1998

Throwing velocity after training with the throwing cord versus a throwing protocol

Mark A. Shropshire

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THROWING VELOCITY AFTER TRAINING WITH
THE THROWING CORD VERSUS A THROWING PROTOCOL

by

Mark A. Shropshire

B. S., North Dakota State University, 1993

Presented in partial fulfillment of the requirements for the degree of

Master of Science

The University of Montana

1998

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9-1-98

Date
The Effects of Throwing Velocity After Training With the Throwing Cord Versus a Throwing Protocol

Director: Dr. Lewis Curry

The purpose of this study was to determine the effects of the throwing cord (TC) on mean and peak throwing velocity in male college baseball players. The (TC) is a device marketed by Acceleration Products Inc. to increase the velocity of a thrown ball. In theory, the (TC) may be a speed/exercise specific training tool that allows a full range of motion, while at the same time approximating the acceleration and velocity patterns of the throwing arm.

The subjects were 15 male college baseball players ranging in age from 18 - 24 years. Only individuals with at least two years of prior pitching experience were allowed to participate in the study. The subjects were randomly divided in to two groups: group one which did not use (TC) and group two, which supplemented half of their throwing volume with (TC). Both groups trained two times per week for five weeks, with a two to three day rest period between training days. The training consisted of throwing off a wooden pitching mound at maximal effort. The training load (number of throws per training day) was progressively increased each week. Subjects were pre and post tested for mean and peak throwing velocity over ten pitches. The subjects were instructed to throw with maximal effort for each of the ten pitches thrown. Both groups threw off a wooden mound to a catcher who was located sixty feet six inches away. Velocity was measured using a Jugs Radar Gun. The results were analyzed using a 2 (group) by 2 (pre/post) mixed design ANOVA with appropriate post hoc analysis with a Bonferroni adjustment to control for alpha.

The results indicated a non significant (p = .05) increase in both mean (p=.03) and peak (p=.06) throwing velocity in group two of 1.80 and 1.88 m.p.h. respectively. There was no significant increase or decrease in mean or peak throwing velocity for group one. Although not statistically significant, a treatment effect was noted for the intervention group. An effect size formula was utilized to measure the treatment effect. This analysis revealed an effect size of (.95) and (.97) for mean and peak velocity respectively. The results of this study indicate a non significant transfer of training effect to both mean and peak throwing velocity after training with the (TC) two times per week for five weeks.
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In 1977, Colman analyzed the reaction time of a batter to various speeds of a pitched baseball. He determined that at 70 miles per hour, a baseball will reach home plate in .54 seconds. He calculated that a batter uses approximately .28 seconds during the swing phase of hitting, leaving .26 seconds for the batter to assess if the ball is hittable. If the velocity of the pitch is increased to 90 miles per hour, the ball takes .42 seconds to reach the catcher’s mitt. Given that swing time is the same, the batter now has .14 seconds to make his decision. When the velocity of the pitch is 100 miles per hour, the ball arrives at home plate in .38 seconds. The batter has only .10 seconds to judge the pitch and initiate his swing. Assuming Colman’s analysis is correct, it may be reasonable to conclude that increasing the throwing velocity of a baseball would give the pitcher an advantage over the batter. By decreasing the amount of time a batter has to react to a pitch, the better the chances of the pitcher getting the opponent out.

Attempts to maximize throwing velocity have been largely anecdotal since the beginning of organized baseball in the late 1800s. A traditional belief is that velocity may be improved through high velocity repetitious throwing. Still, many (House, 1994; Ryan, House, & Rosenthal, 1991; Seaver & Lowenfish, 1984) believe you either have a great fast ball or you don’t, and that this trait is genetically determined. Additionally, they believe that strength training and conditioning have little effect other than to allow the athlete to pitch more (House, 1994; Ryan, House, & Rosenthal, 1991; Seaver &
Lowenfish, 1984). To some extent, research can be found to support both points of view. Research on the genetic determination of muscle fiber has indicated that 99.5% of the quick and slow twitch muscle fiber distribution in men is genetic (Komi, Viitasalo, Sjodin, & Karlsson, 1977). Bosco and Komi (1979) concluded that the skeletal muscle composition may determine the performance of a multi joint movement. They found that subjects with a higher percentage of fast twitch fibers performed better on a static and counter movement vertical jump than did those with lower percentages. Hakkinen, Komi, and Alen (1985) determined that “in training for fast force production, considerable neural and selective muscular adaptations may occur to explain the improvement in performance, but that genetic factors may determine the ultimate trainability of this aspect of the neuromuscular performance”. However, there is substantial documentation to suggest that specificity in training may enhance performance, skill execution, peak force and the rate of force development (Behm, 1988; Coleman, 1991; Hakkinen, Komi, & Alen, 1985; O'Shea, 1985; Sale, 1986, 1988; Sale & MacDougall, 1981).

Physical training has been shown to enhance athletic performance. Biomechanics, speed of muscular contraction, and the type of energy system used are important factors to be addressed prior to and during training. For physical training to be optimally beneficial, a high degree of specificity to the sport is an indispensable consideration (DeRenne, 1987; Fox, Kirby, & Fox, 1987; MacDougall, Wenger, & Green, 1991; Sale, 1986; Wescott, 1991). In order to maximize the specificity principle,
DeRenne (1987) outlined four provisions. First, the exercise must provide an overload to the muscle. Second, the exercise must provide resistance through a complete range of motion. Third, it should duplicate the acceleration (and velocity) pattern of the primary movement. Finally, the exercise needs to be safe. Specific to baseball, DeRenne (1987) noted:

Specificity of exercise states that there is a positive transfer of training effect when the elements of the supplementary and overloading exercises (i.e. weight training, running, etc.) are similar to those of the primary activity, in this case baseball. The closer the supplementary exercise is to the primary activity, the greater the transfer of training effect. (p.35)

Thus, a device or exercise routine that overloaded the appropriate musculature and mimicked the specific throwing patterns of the athlete may be beneficial during training.

The throwing motion has been studied and analyzed by many researchers (Dillman, Fleisig, & Andrews, 1993; Jacobs, 1987; Jobe, Moynes, Radovich, Tibone, & Perry, 1984; Jobe, Tibone, Perry, & Moynes, 1983;). Jobe et al. (1983) broke down the pitching motion into four distinct phases: (1) The wind up is characterized by upper extremity flexion with both hands holding the ball; (2) Cocking consists of shoulder abduction and external rotation. It begins with release of the ball by the gloved hand, and terminates with maximal external rotation at the shoulder; (3) Acceleration begins with maximal external rotation at the shoulder and continues until ball release. During this phase, internal rotation of the shoulder and horizontal flexion are observed. Jobe et al.
(1983) found that this phase was very short, lasting less than one tenth of a second; (4) The follow through is a continuation of shoulder inward rotation and horizontal flexion while the subscapularis assists in the internal rotation of the shoulder. The remaining muscles of the rotator cuff and deltoid are believed to be responsible for deceleration of the arm.

The specificity principle dictates that training aimed at increasing the velocity of a pitched ball follow the act of throwing as closely as possible. Training must mirror joint angles, velocities of muscular contraction, range of motion used while throwing, and provide an overload in a safe training environment. This has been difficult to accomplish due to the fact that throwing a baseball is one of the most complicated, ballistic, and dynamic skills performed in sport (Dillman, Fleisig, & Andrews, 1993; Jobe, Tibone, Perry, & Moynes, 1983; Mullins, 1993; Pawloski & Perrin, 1989;)

Dillman et al. (1993) noted that the time between stride foot contact with the ground and the ball being released was 0.145 seconds. Within this time frame hip rotation, trunk rotation, upper trunk extension, elbow flexion, shoulder external rotation, elbow extension, hip flexion, upper trunk flexion, shoulder internal rotation, and pronation of the forearm are performed sequentially.

In an effort to increase throwing velocity using the principles of specificity, the throwing cord was developed by John Frappier, the president of Acceleration Products Inc. The throwing cord is composed of two neoprene straps, one attaching around the biceps and the other attaching to the wrist. The straps are secured with Velcro™ that has
been stitched into the neoprene, much like a knee brace. The straps are connected to a common resistance point by two nylon belts that are tethered to an eight foot resistance cord (surgical tube). It is designed to provide an overload to the throwing muscles through a full range of motion while at the same time being safe and approximating the acceleration and velocity patterns of the arm, typical of throwing a baseball.

A preliminary case study was conducted by Frappier (1994) on the effects of the throwing cord. Subject’s biomechanics were evaluated and corrections made for those who displayed improper throwing motion. Significant results were obtained from the study, although it did not contain a control group. Thus, this study was implemented to further examine the effects of training with the throwing cord.

In theory, the training associated with the throwing cord is in accordance with the principles of exercise specificity. The results of Frappier’s (1994) study indicated a possible carry over effect of training with the Throwing Cord, and warranted further investigation.

Purpose

The purpose of the study was to determine differences between a 5 week training intervention using the throwing cord resistance methodology to supplement regular throwing on mean and peak velocity as compared to a 5 week training intervention using throwing only.

