"Effects of Trunk-Specific Medicine Ball Training on Instantaneous Bat Velocity among High School Baseball Players"

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I. Introduction

A. Statement of Problem

In high school athletics, the winter sports season ends very shortly before the spring sports season begins. Thus, spring sport athletes and coaches are left with very limited time to prepare, and are often still in the preparation phase once the competitive season has begun. Having such a pressing time frame within which to work, both coaches and athletes must make the utmost of their time spent in practice, including elements of physical conditioning.

Ever since Abner Doubleday invented the game of baseball, ways and means by which to improve performance have been fervently sought after. These methods have ranged from the anecdotal to the absurd, but have not often touched on the practical or applicable. Limited research has been conducted to scientifically investigate the various training strategies often utilized in the conditioning of baseball athletes.

Since high school baseball coaches and athletes, especially in the colder states, have such a limited time to prepare themselves for the season, no time can be wasted in pursuing means of training that are backed only by hearsay and conjecture. The coach must find the most effective means for his players to improve performance and sport-specific fitness in a short amount of time. Determining the regimen that is most effective will require empirical research, and a renewed focus on the precise nature of baseball as a primarily explosive and anaerobic sport so that it can be trained as such.

Baseball, presently, is trained very similarly to football, especially on the high school level where many baseball players are on the gridiron in the fall. However, it is important to note that baseball is not football. While components such as agility, durability, explosiveness, linear and multi-directional speed, quickness, and general strength and fitness are important to both sports, baseball employs far more rotational movements than most other sports, football included.

Hitting and throwing, the two primary activities of baseball, rely on torque generated in the sequential rotation of each of three body segments: the lower extremities, the trunk, and the upper extremities in order to apply force to the ball or bat. In the kinetic chain sequence, the larger muscles initiate the movement, while the smaller muscles direct it. In the case of a baseball swing, the legs and hips initiate the movement and provide the power, while the shoulder, arms, wrists and hands provide fine control in order to direct the bat to the ball as squarely as possible. The function of the trunk in this kinetic chain is to transfer the power generated by the lower extremities into the movement of the upper extremities. This requires the musculature of the trunk to stretch and contract rapidly so that minimal force is lost in the transition.

Unfortunately, as it stands now, the rotational muscles of the trunk are all too often not trained for baseball, trained incorrectly, or trained without specificity to baseball movements. The researcher proposed that methods to train the muscles of the trunk correctly, such as the plyometric exercises done with medicine balls incorporated in this study, are not employed in many baseball training programs because there still remains a minimal body of research on the direct effects of such training on baseball performance.

B. Purpose of Study

The purpose of this study was to investigate the effects of six weeks of trunk-specific medicine ball training on instantaneous bat velocity in high school baseball players. This study served to establish whether or not medicine ball training has a value as a sport-specific training technique, as well as to add to the limited body of research examining the best way to prepare athletes for the highly sport-specific demands of baseball. The results of this study may also have applications in other sports that are largely rotational in nature, such as softball, golf, and tennis. This study also tested whether or not the medicine ball training program used increased the strength of the trunk muscles in the population examined.

This study will be most applicable to high school age males who participate in baseball. The subjects in this study ranged from ages 14 to 18, a stage of development in which a significant amount of physical, mental, and neurological maturation is still taking place. Further, the skill level of many of these subjects is still developing pronouncedly, and is more focused on increasing the general skill base of the athlete, and less of refinement of particular aspects of skills.

The results of this study may have applications among collegiate level baseball players, especially in the Junior College, NAIA or NCAA Division II or III ranks. The skill level and conditioning of the athletes is still developing markedly, and physical development is still occurring, albeit in its latter stages.

The study may not be applicable in the professional or NCAA Division I levels of baseball, because the athletes at this phase of their career have refined their physical attributes to a desired level of specificity to the task at hand. Most of the development at these levels is more focused on refinement of movements in pursuit of technical perfection. However, regardless of level of play, medicine ball training may still be of value for sustaining overall and sport-specific physical fitness.

The results may also have an application to high school athletes in other sports whose movement is primarily rotational in nature. Athletes in golf and tennis, especially, may be able to glean some benefit from the information found in this investigation, as many of the same principles applied in baseball batting also apply in the strokes of golf and tennis. However, the angle of swing in golf is very different than that in baseball, which will call for a different angle and degree of rotation in the trunk. Additionally, the applications to tennis may be limited by virtue of the fact that a tennis player often must strike the ball when his or her feet are not completely set, unlike in baseball. Swinging on the run as such will require different mechanics of the swing, as compared to baseball. Furthermore, the serve aspect of tennis follows a pattern that is very different than that of a baseball batter, and requires trunk rotational movement at a very different angle.

