.773
	Hotelling's Trace	3.398	6.796[b]	9.000	18.000	.000	.773
	Roy's Largest Root	3.398	6.796[b]	9.000	18.000	.000	.773
Group	Pillai's Trace	.449	1.633[b]	9.000	18.000	.180	.449
	Wilks' Lambda	.551	1.633[b]	9.000	18.000	.180	.449
	Hotelling's Trace	.816	1.633[b]	9.000	18.000	.180	.449
	Roy's Largest Root	.816	1.633[b]	9.000	18.000	.180	.449

a. Design: Intercept + Group

b. Exact statistic

Pairwise Comparisons

Dependent Variable	(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.[b]	95% Confidence Interval for Difference[b]	
						Lower Bound	Upper Bound
Change_Weight	Experimental	Control	-1.535*	.579	.013	-2.725	-.346
	Control	Experimental	1.535*	.579	.013	.346	2.725
Change_Fat_Percentage	Experimental	Control	-1.210*	.390	.005	-2.011	-.409
	Control	Experimental	1.210*	.390	.005	.409	2.011
Change_LBM	Experimental	Control	-.627	.544	.260	-1.746	.492
	Control	Experimental	.627	.544	.260	-.492	1.746
Change_Fat_Mass	Experimental	Control	-1.058*	.334	.004	-1.746	-.370
	Control	Experimental	1.058*	.334	.004	.370	1.746
Change_1RM	Experimental	Control	1.465	1.736	.406	-2.103	5.034
	Control	Experimental	-1.465	1.736	.406	-5.034	2.103
Change_Internal_Rotation	Experimental	Control	1.021	7.317	.890	-14.019	16.060
	Control	Experimental	-1.021	7.317	.890	-16.060	14.019
Change_External_Rotation	Experimental	Control	-4.221	5.200	.424	-14.910	6.469
	Control	Experimental	4.221	5.200	.424	-6.469	14.910
Change_Peak_Velocity	Experimental	Control	1.077	.901	.243	-.775	2.929
	Control	Experimental	-1.077	.901	.243	-2.929	.775
Change_Average_Velocity	Experimental	Control	.746	.852	.389	-1.005	2.496
	Control	Experimental	-.746	.852	.389	-2.496	1.005

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

b. Adjustment for multiple comparisons: Bonferroni.