Research Hypothesis

Based on strong theoretical support of velocity training specificity, exercise
specificity, joint angle resistance training specificity, and the previous pilot study regarding the throwing cord, it is hypothesized that subjects training with the throwing cord will increase mean and peak velocity as compared to the control subjects using throwing only. With the exception of over training and the resultant muscle soreness and fatigue, there is no research to support that there is the possibility of decreased mean and peak velocity when training with the throwing cord as outlined in the throwing methodology section. However, due to the inability to control intervening variables and the lack of previous research on the throwing cord, a two tailed test for significance was used.

Assumptions

1. The athletes were healthy, with no preexisting injury that hindered participation in the study.

2. The athletes were skilled baseball players possessing the proper mechanics involved in pitching.

3. The athletes followed instructions regarding participation in the study.

4. The Jugs Radar Gun was a valid and reliable instrument for recording ball velocity. It was calibrated for each use using the same methods. Since the same device was used to pre and post test, it may be assumed that the differences are accurate even if the miles per hour accuracy is lacking research support.
5. The resistance of the cord remained constant throughout the testing period.

6. The throwing motion is assumed to be similar with and without the throwing cord.

7. Arm velocity was not significantly impaired by the throwing cord apparatus being placed on the arm.

Limitations

1. The athletes could not be completely controlled. Weight lifting, biomechanical training, physical training and coaching are all a part of being involved in athletics, and could not be accounted for.

2. The athletes may have entered the study in various forms of physical condition. Athletes who entered the study with their arm accustomed to throwing may not realize a benefit to training (if any) if the overload prescribed was insufficient.

3. There may have been some slippage of the neoprene on the skin during each individual throwing set due to perspiration. The neoprene attachment sites were repositioned on the humerus and forearm after each set.

4. The force of the resistance of the throwing cord in foot – pounds was not measured.

5. Height, throwing motion and experience in pitching may affect the resistance of the throwing cord at the release point of the ball. All that
can be stated is that there is resistance at the point of release due to the stretch of the cord.

6. The Jugs radar gun only measures velocity in whole numbers. Therefore it may not be able to detect subtle increases in velocity.

Delimitations

1. The study included athletes from the Minot State University baseball team. This may limit the ability to generalize the results to high school or elite level athletes.

Significance of the study

The significance of this study was to validate the Throwing Cord as a training tool for increasing throwing velocity. This study also attempted to reinforce the specificity of exercise principles. The present study can not address why the throwing cord does or does not work. If finding a significant effect, future research studies will need to be conducted to measure precise effects. For example, the amount of resistance at the release point, or kinematic measurements matching throwing motion with and with out the throwing cord attached. The results of the study should be noteworthy to anyone interested in improving the throwing velocity of a baseball and throwing in general. The device studied may lend itself to other research efforts in the areas of training specificity and velocity development. With non- significant findings, this study may indicate the need to reexamine the efficacy of exercise specificity as it relates to the throwing cord.
**Definition of terms**

**Velocity:** Displacement per unit of time. A vector quantity requiring that direction be stated or strongly implied.

**Speed:** Total distance traveled per unit of time.

**Rad/Sec:** Unit of measurement. To convert to degrees, multiply by 57.30.

**Prime Movers:** muscles or muscle that is directly responsible for effecting the movement.

**Hip Rotation (external):** a rotation of the femur around its longitudinal axis so that the knee is turned laterally.

**Trunk Rotation:** A rotary movement of the spine in the horizontal plane about a vertical axis.

**Trunk Flexion:** A forward - downward bending in the sagittal plane about a frontal horizontal axis.

**Trunk Extension:** The return movement from flexion.

**Elbow Flexion:** A forward - upward movement in the sagittal plane.

**Elbow Extension:** The return movement from flexion.

**Shoulder External Rotation:** A rotation of the humerus around its mechanical axis so that the anterior aspect turns laterally in the horizontal plane.

**Shoulder Internal Rotation:** A rotation of the humerus around its mechanical axis so that the anterior aspect turns medially in the horizontal plane.

**Hip Flexion:** A forward movement of the femur in the sagittal plane.
Forearm Pronation: Movement of the forearm at the two radioulnar joints.

Traditional High Velocity Repetitious Training Method: Warm up, position specific, and skill specific throwing (i.e. pitching drills).
CHAPTER 2

Review of the literature

Researchers have studied many different variables with respect to their effects on the development of pitchers and throwing velocity (Behm, 1988; Newton & McEvoy, 1994; Page, Lamberth, Abadie, Boling, Collins, and Linton, 1993; Pedegana, Elsner, Roberts, Lang, & Farewell, 1982; Pezzullo, Karas, & Irrgang, 1995; Potteiger & Wilson, 1989; Rosenboom, 1992). They include the use of isokinetic machines, strength training, plyometric training, implement training, surgical tubing, or any combination of the above. This chapter is a review of the related literature as it pertains to differing training methods. The research that is presented includes research that does not relate to the throwing motion. However, it may be possible to generalize the results of these studies to training programs with the goal of increasing throwing velocity.

Strength Training

Traditionally, strength training has been shunned by most baseball players. This is evident by the following quotes from former major league pitchers. "Old school instructors believed lifting weights was bad for pitchers, that it made a pitcher muscle bound" (House, 1994, p.67). According to Nolan Ryan, "the 1972 season was a transitional point in my career; it was the year that I started lifting weights. In those days, of course, it was unheard of for a pitcher to train with weights" (Ryan, House, & Rosenthal 1991, p. 20). Tom Seaver commented, "In my eighteen years of pitching, the emphasis on conditioning, weight training, and flexibility is one of the most dramatic changes I've seen (Seaver & Lowenfish, 1984, p.24). Strength training has since gained
changes I've seen (Seaver & Lowenfish, 1984, p.24). Strength training has since gained acceptance in baseball as research has shown the benefits of strength in regard to power, speed, flexibility, and injury prevention (Cimino, 1987; Kephart, 1984; Lefebvre, 1983; Mullins, 1993; Potteiger & Wilson, 1989; Roll, Omer, & Pontiff, 1986; Rosenboom, 1992; Simmons, Hall, & Hille, 1983).

Research has shown that strength training methodologies will increase muscular strength and size (Howard, Ritchie, Gater, Gater, & Enoka, 1985; Komi, 1986; MacDougall, 1992; Sale and MacDougall, 1981) and may decrease contractile time (Sale, 1988). Using specific and non specific velocity training, improvements in muscular torque (the measure of force's tendency to produce torsion and rotation about an axis) have also been realized. These studies have used isokinetic machines to train subjects at various training speeds. Upon completion of the training protocols, the subjects were tested at lower and higher velocities to measure any training carry over effect. Most of the studies performed have used the lower extremity in their investigations.

High speed velocity training has correlated with increases in muscular power production at both slow and fast test speeds, while training at slower velocities correlated only with improved power at slower speeds (Coyle, Feiring, Rotkis, Cote, Roby, Lee, & Wilmore, 1981; Moffroid & Whiple, 1970; Pipes and Wilmore, 1975; Sale & MacDougall, 1981). These studies are in contrast to others that have shown training at slow speeds results in improvement of strength at slow rates of contraction only, while training at fast speeds corresponds to increases of power at fast test speeds only (Caiozzo
et al., 1981; Coyle & Ferring, 1980; Ewing, Wolfe, Rogers, Amundson, & Stull, 1990; Kanehisa & Miyashita, 1983). Still another study has shown that training at an intermediate speed produced changes in strength at that test speed and slower speeds, but not at higher velocities (Lesmes, Costill, Coyle, & Fink, 1978). Significant \((p < 0.05)\) improvements have also been seen in all test speeds except the fastest regardless of slow or fast training speed (Caiozzo, Perrine, & Edgerton, 1981). There seems to be great debate as to which training speeds are the most appropriate for developing peak torque and power. The variance of these studies can probably be explained by differences in methodology, subjects, and movements.

Kanehisa and Miyashita (1983) examined the relationship between isokinetic training velocity and power output (measured in watts) at five specific speeds. The subjects consisted of 21 male volunteers aged 23-25 years, who were randomly assigned to one of three training groups: slow (S), intermediate (I), and fast (F). Group S trained at 1.05 rad/sec, group I at 3.14 rad/sec, and group F at 5.24 rad/sec. The subjects trained the knee extensors by performing 10 consecutive maximal knee extensions in S, 30 in I, and 50 in F. The training consisted of six sessions per week for eight weeks. The subjects were tested pre and post training for maximal knee extension power at 1.05, 2.09, 3.14, 4.19, and 5.24 rad/sec.

Changes with in a group were analyzed using a Student's t-ratio. A one way analysis of variance was used to determine if a significance among groups was evident. Significant \((p < .05)\) increases in average power were seen for groups S and I at all test
speeds. Group F showed statistically significant ($p < .05$) increases at only 4.19 and 5.24 rad/sec. The percent increase in power obtained by group S decreased as training speed increased. Group I showed almost identical percent increases in average power at all test speeds except 2.09 rad/sec. Groups I and F showed greater statistical increases ($p < .05$) in power than did group S at test speeds of 4.19 and 5.24 rad/sec. The authors concluded that their results displayed a specificity of velocity effect. Training at slower speeds results in increased power at slow rates of contraction, while training at higher speeds develops the power only at high rates of contraction. Due to the results of group I showing similar percent increases in power at all test speeds, the authors indicated that a non specific training velocity may also exist.