The results of this study may not apply as directly to those who play softball, as the batting philosophy and strategy, and thus technique, is often different in softball. However, the findings may apply more so to those softball players who are less of the "slap hitter" type.

C. Delimitations & Limitations

1. Delimitations

This study focused on male high school baseball players, ages 14 to 18 years, who are players in the Alamosa High School baseball program in Alamosa, Colorado. The subjects had between 0 and 3 years of high school baseball experience, and varying degrees of pre-high-school experience, although all had played organized baseball at some point prior to high school. This sample resulted in a more manageable initial population of 23 players. Additionally, use of this population assured that the participants were already somewhat familiar with the skills associated with baseball, especially the act of swinging a bat, which is to be investigated in the study. By targeting this population, the researcher did not have to teach the elements of the swing completely anew. All participants were of good health and able to participate fully in the study.

The time frame for this study was relatively brief, and long-term training effects were not investigated. A brief time frame was selected so as to be similar to the actual pre-season period that coaches and athletes have to prepare for competition in baseball at the high school level. The tests selected to determine whether the medicine ball exercises had an effect on the strengthening of trunk muscles were simple and quantifiable, as was the swing velocity test. Simplicity of the task, it was hoped, would yield the most accurate results.

The investigation was conducted during the baseball team's preseason practices in order to best replicate actual training conditions that high school coaches and athletes must consider. The training did overlap the first few weeks of the actual season to further replicate the real-life scenario in which the preparation phase and the competitive phase coincide with one another in part. Those in the experimental group did the prescribed medicine ball exercises twice per week for six weeks in addition to their regular practice and conditioning routine. The exercises performed are depicted in the illustrations in Appendix 1A through 3B, and were selected or developed by the researcher due to their focus on the trunk musculature, as well as their rotational and explosive nature. The researcher was present as the primary facilitator and observer at all testing and training sessions.

Pre and post treatment testing was completed as described under "III. Procedures; C. Research Design; 1. Methods of procedure" because those exercises used are simple in procedure, and relatively controllable and quantifiable. The exercises for the pre-test and post-test are designed to focus specifically on the musculature of the trunk, in particular, the oblique muscles, rectus abdominus, and erector spinae.

2. Limitations

This study was limited to a specific population from similar athletic backgrounds. The results, therefore, may not be readily applicable to other populations, or people with other experience levels, especially those who have not played baseball before and are learning the very basics of swinging a baseball bat. Those with disabilities, physical limitations, and acute or chronic injuries may also be excluded from the external applications of this study.

The budget for this study was $330, which covered the cost of data collection instruments and training devices used; all baseball equipment was provided by the high school baseball program. Medicine balls were selected because they are an inexpensive tool, and can be used in any setting, and in a very limited amount of space. They are also easily transported and durable.

Although more intricate means of measurement may have existed, the researcher was confident that the BatMaxx 5500 would accurately measure bat velocity. However, reactions within the muscles to medicine ball training were not measured, nor were any physiological adaptations that took place in the muscles trained, as expense was a prohibiting factor, and practicality was a focus. Further, a good swing was only be characterized in the subjects' ability to strike a ball cleanly off of a tee; actual kinesiological properties of the swing were not tracked.

The time frame for this study was relatively brief, so long-term training results were not be tested during the course of this experiment. What is more, the tests done to determine whether the medicine ball exercises had an effect on the strengthening of trunk muscles may not have been ideal in their replication of the hitting movement, but the swing velocity test, in the opinion of the researcher, accounted for that aspect of the investigation.

While the researcher was able to monitor the subjects' activities while at practice, it was not be feasible to monitor their individual activities beyond that. Subjects, then, may have participated in some form of resistance training apart from the experimental setting, which could have had an impact on the dependent variable.

The researcher also had very limited control over motivation of the individual subject. It was assumed that the subjects would give a maximum effort in training sessions, but this was very difficult to quantify. Furthermore, individuals who made a connection between the training stimulus and the relationship to bat speed may have elected to work even harder during training sessions in order to produce a more positive training effect. The experimental group subjects, further, may have also engaged in other activities beyond those prescribed during the experimental period that may have had an impact, either positive or negative, on the dependent variables measured.

Another limitation of this study is the fact that there are more factors involved with the baseball swing than trunk rotation and explosiveness. Timing, coordination, confidence, adjustment to different pitch speeds, pitch location, prior experience, implement selection, weather conditions, vision, reaction time, and overall strength and quickness also impact the success of a batter's swing. Simply strengthening the trunk, or even increasing bat speed may not necessarily yield a more successful hitter.