Behm and Sale (1993) reported a specificity of velocity response to high velocity training. They investigated whether rapid and extensive muscle shortening was a necessary stimulus in producing a high velocity training response. The subjects trained with one foot restrained so that the contractions in that foot were isometric. The other foot was also restrained, but was allowed dorsiflexion at a rate of 5.23 rad/sec. They found that peak torque increased most at the training velocity of 5.23 rad/sec in comparison to slower velocities. The authors also found that the intention to move at a high rate produced similar test results. The isometrically trained foot had similar increases in voluntary isometric rate of torque development (26%) and relaxation (47%). A decrease in twitch time to peak torque and half relaxation time was also seen in the isometrically trained foot. Behm and Sale noted that while the isometric training could
be interpreted as slow velocity training, they believed that their training was unique. This uniqueness was attributed to the attempted high velocity movements. They cite typical isometric or low velocity studies where no emphasis is placed upon rapid movement, thus a low rather than high velocity specific training response is produced (Behm & Sale, 1993 p. 365).

Pawlowski and Perrin (1989) studied the relationship between throwing velocity and isokinetic measurements of peak torque, torque acceleration energy, average power, and total work during shoulder flexion and extension, shoulder internal and external rotation, and elbow flexion and extension. Ten intercollegiate baseball pitchers participated in the study (age = 19.6 + 1.4 years). College pitching experience ranged from 1 to 4 years with a mean of 1.7 + - .9 years. Data were collected in two phases: isokinetic testing and velocity measurement. A Cybex II Isokinetic Dynamometer equipped with an upper body exercise table interfaced with a Cybex data reduction computer was used to measure the strength testing. An M.P.H. K-15 hand held stationary radar device was used to measure velocity.

The pitchers were tested for peak torque at 60 and 240 deg/sec, while torque acceleration energy, average power and total work were tested at 240 deg/sec during the previously mentioned isokinetic contractions. These results were correlated with throwing velocity using a Pearson Product Moment correlation. The correlations between throwing velocity and isokinetic measures of shoulder flexion and extension and elbow flexion and extension were not significant. Significant correlations were found
between shoulder internal rotation at 240 deg/sec and throwing velocity: peak torque
($r = .66, p < 0.05$), total acceleration energy ($r = .68, p < 0.05$), average power ($r = .80, p < 0.01$), and total work ($r = .81, p < 0.01$). Significant correlations were also observed
between throwing velocity and shoulder external rotation at 240 deg/sec: peak torque ($r = .75, p < 0.05$), average power ($r = .76, p < 0.05$), and total work ($r = .78, p < 0.05$). There
were no significant results between throwing velocity and shoulder internal and
external rotation at 60 deg/sec. The researchers concluded that while the results did not
indicate a cause and effect, they do suggest a specificity of exercise for the internal and
external rotator muscle groups. In addition, since the only significant results were at 240
deg/sec, training may be the most appropriate at faster speeds of contraction.

Pedegana, Elsner, Roberts, Lang and Farewell (1982) studied the relationship
between upper extremity strength and throwing speed. The subjects were eight volunteer
professional baseball players. Throwing speed was recorded with the use of a Ray-Gun
radar gun, while upper extremity strength (power) was recorded using a Cybex II
Isokinetic Dynamometer. Peak torque was recorded during shoulder abduction and
adduction, shoulder flexion and extension, shoulder horizontal abduction and adduction,
shoulder internal and external rotation, elbow flexion, extension, supination, and
pronation. The testing speeds used were 60 and 180 deg/sec. for shoulder and elbow
movements, and 30 and 120 deg/sec. for the wrist and forearm. No reason was given for
the different test speeds.

A simple linear regression was used to relate throwing velocity to the different
movements tested. The data were analyzed for significance of the regression coefficient. The results indicated that elbow extension, shoulder external, shoulder extension, shoulder flexion, and wrist extension significantly related to throwing velocity. Using a multiple linear regression to examine the combined influence of these variables on velocity with wrist extension as the most significant single variable, regression models with wrist extension and the other four significant variables as independent variables were fit (Pedegana et al. 1982). The authors concluded that wrist extension and elbow extension have a higher relationship with regards to throwing velocity than do the other variables tested.

The test speeds in the previous studies were much slower than the actual velocities of game competition. To date, there is no isokinetic resistance machine that can simulate the velocities that are reached in throwing a baseball. During the acceleration phase of pitching, internal rotational velocity in the pitching arm approaches 7,000 deg/sec (Dillman, Fleisig, & Andrews, 1993). Another limitation of isokinetic machines is that constant velocity is seldom seen during everyday or athletic events (Westing, Seger, & Thorstensson, 1991 p. 631).

Using a comparison of plyometrics and weight training, Newton and McEvoy (1994) found that weight training was an effective means to increase both strength as based on a 6 RM bench press and ball velocity. The subjects (24 junior development baseball players) were randomly divided in to three different groups; medicine ball, weight training, and control. They participated in the eight week study in conjunction
with their baseball training. The medicine ball group performed "explosive upper body medicine ball throws" (Newton & McEvoy, 1994, p. 198) twice per week. This consisted of maximal chest pass and overhead throw exercises with a 3 kilogram ball. The subjects were instructed to perform 3 sets of 8 throws for each exercise for the first 4 weeks of the study. The volume of throws was increased to 3 sets of 10 throws for the last 4 weeks of the study. A rest period of 3 minutes was allowed between each set of exercises. The weight training group performed a barbell bench press and barbell pullover twice per week. The subjects in the weight group performed 3 sets of 8 to 10 repetitions maximum for the first 4 weeks of the study. The intensity of the lifts was then increased to 3 sets of 6 to 8 repetitions maximum for the last four weeks of the study. A 3 minute rest period was allowed between each set of the exercises. The control group did not participate in any form of resistance training. Both the medicine ball (two tailed $t = 3.53$, $p = 0.01$) and weight training group (two tailed $t = 6.57$, $p < 0.000$) improved their strength significantly. The only group that improved velocity with significant change from pre to post training was the weight trained group (two tailed $t = 2.56$, $p = 0.038$). However, there was no significant relationship found between the change in throwing velocity and the change in 6 RM strength ($r = 0.147$, $p = 0.25$).

**Neural adaptations.** Strength training is not only dependent upon the amount of weight lifted or the number of repetitions performed, but also on the ability of the nervous system to properly activate the muscles. Sale (1988) noted that strength training may cause changes in the nervous system to allow a subject to activate prime movers.
more completely and to improve coordination of all other relevant muscles. This occurrence would effect a greater amount of force in a movement (Faulkner, Claflin, & McCully, 1986). Force may also be produced quicker as a result of strength training as evidenced in decreased time to peak force by EMG studies. This peak force may also be maintained longer. Motor neuron excitability may also be enhanced by training (Chu, 1996, p. 11; Enoka, 1994, p. 158; Hakkinen & Komi, 1983; Sale, MacDougall, Upton, & McComas, 1983; Sale, 1986, p. 289).

**Surgical tubing.** Behm (1988) reported that surgical tubing can be used as an inexpensive and adaptable form of resistance training. The elasticity of the tubing allows the subject to perform activities at the speeds encountered in sport, while offering resistance through the normal range of motion. Of interest is the fact that the velocity specific effects of isokinetic training may be applicable in training programs using surgical tubing.

Behm (1991), conducted a study to compare the effectiveness of 10 weeks of training using surgical tubing, light resistance, and isokinetic exercise on velocity specific strength gains. His subjects were randomly assigned into three training groups: group one using the Hydragym, group two using surgical tubing, and group three using a Universal gym. The subjects trained three times per week on alternate days. All subjects trained using a shoulder press action, extending the resistance behind the head and neck. The load was assigned according to 50% of each subject’s individual one repetition maximum on the Universal machine shoulder press. All subjects moved at the same
training velocity of approximately 3.14 rads per second. This was achieved by timing with a metronome and monitored by the researcher. Each training session consisted of 3 sets of 10 repetitions with a 6 to 1 relief to work ratio. Testing was conducted on an isokinetic dynamometer for shoulder abduction strength both pre and post training. Testing was done randomly at five different test speeds: 60° per second, 120° per second, 180° per second, 240° per second, and 300° per second. Subjects were also post tested for their one repetition maximum strength on the Universal machine. A three by five repeated measures ANOVA was used to analyze the isokinetic data. A three by two repeated measures ANOVA was used to analyze the Universal machine data. Significance was set at the .05 level. The results showed a significant increase in peak torque of 14.7% in the surgical tubing group, 14.1% in the Universal group, and 10.4% in the Hydragym group. There were no significant differences between groups. There was also no velocity response to the training in any of the three groups. The conclusion was made that “all three training methods are equally effective in promoting strength gains” (Behm, 1991).

Frappier (1994) conducted a case study that examined the effects of the throwing cord on mean and peak velocity during a six week intervention period. The subjects were 27 baseball players who participated at the collage level. No specific level of competition or experience was specified in the case study report. There was no control group. The study was not limited to pitchers as an outfielder and a catcher participated in the study. The subjects participated in the study “just after the completion of fall
baseball" (Frappier, 1994). It was assumed that the subjects' arms were in a highly trained state due to the completion of fall practice and participation in spring and summer league play. Each subject was filmed prior to the study and corrections made for those subjects who displayed improper throwing mechanics. The subjects were to reduce their total throwing volume by 20% and take part in the throwing cord exercises two days per week for six weeks. During the throwing cord training sessions, the subjects threw 6 sets of 10 repetitions. A five to six minute rest period was allowed between sets of throws. Velocity was measured at the beginning, three week, and upon completion of the 6 week study. Velocities were recorded with a Jugs radar gun over twenty pitches. Only pitches characterized as strikes were recorded. This procedure was followed for all subjects for all three recording trials. Only mean and peak measures of velocity were used to describe the results of the study. Loads for the amount of stretch are indicated in Appendix A1 and A2, although the amount of load on the arm was not measured in this study. According to Frappier (1994), a mean increase in velocity of three to four miles per hour was observed. To investigate these findings further, a one-way Repeated Measures ANOVA on the raw data (Shropshire, Frappier, & Curry, 1998) was conducted. Results indicated significant findings for mean velocity of \( F = 207.70, p < .0001 \), and for peak velocity \( F = 167.42, p < .0001 \). Post hoc analyses were performed with Bonferroni adjusted alpha to see where the effect took place. These results indicated that for both mean velocity and peak velocity significant differences were noted from beginning to end, beginning to middle, and middle to end (all \( t_s > -9.372, all \ p_s < .001 \).
Even though these results demonstrated the effectiveness of training with the throwing cord, methodological concerns limit interpretation. The lack of a control group, undocumented sampling methods, and biomechanical coaching may have confounded the significant findings specific to the effectiveness of the throwing cord.

Surgical tubing can also be used for muscle strengthening in rehabilitation and injury prevention settings. Page et al. (1993), studied the effects of Theraband™ Elastic Band training on eccentric strength of the posterior rotator cuff muscles as compared to a traditional isotonic resistance exercise program. Twelve subjects were randomly assigned to 2 groups that exercised for 6 weeks. One group exercised with the Theraband™, in addition to an isotonic strength program (experimental group). The other group performed only isotonic exercises (control group). The subjects were pretested and posttested for average eccentric strength of the posterior rotator cuff in a functional diagonal pattern. An isokinetic device was used to determine average strength values of each subject. Test speeds of 60° and 180° per second were used to assess strength. Isotonic training consisted of 1 set of 10 repetitions with a five pound dumbbell performed three times per week. The exercises performed were Circumduction, Abduction, Biceps Curls, Triceps Extensions, Standing supraspinatus “empty can”, Posterior Cuff External Rotation, and Horizontal Abduction. “The Theraband™ routine consisted of exercise in the D2 diagonal pattern of proprioceptive neuromuscular facilitation patterns” (Page et al., 1993). Subjects initially completed three sets of 10 repetitions per day at a given resistance, each repetition lasting
approximately 10 seconds. Each training session added five more repetitions up to a total of 25. Once 25 repetitions were achieved a heavier resistance was used and the repetitions were returned to 10. The Theraband™ is color coded in progressive resistances beginning with yellow (lightest resistance), and progressing through red, green, and blue. The subjects initially used the yellow resistance and progressed as they tolerated the protocol.

The data was analyzed with an analysis of covariance at the .05 level. Significance was found at the $60^\circ$ per second test speed only. Subjects in the Theraband™ group increased eccentric force production ($+19.8\%$) more than the control group ($-1.6\%$). There was no difference in both groups at $180^\circ$ per second. The authors concluded that the Theraband™ was effectively increased eccentric strength at $60^\circ$ per second in the posterior rotator cuff in the pitching arm.

Pezzullo, Karas, and Irrgang, (1995) outlined the use of Theraband™ as a part of a rehabilitation program specific to throwing athletes. The authors state that Theraband™ is “a useful strengthening tool in the clinic as well as an effective component of a home exercise program. The trainer can design Theraband™ exercise programs to provide resistance to any phase of the throwing motion desired” (Pezzullo et al, 1995). Various exercises are described that are used to strengthen the internal and external rotators, as well as diagonal patterns to strengthen the throwing arm that “mimic the acceleration and deceleration phases of throwing” (Pezzullo et al, 1995).

Regan and Underwood (1981) also describe the use of surgical tubing for the
rehabilitation of the shoulder and ankle. The authors state that "Tubing provides variable isotonic resistance that increases progressively as the tubing is stretched" (Regan & Underwood, 1981).

**Plyometrics**

Plyometrics is a term used to describe training exercises where the involved muscles undergo a rapid deceleration of mass followed by an almost immediate acceleration in the opposite direction (Wathen, 1993). This action has many different names, but is usually referred to as the stretch reflex (Chu, 1983, 1992; Hakkinen, Komi & Alen, 1985; Komi, 1992; Lundin & Berg, 1991; Wathen, 1993).

The stretch reflex can also be thought of as the rubber band principle, where the greater the muscle is stretched, the stronger the contraction of the rubber band (muscle) will be when it is released. This simple explanation can be explained physiologically as follows. The muscles of the body are controlled by the central nervous system. This is known as motor control. Within each skeletal muscle, joint, tendon, and ligament, proprioceptors exist to allow the brain to monitor the degree of stretch of the muscle they occupy (Marieb, 1992). These proprioceptors include the muscle spindle and the Golgi tendon organ. The muscle spindle is responsible for detecting the degree and rate of stretch in a muscle while the Golgi tendon organ senses the amount of tension in a tendon during contraction of a muscle. The effects of these two proprioceptors on the muscle is facilitation and reinforcement, and inhibition respectively (Chu, 1992; Marieb, 1992).

When the muscle is stretched the muscle spindle monitors the rate of stretch, and
the length of that stretch by sending an afferent sensory message to the spinal cord. The spinal cord then sends efferent impulses back to the muscle causing contraction of the stretched muscle and inhibition of the antagonist muscles (Marieb, 1992). The greater the rate of stretch or the higher the load that the muscle encounters, the greater the concentric contraction after the stretch. (Chu, 1992; Lundin & Berg, 1991)

The Golgi tendon organ helps to guarantee a smooth beginning and ending of muscle contraction. It is activated when a muscle contracts and tension is developed in its respective tendon. Afferent signals are sent from the Golgi Tendon organ to the spinal cord, and a corresponding message is sent to inhibit the contracting muscle while at the same time activating the antagonist (Marieb, 1992). This inhibition may be done in order to protect the muscle from injury. While this may seem disadvantageous, the inhibition may be off set during voluntary exertion until muscle tension becomes excessive and injury becomes possible (Lundin & Berg, 1991 p. 23).

In order to take advantage of these physiological occurrences, jumping, depth jumping, bounding, and medicine ball exercises have been used. The goal of plyometrics is to link speed of movement and strength to elicit power (Chu, 1992). Most of the research conducted has analyzed how plyometrics affect performance in the lower body (Newton & McEvoy, 1994).

Wilson, Newton, Murphy, and Humphries (1993) compared the effects of plyometric training, weight training, and explosive weight training at a load that maximized mechanical power. They found this load to be approximately 30% of each
subject’s one RM. The 64 previously trained subjects were randomly selected into one of four training groups; plyometric, weight training, explosive weight training, and control. The training period lasted for 10 weeks with testing for maximal performance done pre, mid and post. The test consisted of a 30 meter sprint, vertical jumps performed with and without a counter movement, maximal power during a six second cycle test, an isokinetic leg extension test measuring peak torque at 5.2 rads/sec, and a maximal isometric half squat test performed at 2.36 rads/sec. They found that of the three training methods, the plyometric trained group showed the least pre to post training statistical improvement, showing a 10.3% increase in the counter movement jump test only.

Hakkinen et al. (1985) examined the effects of 24 weeks of explosive type strength training on isometric force and relaxation time, electromyography, and fiber characteristics of the leg extensor muscles. The subjects consisted of 10 strength trained non-competitive males, and eight subjects who served as controls. After the 24 week training session, a 12 week period of detraining occurred. The experimental group trained three times per week performing the explosive exercises. These exercises were: (1) a maximal counter movement jump with a loaded (10 - 60% one RM) barbell, (2) a maximal standing five jump, (3) a maximal five hurdle jump, (4) a maximal drop jump followed by a maximal rebound, and (5) a maximal drop jump followed by a maximal rebound which was helped by a rubber band that was attached to the subject’s waist and extended from the ceiling. The subjects also participated in a strength training regimen three days per week. The subjects strengthened the trunk, arms, and leg extensor muscles
A significant ($r = .055, p < 0.05$) correlation was found between the increases in the maximum average overall IEMG and the maximal isometric force during the latter half of the training period. The force time curve for the muscles studied shifted up and to the left, indicating an improvement in the muscles ability to generate force in less time. The authors concluded that the explosive training resulted in improvements in time of force production. They cited the progressive nature of the exercises as well as the many different jumping exercises used during the training for the improvement in fast force production.

**Implements**

Implement training uses equipment that is lighter or heavier than the actual equipment to attempt to induce increases in velocity. Extremely heavy or light implements have been shown to have adverse effects on normal velocity (DeRenne, 1987). The normal neurological recruitment pattern is changed when using extremely heavy or light implements and thus does not follow the principles of specificity (DeRenne, Tracy, & Dunn - Rankin, 1985). Implement training is designed around the specificity of exercise principle that states the training preceding the event should duplicate the actual event as closely as possible.