Finally, hitting a baseball is an extremely complex movement, and involves many more muscles and movements than those in the trunk. This study did not address the strength of the upper or lower extremities, which are both crucial to success in batting and the generation of bat speed, nor did it track any changes in vision, coordination, or confidence, which are also key elements of the success of a swing, although largely difficult to quantify and track practically.

D. Definition of Terms

baseball swing—for the purposes of this study, a maximal effort in striking a stationary ball off of a tee

instantaneous bat velocity—the speed of the bat at the point immediately before it contacts the ball; this was measured by the BatMaxx 5500 machine

kinetic chain principle—states that larger and more proximal muscles and motor units will fire first, and be followed in sequence by smaller, more distal muscles and motor units

medicine ball—for the purposes of this study, a six-pound weighted rubber ball

plyometrics—a genre of exercise that focuses on a rapid stretch, or eccentric contraction of a muscle, followed immediately by a powerful concentric contraction of that same muscle

power—the ability to produce force per unit of time

repetition—one time through the complete range of motion of an exercise

set—one group of repetitions of an exercise

strength—the ability to produce force

trunk—the musculature of the midsection; for the purposes of this study will be referred to as the internal and external obliques, rectus abdominus, and erector spinae muscles

trunk-specific—describes the nature of a particular exercise as one whose particular emphasis is on the oblique, rectus abdominus, and erector spinae muscles of the torso

E. Hypothesis or Research Question

This study was an experimental research design, whose aim was to address the following questions:

I. "Will trunk-specific medicine ball training increase strength in the muscles of the trunk?"

II. "Does trunk-specific medicine ball training have a positive effect on bat speed among high school players?"

Research Hypotheses:

I. Baseball players who participate in medicine ball training that focuses on the musculature of the trunk, as in those exercises used in this study (Appendices 1, 2, and 3), will exhibit significantly greater increases ($p \leq .01$) in strength in the muscles of the trunk, as indicated by the 30-Second Abdominal Crunch Test, as compared to those who do not engage in medicine ball training.

II. Baseball players who participate in medicine ball training that focuses on the musculature of the trunk, as in those exercises used in this study (Appendices 1, 2, and 3), will exhibit significantly greater increases ($p \leq .01$) in strength in the muscles of the trunk, as indicated by the 15-Second Medicine Ball Standing Twist Test, as compared to those who do not engage in medicine ball training.

III. There will be a more significant increase in bat speed ($p \leq .01$), as measured by the BatMaxx 5500 machine in the Bat Velocity Test, among baseball players trained via the medicine ball exercises prescribed by the researcher in Appendices 1, 2, and 3, in addition to the normal activities of baseball practice, as compared to those who only participate in practice activities without trunk-specific medicine ball training.

Null Hypotheses:

I. Medicine ball training has no significant effect ($p \leq .01$) on the strength of the trunk muscles as indicated by the 30-Second Abdominal Crunch Test.

II. Medicine ball training has no significant effect ($p \leq .01$) on the strength of the trunk muscles as indicated by the 15-Second Medicine Ball Standing Twist Test.

III. Medicine ball training has no significant effect ($p \leq .01$) on bat speed as measured by the BatMaxx 5500 machine in the Bat Velocity Test.

II. Review of Literature

The process of physical conditioning for baseball is rich in mythology. Training programs have often consisted of equal parts of science, art, and superstition (Hughes, Lyons, & Mayo, 2004). Coaches have typically been very resistant to change in the programs that they prescribe to their players, and often base their conservative regimens purely on anecdotal evidence (Potteiger, Williford, Blessing, & Smidt, 1992). The adage "if it ain't broke, don't fix it" certainly applies, but it may be more accurate to say, "If it isn't *not* working, it must be working". For years baseball players have operated under the notion that the training that they are subject to is based on research and science more than mere conjecture. This legacy of ignorant training is often passed on to the next generation of coaches when they are players because the way that they were trained is the way that their coaches were trained, is the way that their coaches were trained, and so on. Essentially, it can be argued that, historically speaking, baseball has typically been trained in one of three ways: as an aerobic sport (Potteiger, et al., 1992), just like football, especially at the high school level where there are more dual- and multi-sport athletes (DeRenne, 1992), or in ways that are supposedly baseball specific.

Baseball, first of all, is certainly not an aerobic sport, which can be evidenced by more than just casual inspection. In fact, with few exceptions, the player skills and game-situation plays associated with baseball occur in less than 10 seconds (DeRenne, 1990). Powers and Howley (2001) estimate that 80 percent of exertion in baseball occurs via that ATP-Creatine Phosphate cycle, 15 percent is fueled by anaerobic glycolysis, and only 5 percent can be viewed as aerobic. It can be understood, then, that baseball is almost entirely a power sport that relies heavily on ballistic movement to execute the necessary skills of the game (DeRenne, 1990; Miller, 1984).