Recent research appears to be limited in this area. Based upon the most recent studies, there may be a transfer of training effect using baseballs of lighter and heavier weights (Bagonzi, 1978; Brose & Hanson, 1967; DeRenne, Tracy & Dunn - Rankin, 1985; DeRenne, Ho, & Blitzblau, 1990; Litwhiler & Hamm, 1973).

DeRenne, Ho, and Blitzblau (1990) have studied the effects of using over and
under weighted baseballs on throwing velocity. They used 30 high school varsity male baseball pitchers as subjects. The subjects were assigned randomly into an over weighted implement training group, an under weighted implement training group, or a control group. All three groups trained for 10 weeks. Throwing velocity of a “standard weight ball of five ounces” (DeRenne, 1990) was recorded pre and post training using an electromagnetic radiation radar device. The over weighted training group threw balls that systematically varied from five to six ounces. During weeks 1 to 2, they threw a 5 ounce ball. The weight of the ball was increased by .25 ounces every two weeks until the completion of the study when they used a 6 ounce ball for weeks 9 and 10. The under weighted training group threw balls that varied from five to four ounces. They followed the same progression, but in reverse. The under weighted group threw a 5 ounce ball during weeks 1 and 2, with the weight of the ball decreasing by .25 ounces every two weeks until weeks 9 and 10 when they threw a 4 ounce ball. The control group threw a 5 ounce ball for the duration of the study. All three groups showed improvement in throwing velocity at the conclusion of the study. However, both the over and under weighted groups showed significantly greater gains in velocity when compared to the control group (p < 0.05). The researchers did not report any residual effect of the study, only that throwing velocity increased in the under and over weighted training groups. The researchers attributed the increase in throwing velocity to the implements as the subjects threw the same number of pitches and did not participate in any other strength training during the study.

Bagonzi (1978) concluded that the use of over weighted baseballs improves
throwing velocity. He studied the effects of various overload techniques on velocity and accuracy of a thrown baseball. The subjects were 48 high school baseball candidates ranging in age from 15 to 19 years. They were randomly divided into one of eight groups that trained twice a week for 18 weeks. The eight groups were as follows: (1) throwing regulation baseballs, (2) throwing overweighted baseballs (the balls weighed 7, 9, 10, 11, 12, and 13 ounces) (3) free weight training group, (4) free weights and weighted baseballs, (5) bullworker group (an isometric device), (6) bullworker and weighted baseballs, (7) bull-worker and free weights, and (8) free weights, bullworker, and weighted baseballs. Each group exercised according to a protocol set forth by the researcher. At the end of each exercise session, all participants threw a regulation baseball maximally 10 times. Velocity was measured with the use of a radar gun. The data analysis indicated that the treatments significantly improved the velocity of a baseball throw. There was no significant change in velocity that took place among groups. When all groups were compared with the control group, a Scheffe Test indicated that the weighted ball group (2), the free weight and weighted ball group (4), and the bullworker, free weight, and weighted ball group (7), showed significant differences from the control group \( p < 0.05 \). The author concluded that: (1) Overload techniques do not have a strong effect on the velocity and accuracy of a thrown ball (2) The use of weighted balls improves velocity in throwing a baseball (3) Overload training over an 18 week period increases velocity and accuracy of a thrown baseball. (4) There appears to be a small relationship between accuracy and velocity of a thrown baseball.

DeRenne, Tracy, and Dunn-Rankin (1985) studied the effects of overload and
speed training exercises, also known as variable speed training, on throwing velocity. This was done using over and under weighted baseballs. The subjects were 10 trained high school pitchers. They were between the ages of 16 and 18, and were currently playing in a competitive summer league at the time of study. The subjects were randomly assigned into two groups (A and B). Each group was instructed to avoid any other type of weight training during the 10 week study. Due to limited number of participants, there was no control group. Both groups exercised 3 times per week. Group A participated in the overload exercises only. These exercises consisted of throwing progressively heavier weighted baseballs. The balls weighed 5 1/4 ounces, 5 2 ounces, 5 3/4 ounces and 6 ounces. Each pitcher in group A warmed up for 15 minutes with a heavy ball, gradually increasing the distance between them and the catcher to 150 feet. After the warm up, they would throw to a catcher for an additional 10 to 15 minutes at 2 to 3/4 speed. Once a week each pitcher would throw hard in the bullpen for 20 to 25 minutes. In the first 10 to 15 minutes, the pitcher would throw the heavy baseball. During the last 10 to 15 minutes, he would throw a regulation weight baseball. Each pitcher would work out with a specific weighted baseball for two weeks. During the next two weeks, he would work out with the next heaviest ball and so on until completion of the study. The subjects in group B were considered the variable speed training group. The balls group B used followed the opposite progression of weighting as in group A, ranging from 4 3/4 ounces to 4 ounces. They followed the same throwing procedures as group A for warm up and bullpen workouts. As in group A, the group B pitchers threw hard using an under-weighted ball. The remaining 10 minutes, they used a regulation
ball. During the bullpen exercises, each pitcher concentrated on throwing with maximal velocity. Each pitcher also used an exaggerated wrist snap during the release of the ball.

Velocity was recorded at the end of each two week training bout with a commercial police velocity analyzer (DeRenne et. al, 1985, p. 38). Each pitcher warmed up with a regulation weight baseball. After the warm up, each pitcher threw 10 consecutive pitches with a regulation weight ball, with velocity recorded for each pitch. A pre and posttest was conducted in conjunction with the study to measure differences, if any.

A Friedman two - way analysis of variance by ranks was performed on each subject’s average velocity. Median velocity over 10 pitches was calculated for each subject after each two week period. These medians were then rank ordered for each of the five subjects per group for the five two week training sessions. The researchers found a significant ($p < 0.05$) gain in velocity for both groups. Average gains were twice as great in the under loaded group (3.0 mph) compared to the overloaded group (1.5 mph). The researchers concluded that variable speed implements should be weighted close to the standard game implement.

EMG throwing studies

Jobe, Radovich- Moynes, Tibone, & Perry, J. (1983, 1984) studied the EMG activity of the deltoid, subscapularis, supraspinatus, infraspinatus, teres minor, pectoralis major, biceps, lateral and long heads of the triceps, latissimus dorsi, brachialis, and serratus anterior. They used dual wire electrodes inserted directly into the muscles to determine electrical activity during different stages of the throwing motion. High speed
(450-500 frames per second) cameras recorded the subjects during the throwing motion from the front, side and overhead. This data was synchronized with the EMG by simultaneous marks on the EMG recorder and film every 50 frames, allowing determination of muscle firing sequence. The authors broke the throwing motion down into four separate stages. (1) The wind up is characterized by upper extremity flexion with both hands holding the ball: (2) Cocking consists of shoulder abduction and external rotation. It begins with release of the ball by the gloved hand, and terminates with maximal external rotation at the shoulder; (3) Acceleration begins with maximal external rotation at the shoulder and continues until ball release. (4) The follow through is a continuation of shoulder inward rotation and horizontal flexion while the subscapularis assists in the internal rotation of the shoulder.

They found that during the wind up, all muscle activity was minimal and that any firing of the muscles that took place was of low intensity. During the early phase of the cocking stage, deltoid supraspinatus, infraspinatus, and teres minor had high levels of activity, with peak levels occurring in the deltoid. The later stages of the cocking phase produced moderate activity from the biceps and high amounts of activity from the subscapularis. During the acceleration phase, the deltoid, subscapularis, supraspinatus, infraspinatus, biceps and teres minor displayed minimal levels of activation, while the pectoralis major, triceps, latissimus dorsi, and serratus anterior were all highly active. This may suggest that the role of the rotator cuff musculature is primarily one of stabilization, rather than that of activation (Jobe, et al., 1983). During the follow through, there were high amounts of activity seen in the deltoid, subscapularis, supraspinatus,
infraspinatus, bicep, and teres minor as the arm decelerated. Activity was also noted in this stage by the pectoralis major and latissimus dorsi as the arm moved across the body.

In a somewhat related effort, Shropshire and Leonard (1995) recorded the surface EMG activity of the anterior deltoid, posterior deltoid, pectoralis major, and the latissimus dorsi. Two recordings of EMG activity were taken during two trials, one without the throwing cord, and the other with the throwing cord. The subject was allowed to warm up until he felt warmed up and ready to throw. All throwing motion was done with out a baseball. The researchers were unable to use a high speed camera to synchronize the data with the throwing motion, so the analysis is somewhat speculative. (see Appendix B and C for EMG tracings). From the recordings with the throwing cord off, the activity levels in the deltoid muscles seem to be in accordance with the Jobe et al. (1984) findings in that there were minimal levels of activity except in trial one for the anterior deltoid. The pectoralis major was most active after approximately 125 milliseconds. This is especially true in trial one, which would approach the Jobe et al. (1984) findings as well. Latissimus dorsi showed little activity throughout the recording session. The activity with the throwing cord on was similar to that with it off except for the activity in the anterior deltoid, which was noticeably higher.

Summary

Based upon the research, several conclusions can be made with relative certainty. First, a velocity specific effect of training seems to exist. Research performed with isokinetic machines that compared different training speeds to a variety of testing speeds shows that training at slow speeds will increase strength at slow test speeds. Inversely,
training at fast training speeds resulted in gains in strength at fast test speeds, though the
effect (% strength increase) was not always as great when compared to the slower speed
results (Caiozzo et al., 1981; Coyle & Ferring, 1980; Coyel et al., 1981; Ewing et al.,
1990; Kanehisa and Miyashita, 1983; Moffroid and Whipple, 1970; Pipes and Wilmore,
1975; Sale and MacDougall, 1981). Increases in strength are also specific to the
movement pattern (or exercise), contraction type and joint angle used during training
(Lindh, 1979; Newton & McEvoy, 1994; Sale, 1988; Sale & MacDougall, 1981;
Thorstensson, Hulten, VonDoblem, & Karlsson, 1976).

Secondly, surgical tubing can be used as an instrument in developing strength
through a functional range of motion (Behm, 1991, Page, et al., 1993; Pezzullo, et al.,
1995), to rehabilitate from an injury, (Pezzullo et al., 1995; Regan & Underwood, 1981),
and can be used in the enhancement of athletic performance (Behm, 1988, 1991;
Frappier, 1984). There are however limited research findings documenting actual
performance enhancement.

Third, some types of training may have limited effects on the velocity of a pitched
baseball. The use of slightly over or under weighted baseballs appears to increase
throwing velocity (Bagonzi, 1978; DeRenne, Tracy, & Dunn-Rnkin, 1985; DeRenne,
1987; DeRenne, Ho, & Blitzblau, 1990). However, the research to document such gains
are limited at this time. Plyometric training has limited if any affects on throwing
velocity. More research is need in this area to document conclusive results (Newton and
McEvoy, 1994).

Last, EMG studies on the throwing motion allow researchers to determine the
sequential firing patterns of the muscles involved (Jobe et al. 1983, 1984). These two studies were initial investigations with limited numbers of subjects and subjective data interpretations. More studies like these are needed to fully understand the neuromuscular aspects of the throwing motion.
Chapter 3

Methodology

Subjects

A purposive sample was selected from the Minot State University baseball team in Minot, North Dakota. Minot State competes at the NAIA Division I level. The subjects were 15 males ranging in age from 18 to 24. Only individuals with at least two years of prior pitching experience inclusive of legion and high school were included in the study. The subjects were randomly assigned to one of two groups. Subjects in group one (n = seven) threw without the use of the throwing cord, and subjects in group two (n = eight) supplemented half of their training volume with the throwing cord (see Appendix D for complete descriptive statistics for each group).

Instruments

The throwing cord apparatus is a device consisting of two Neoprene straps tethered to a common resistance point by nylon stirrups which in turn are attached to an eight foot piece of resistance cord, more commonly known as surgical tubing. The device is designed to allow the subject to throw using individually specific biomechanics with an overload to the throwing musculature provoked by the stretch of the surgical tubing.

All subjects threw off a wooden mound designed for indoor use (see Appendix E1 and E2). The throwing velocity of both groups was determined by the use of a Jugs Radar Gun.
Procedures

Prior to any data collection, the athletes were randomly divided by using a table of random numbers into one of two groups: (1) subjects who threw without the use of the throwing cord; and (2) subjects who supplemented half of the total throwing volume with the throwing cord. Pre and post testing was done two to three days prior to and at the end of the training period. The total number of throwing repetitions was the same in both groups. The subjects did not participate in any other baseball related activities such as practice, throwing, or hitting. However, they did participate in a strength program conducted at Minot State University. All subjects used the same program. This program is a part of the off season conditioning program, and participation was mandatory.

The training period for both groups was five weeks, done twice per week. Two to three days of rest between sessions was allowed. The duration of the study was based on research conducted by Adams, O'Shea, O'Shea, and Climstein (1992), and Frappier (1994). Adams suggested that four to six weeks is the optimal length of time that the central nervous system can be stressed during high speed, high intensity strength training without undue strain or fatigue. Frappier used six weeks as the time frame for his case study.

Treatment Intervention. The subjects followed a set protocol of throwing repetitions throughout the entire five week training period. None of the subjects missed a scheduled throwing session.
### Five Week Progressive Throwing Protocol for Group One

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<th>Week #</th>
<th># of Sets and Reps</th>
<th>Total Reps</th>
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</thead>
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<td>2x10</td>
<td>20</td>
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<tr>
<td>2</td>
<td>3x10</td>
<td>30</td>
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<tr>
<td>3</td>
<td>3x10, 1x6</td>
<td>36</td>
</tr>
<tr>
<td>4</td>
<td>4x10, 1x6</td>
<td>46</td>
</tr>
<tr>
<td>5</td>
<td>6x10</td>
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</table>

### Five Week Progressive Throwing Protocol for Group Two

<table>
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<th># of Sets and Reps</th>
<th>Total Reps</th>
</tr>
</thead>
<tbody>
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<td>36</td>
</tr>
<tr>
<td>4</td>
<td>2x10, 1x3 / 2x10, 1x3</td>
<td>46</td>
</tr>
<tr>
<td>5</td>
<td>3x10 / 3x10</td>
<td>60</td>
</tr>
</tbody>
</table>

Note. The split figures under # of Sets and Reps represents the number of throws with the throwing cord on (performed first) and with it off.
The progression of sets and repetitions was chosen so as not to over train the throwing arm, and subsequently avoid any over-use injuries. The number of sets and repetitions was chosen to stress the ATP-PC system used in ballistic type contractions such as throwing (Potteiger & Wilson, 1989) and to mimic the Frappier case study (1994). After each set, a 5 to 6 minute rest period was allowed to insure a recovery of the ATP-PC system as well as mirroring the Frappier study (1994). The throwing was done from either the stretch or the wind-up, as the throwing motion is the same in either delivery style (Hay, 1993). The subjects were instructed to warm up on their own prior to any throwing. The warm up for each individual was different, but consisted of a 5 to 10 minute jog followed by stretching of the body and throwing arm. The subjects were then instructed to throw a baseball as many times as needed for them to feel loose. This method of warm up was used by Jobe et al. (1983, 1984). When the subject felt ready to throw, he was fitted with the throwing cord and then instructed to throw (group two), or would begin throwing without the use of the throwing cord (group one). In every throwing session, the subjects in group two would throw with the cord on first, completing the necessary sets of throws. They then completed the sets designated as those without the cord second.

The positioning of the Neoprene straps around the throwing arm remained approximately constant for the duration of the training period. The larger of the two straps was positioned on the lateral side of the humerus, so that when the humerus is
laterally abducted in the frontal plane to 90 degrees and the forearm is flexed to 90 degrees at the elbow (see Appendix F), the pull of the cord upon the humerus is posterior (see Appendix G1 and G2). The second Neoprene strap was attached to the wrist at the radio-ulnar joint, with the top border of the strap in line with the head of the ulna. The strap was centered on the radio-ulnar joint by measuring its width, and aligning the center of the strap with the center of the joint (see Appendix H). The strap was positioned on the wrist when the humerus was laterally abducted in the frontal plane to 90 degrees, externally rotated, and the elbow flexed at 90 degrees. The pull of the second strap was posterior to its attachment site (see Appendix I). The positioning of the Neoprene straps remained approximately constant during the study. Due to some slippage that occurs with sweating and measurement error, the positioning of the straps may have varied slightly. The position of each strap was evaluated prior to throwing, and after every set to confirm its position.

A facilitator was needed at the end of the throwing cord to hold the apparatus thus providing an anchor point. The positioning of the facilitator was 274.32 cm (9 feet) behind the pitcher. This was chosen by analyzing the distance between the front of the pitching mound rubber, and the point at which the cord became taunt, but not stretched. This distance remained constant throughout the training period and was evidenced by a white tape line measured and stuck to the floor (see Appendix J). This same distance was remeasured before each training session to ensure the proper distance had not been changed. In order for the stretch of the throwing cord to remain as constant as possible
(for each subject), the cord was not pulled on or lengthened in any way by the facilitator during the throwing motion. Additionally, the cord was held in the same position for each individual. The facilitator gripped the end of the cord via a nylon loop. The cord was held at the level of the umbilicus, with the hand held next to the abdomen (see Appendix J).

Once the subject was fitted with the throwing cord, he was instructed to throw the ball at maximal velocity using his own natural throwing style off the wooden mound. The ball was stopped by a net that was placed 10 to 15 feet from the mound. This eliminated the need for a catcher, and expedited the trials. No rest was given between throws other than what was required to obtain another ball and become ready to throw again. This was estimated to be between seven and ten seconds. After 10 consecutive throws, the subject was rested for five to six minutes. The throwing cord remained on the subject's arm, unless it had to be refitted due to slippage and perspiration. In the trials where the subjects threw sets containing fewer than 10 throws, the same protocol of work and recovery was followed.

Velocity was recorded at the beginning and end of the five week study. This was done indoors, off a wooden mound. The distance thrown was 60 feet 6 inches, the same as used on a regulation baseball diamond. This distance was measured pre and after 5 pitches to ensure that the mound had not slipped during the testing.

For each subject, the mean and peak velocity of 10 consecutive pitches was recorded using a Jugs Radar Gun (Decatur Electronics). None of the subjects used the
throwing cord while determining velocity. The number of pitches to be recorded was based on a pilot study by Frappier (1994). The subjects participated in the same warm up routine as during the trials. This identical procedure was repeated at the end of the study, two to three days after the last throwing session was completed.

**Design and Analysis**

A 2 (group) by 2 (pre/post) Mixed Design ANOVAs was conducted to determine differences in both average velocity and peak velocity with significance set at .05. A post hoc analysis was done to determine any pre-post differences with a Bonferroni alpha adjustment to control for type I errors.
Chapter 4

Results

The duration of the study was in accordance with the recommendations of Adams et al. (1992) who advised that high speed, high intensity training of the central nervous system be limited to four to six weeks. The training procedures were set back one week due to delay of equipment delivery combined with Christmas break for the athletes. One subject in group one dropped out of the study due to arm soreness and participation in an athletic enhancement program separate from the present study.

Raw score data from pre-post testing are reported in Appendix K. Descriptive pre-post statistics on average velocity and peak velocity for the control group (n = 7) and the throwing cord intervention group (n = 8) are as follows:

Group One (control)

<table>
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<th>Range</th>
<th>Mean</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre – Average Throwing Velocity</td>
<td>69.6 – 82.7 MPH</td>
<td>76.36 MPH</td>
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<tr>
<td>Post – Average Throwing Velocity</td>
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<td>76.10 MPH</td>
<td>3.51</td>
</tr>
<tr>
<td>Pre – Peak Throwing Velocity</td>
<td>74.0 – 84.0 MPH</td>
<td>77.57 MPH</td>
<td>4.16</td>
</tr>
<tr>
<td>Post – Peak Throwing Velocity</td>
<td>72.0 – 83.0 MPH</td>
<td>77.43 MPH</td>
<td>3.69</td>
</tr>
</tbody>
</table>
Specific to the purpose of this study, 2 (group) by 2 (pre/post) Mixed Design ANOVAs were conducted to determine differences in both average velocity and peak velocity with significance set at .05. For average throwing velocity, a significant group by time interaction was noted ($F=4.77, p<.05$). Two post hoc dependent t-tests were performed to determine pre-post differences in the control group and the throwing cord intervention group. A Bonferroni adjustment to alpha for the purpose of decreasing the likelihood of type I errors was performed ($.05/2 = p<.025$). Post hoc test results indicated non-significant pre-post differences in average throwing velocity for the control group ($t=.387, p=.71$), and for the throwing cord intervention group ($t=-2.72, p=.03$). Although not statistically significant, a treatment effect was noted for the throwing cord intervention group. Therefore, an effect size formula (Harris, 1998) was utilized to
measure the treatment effect \((M_{T,\text{Post}} - M_{C,\text{Post}} / SD_{C,\text{Post}})\). This analysis indicated a
treatment effect size of (.95) for the throwing cord intervention group.

For peak throwing velocity, a significant group by time interaction was noted
\((F=3.95, p<.05)\). Two post hoc dependent t-tests were performed to determine pre-post
differences in the control group and the throwing cord intervention group. A Bonferroni
adjustment to alpha for the purpose of decreasing the likelihood of type I errors was
performed \((.05/2 = p<.025)\). Post hoc test results indicated non-significant pre-post
differences in peak throwing velocity for the control group \((t=.868, p=.42)\), and for the
throwing cord intervention group \((t=-2.20, p=.06)\). Although not statistically significant,
a treatment effect was noted for the throwing cord intervention group. Therefore, an
effect size formula (Harris, 1998) was utilized to measure the treatment effect \((M_{T,\text{Post}} -
M_{C,\text{Post}} / SD_{C,\text{Post}})\). This analysis indicated a treatment effect size of (.97) for the
throwing cord intervention group.
Chapter 5

Discussion

The purpose of this study was to determine differences between two groups in average and peak throwing velocity after a five week training period with one group training by throwing only (control) and one group supplementing the throwing training by using the throwing cord (intervention). With over 500 athletes having used the throwing cord in training for increasing throwing velocity, the importance of the study was to document a training effect if one was present. At this preliminary stage of research on the throwing cord and its possible beneficial effects, methodology to assess why the throwing cord may or may not assist in increasing throwing velocity was not fully addressed. An attempt was made in this study to determine possible intervention effects with how the throwing cord is being utilized in performance enhancement settings at the present time. Assumptions of the currently used throwing cord training methodology, as well as the limitations of using this methodology in a research setting will be discussed. Lastly, this study's results will be discussed in relation to specific methodologies for assessing throwing cord effectiveness in future studies and possible methodologies to improve throwing cord effectiveness in applied settings.

Post hoc testing for the 2 (group) by 2 (pre/post) Mixed Design ANOVA significant interaction revealed a non-significant treatment effect for the throwing cord to increase average and peak throwing velocity over a five week training period. These results, taken literally, would indicate that this study contradicted findings of the case
study (Frappier, 1994), and contradicted previous research on the importance of velocity, movement pattern, and contraction type resistance training specificity. Yet, a concern in this study and in research in general, is that in controlling for type I error in research, there is an increased opportunity to commit a type II error. A problem in literal interpretation of this study's results is the issue of type I/type II error, and the lack of power due, primarily, to the small sample size used in this study.

The treatment effect size for increased average velocity (.95) and increased peak velocity (.97) would lead one to suspect the occurrence of a type II error. Cohen (1988) concluded that an effect size of .80 or higher would indicate a large treatment effect. Yet, making a conclusion that a type II error occurred in interpreting this study's results may be risky and even somewhat foolish. What can be concluded by this study's results, statistically, is that further research is warranted. The simple adjustment would be to utilize larger sample sizes for both the control and intervention groups, thus increasing power and reducing the chances of not detecting differences that indeed are present.

**Interpretation of raw scores** The raw scores (see Appendix K) indicate that the throwing cord had a greater effect for subjects with lower throwing velocities than for subjects with a higher throwing velocity (81 mph or greater). Of the subjects in group two, three had pre test mean velocities of 81 miles per hour or greater (mean = 81.63). The posttest mean velocity for these subjects was 81.56 miles per hour. For this same group, the lack
mean peak = 83mph) This is in accordance with the assumptions of many coaches and athletes who believe that high level athletes have reached their genetic potential and therefore it is difficult to enhance performance. These subjects may have needed more time to adapt to the overload, an increased overload, or needed more rest after the completion of the study to realize an improvement in performance, if any. Conversely, subjects with velocities slightly below 80 mph showed the best training effects of all the subjects (mean pre = 77.76 mph, mean post = 80.93 mph, mean peak pre = 79 mph, mean peak post = 82.66 mph).

A possible mechanism for this may be due to the developmental effect of training. The expectation exists for those subjects with the lower scores to improve at a fastest rate than those subjects who are already skilled. These results contrast the Frappier (1994) case study that indicated athletes with higher mean (79.43 mph) and peak (81.18 mph) throwing velocities increased throwing velocity after six weeks of training to a mean of 82.88 mph and peak of 85.18 mph. The difference in results could be attributed to a variety of factors, notably the differences in protocols, the biomechanical instruction that was given to the subjects, or the lack of control over the subjects. Future studies are needed to verify this effect.

Subject 15 in the intervention group (group two) experienced a mean increase of 5.1 miles per hour and a peak increase of 6 miles per hour (see Appendix K). These increases in throwing velocity were on average higher than those experienced by the rest of the subjects in group two (mean subject 15 = +5.1 mph, remaining subjects in group
two = +1.24mph, peak subject 15 = +6 mph, remaining subjects in group two = +1 mph).

This subject's test scores no doubt confounded the interpretation of the results.

Assumptions and limitations

Several assumptions were made while conducting this study that may have played a part in the results. One such assumption was that the Jugs radar gun is a valid and reliable instrument to measure throwing velocity. According to a training manual provided by the manufacturer, Decature Electronics, the radar gun is based on the Doppler Effect. This effect states that "when there is relative motion between two objects, one of which is transmitting wave energy, the frequency of the signal as received by the other object changes due to that relative motion." Since the speed of radio energy always travels at a constant 186,000 miles per second, timing circuits can be used to determine the amount of time that it takes for the radio energy to be reflected off an object and back to the transmitter. The radio signal's frequency is changed (Doppler Shift) when it is reflected off an object that is moving at a speed different from that of the radar set. It is this change in frequency that can be computed into a speed reading. Thus when measuring the speed of a baseball, it is the change in frequency from the moving baseball that gives the read out on the gun. A tuning fork is used to calibrate the radar gun. Since the fork vibrates at a set frequency, the vibration of the fork will be read by the radar gun as motion between the gun and the fork and thus provide a consistent read out. Thus it was assumed that the radar gun was reliable and valid for velocity measurement.
Two other important assumptions were that the throwing motion was assumed to be similar with and without the throwing cord, and that the velocity of the arm would not be impeded significantly by the throwing cord. If the throwing motion was changed by the throwing cord, it would be difficult to assess this without the use of high speed video. Since this was not available during this study, the throwing motion was assessed from the observations of the administrator, and presumed to be similar. However, this assumption could play a role in the results, and further testing is needed to accurately assess this variable. Similarly, ball velocity was not measured with the throwing cord on the arm. If too much tension would have been applied, it is possible that normal throwing mechanics could have been altered, and thus inaccurate measures of any training effect would have taken place. Additionally, if velocity specific effects are desired, then the tension of the throwing cord would have to be light enough to allow similar acceleration patterns as observed without the cord on.

Two important limitations must also be addressed. First, the force of the resistance provided by the cord was not measured. Since surgical tubing provides more resistance the further it is stretched, it is possible that some subjects were able to stretch the cord further than others during the throwing motion. This would cause the intensity of the throwing cord exercise to be disproportionate amongst all the subjects. Secondly, since height, throwing styles, and experience was varied amongst the subjects, the resistance of the throwing cord at the point of release was inconsistent (see Appendix A for resistance information) for information regarding the resistance of the surgical
tubing). Future studies should attempt to control for both of these factors. Perhaps one way to control for this would be to use different gauges of surgical tubing to try to equate the resistances encountered when using subjects of different heights and pitching styles.

The EMG information that was accumulated while using the throwing cord indicates that the anterior deltoid was highly active during the entire throwing motion. This is in comparison to a very brief burst of activity without the throwing cord on. This is probably due to the tension of the throwing cord throughout the throwing motion. The EMG tracing detailing the throwing motion with the throwing cord on are similar to those with it off (see Appendix B and C). If any difference exists, it may be the frequency of spikes for the pectoralis major is less in the throwing cord tracings. Further research is need to investigate the origins of these observations. Dillman et al. (1993) noted that the time between stride foot contact with the ground and the ball being released was 0.145 seconds. After foot strike, the ball is rapidly accelerated to the point of ball release, this phase is referred to as the acceleration phase. According to Jobe et al. (1983, 1984), the acceleration phase is a period lasting less than 1/10 of a second. In this time the pectoralis major and the latissimus dorsi were active as were the triceps and serratus anterior. Looking at the first .14 - .10 seconds of the EMG tracings detailing the throwing cord is subjective at best. Since there is no way to quantify the tracings with the actual pitching motion, analysis is difficult, if not impossible. What they do show is an increased amount of activity in the anterior deltoid with the throwing cord on versus with it off. Whether or not this is beneficial is yet to be determined.
Comparing the tracings of Jobe et al. (1983, 1984) with the tracings of Shropshire and Leonard (1995) would be an unfair at best (see Appendix B and C). Jobe et al (1983, 1984) used an intramuscular technique to obtain EMG data, while Shropshire and Leonard used a surface technique. Jobe et al. (1983, 1984) was also able to synchronize video with EMG tracings to analyze their data. What can be said is that more research is needed to compare the throwing motion with and with out the throwing cord. A simple way to do this would be to replicate the Jobe et al. (1983, 1984) studies using the throwing cord in addition to not using it. Thus a true comparison of the EMG activity could be made.

Conclusions

In this initial study, several problems were encountered: small sample size, a lack of control of training variables, and several assumptions and limitations that could effect the results of the study. Future research should include: (1) a larger sample size to increase the power of the results. (2) A measurement of the resistance of the throwing cord to the throwing arm for different heights of subjects would give some data regarding optimal resistances to be used based on subject height and strength. (3) An anchor for the throwing cord instead of a human facilitator. This would provide a solid point from which constant resistance could be measured. (4) An integration of high speed video with intramuscular EMG recording to analyze the effects the throwing cord has on muscle firing patterns, and to compare to the Jobe et al. (1983, 1984) findings. (5) An analysis of the throwing cord and it’s effects on arm and ball velocity in contrast to an unloaded
movement. A study of this nature could examine the possibility of the throwing cord being a velocity specific device.

Even though the results of this study were non significant, the effect size analysis revealed the possibility of a training effect occurring. This conclusion must be made with some caution given the limited amount of research available on the throwing cord
REFERENCES


### Appendix A

**Throwing Cord Loading for Inches of Stretch**

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<th>Stretch in Inches</th>
<th>Load in lbs.</th>
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### Throwing Cord Loading for Inches of Stretch

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Note. Trials one and two indicate EMG without the throwing cord. Trials three and four indicate EMG with the throwing cord.
Note. Trials one and two indicate EMG without the throwing cord. Trials three and four indicate EMG with the throwing cord.
Appendix C1

Descriptive Statistics for Group One

<table>
<thead>
<tr>
<th>Subject</th>
<th>Age</th>
<th>Ht.</th>
<th>Wt.</th>
<th>Exp.</th>
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Mean 21.29 184.33 90.07 5.57

SD 2.28 6.38 9.33 2.37

Note. Ht. = height in centimeters, Wt. = weight in kilograms, Exp. = experience pitching in years.
Appendix C2

Descriptive Statistics for Group Two

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<th>Wt.</th>
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| Mean    | 19.35 | 181.93 | 71.62 | 4.87 |
| SD      | 0.91  | 8.46   | 7.59  | 1.24 |

Note. Ht. = height in centimeters, Wt. = weight in kilograms, Exp. = Experience pitching in years.
Appendix D

Wooden Pitching Mound
Appendix E

Initial Arm Position
Positioning of the Humeral Attachment
Appendix F2

Humeral Attachment of the Throwing Cord
Appendix G1

Positioning of the Wrist Strap
Appendix G2

Attachment of the Throwing Cord
Appendix H

Position of the Administrator
Appendix II

Raw Data for Mean Throwing Velocity, Group One

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Note. Speed was measured in miles per hour.
Appendix 12

Raw Data for Mean Throwing Velocity, Group Two

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*Note.* Speed was measured in miles per hour
Appendix I3

Raw Data for Peak Throwing Velocity, Group One

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Note. Speed was measured in miles per hour.
### Raw Data for Peak Throwing Velocity, Group Two

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<tr>
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<td>78</td>
<td>84</td>
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</table>

*Note. Speed was measured in miles per hour.*
Appendix J

Athlete Informed Consent

The Department of Health and Human Performance at the University of Montana supports the practice of protection for human subjects participating in research. The following information is provided so that you can decide whether you wish to participate in the present study. You should be aware that even if you agree to participate, you are free to withdraw at any time without penalty.

The study is concerned with increasing the velocity of a thrown baseball. As a participant in the study, you will be randomly assigned to one of two groups. Group one will serve as the control group. Group two will use a device called the throwing cord. The throwing cord allows the athlete to throw in a full range of motion using the approximate acceleration patterns seen in actual throwing with resistance provided. The duration of the study will be five weeks.

Group two will supplement half of their total number of repetitions for the week on the throwing cord. If you are assigned to group two you will be asked to exercise twice per week, for the five week duration of the study. The number of sets and repetitions that group two will perform is dependent on the total number of repetitions that group one will perform. In this manner, the total number of repetitions (throws) is equal for both groups. Your velocity will be recorded by a radar gun pre and post training to test for improvement in velocity.

As a subject, you should be aware that the possibility of adverse changes during the study exist. They may include muscular soreness, fatigue, rapid heart rate, and increased ventilation rate. You may request that the testing be terminated at any time.

"In the event that you are injured as a result of this research you should seek appropriate medical treatment. If the injury is caused by the negligence of The University of Montana or any of its employees, you may be entitled to reimbursement or compensation pursuant to the Comprehensive State Insurance Plan established by the Department of Administration under the authority of M.C.A., Title 2, Chapter 9. In the event of a claim for such injury, further information may be obtained from the The University of Montana’s Claims Representative or The University of Montana’s Legal Counsel."

Your participation is solicited, but strictly voluntary. Be assured that your name will not be associated in any way with the research findings. Do not hesitate to ask any questions about this study. If you would like additional information concerning this study before, during or after it is completed, please feel free to contact us by phone or by mail. A copy of this consent form will be given to you.

We appreciate your cooperation and thank you for your participation.

Sincerely, Sincerely,

Mark Shropshire Lewis A. Curry, Ph.D.
Principal Investigator Supervising Investigator
104 9th Ave. SE Apt. A 220 A McGill Hall
Minot, ND 58701 The University of Montana
(701) 839-8057 (h) Missoula, MT 59812
(701) 857-7333 (w) (406) 243-5242

Name (please print) _____________________________________________ Date ________________

Signature ___________________________________________________________________
Appendix K

Institutional Review Board
THE UNIVERSITY OF MONTANA
INSTITUTIONAL REVIEW BOARD (IRB)
CHECKLIST

Submit one copy of this Checklist, including any required attachments, for each project involving human subjects. The IRB meets monthly to evaluate proposals, and approval is granted for one academic year. See IRB Guidelines and Procedures for details.

<table>
<thead>
<tr>
<th>Date Submitted to IRB</th>
<th>Projected Start Date</th>
<th>Ending Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAY, 1995</td>
<td>SEPTEMBER, 1995</td>
<td>NOVEMBER, 1995</td>
</tr>
</tbody>
</table>

Project Director: Mark Shropshire
Department: HHP
Phone: 728-5596
Signature

Co-Director(s): ________________________________
Department: ________________________________
Phone: ________________________________

Project Title: Velocity Changes in Throwing a Baseball After Training With the "Throwing Cord" versus a Throwing Protocol.

Project Description: To investigate whether the use of a training device called the Throwing Cord will increase velocity in a baseball pitch.

Students only:
Faculty Supervisor: Lewis Curry, Ph.D.
Department: HHP
Phone: 243-5242
Signature:

(My signature confirms that I have read the IRB Checklist and attachments and agree that it accurately and adequately represents the plan of research and that I will supervise this research project.)

Project Director Complete page 2 of IRB Checklist, on back.

For IRB Use Only

IRB Review and Determination:
- Exempt from Review
- Expedited/Administrative Review
- Approve

Conditional approval:

Resubmit proposal:

Disapproved:

Signature/IRB Chair: ________________________________ Date: ________________________________