In the second circumstance, to train baseball in the same capacity as football is errant as well. Coaches do agree that power, flexibility, speed, and strength are important in baseball, as they are in sports such as football (Coaches' Roundtable, 1983). However, weight training for football, as is appropriate to the sport, is performed in the vertical plane. Baseball, however, is a sport that relies more so on the rotational movement of the player's body, and should be trained as such (DeRenne, 1992).

In the type of program that is supposed to be specific to baseball, evidence can be found that may suggest otherwise. For example, the Louisiana State University baseball team's training program emphasizes the chest, shoulders, back, legs, and arms without biceps work. The athletes execute between one and three sets of eight repetitions three times per week for the exercises that target the aforementioned muscle groups. While these muscles groups are certainly important to the overall strength and condition of an athlete, the Louisiana State program only includes two trunk-specific exercises, and does not make use of medicine ball training that emphasizes explosive movement (Bailey, 1988).

The University of South Carolina baseball program's preseason routine includes three trunk-specific exercises done in sets of anywhere from 10 to 50, and does not include any explosive exercises with a medicine ball or similar implement (Kephart, 1984).

Tulane University's program includes the bench press, squat, rowing exercises, as well as movements that target the forearms and torso. Indeed, the coaching staff states that they feel the torso is vital and necessary for throwing and hitting. While the program does include exercises for the lower back and abdominal muscles in sets of five to ten, the goal is to execute these exercises initially in a high volume with low weight in order to build a strength base, and then to progress into exercising with a low number and high weight protocol (Roll, Omer, & Pontiff, 1986). It can be argued that employing this type of low repetition, heavy resistance protocol may limit the athletes' ability to perform the exercises in a way that approximates game speed and range of motion, particularly due to the increased risk of injury. The value of performing exercises in a way that replicates the specific movements, speeds, and ranges of motion for the sport will be addressed in greater depth later in this review.

The program for the United States International University in San Diego, California incorporates back hyperextensions, crunches, forced leg raises, and medicine ball sit-ups to target the trunk area, and utilizes a variety of medicine ball exercises for pitchers, but makes no mention of using similar exercises for hitters (Miller, 1984).

Wichita State University employs six different exercises that target the trunk muscles. Two of these exercises are particularly rotational in nature. However, it did not appear that any of the exercises focused on explosive movement of the trunk muscles, and the program does not make use of a medicine ball, except in medicine ball sit-ups. It was not clear from the article consulted whether the medicine ball sit-up exercise had a rotational element (Rosenboom, 1992).

Palomar Community College of San Marcos, California employs an off-season training program that targets the lower back, hamstrings, gluteal muscles, and abdominals. The players are instructed to perform the hamstring and lower back exercises in an explosive manner during their preseason workouts. The program at

Palomar also includes powerful movements, such as the snatch and power clean, as well as plyometrics and medicine ball exercises. The program for medicine ball training uses a six to ten pound ball, and two or three sets of ten repetitions. Two of the four exercises included emphasize trunk rotation (Burgener & Abruzzo, 1989).

The training regimen for the Baltimore Orioles organization emphasizes the use of plyometrics to build power and speed. Their program makes use of the medicine ball for several different exercises that emphasize both linear and rotational movements of the trunk, including some explosive actions. The Orioles perform these maneuvers once or twice weekly for two sets of 12 to 15 repetitions (Bishop & McFarland, 1993).

It is clear from a look at these different training programs that "baseball specific" is quite loosely defined, especially when in comes to the selection of exercises to perform in order to be best conditioned for baseball competition. Each coach has a very different philosophy for baseball training, and there is no clear framework from which to work. While the majority of the baseball teams aforementioned are quite successful at their respective levels of competition, it is important that training methods be reassessed and evaluated for their adequacy in preparing the athletes for competition.

According to the principle of specificity, a sport should be trained in a manner that approximates the movements concomitant to that sport. It further stands to reason that any strength training ought not detract from the specialized movements of the sport (DeRenne, 1987). After all, the main objective of a sport-specific training program is to optimize athletic fitness for the sport in question. Baseball coaches, then, need to re-direct their focus onto conditioning programs and exercises that target baseball more specifically (Dyrin, 2001).

The rotational components of baseball hinge on the core of the body, and one way to effectively target the core muscles is through plyometric medicine ball training (Murphy & Forney, 1997). However, while there are a plethora of testimonials concerning plyometric training with medicine balls, there is still a need for controlled evaluation to firmly establish the benefits of such training, especially as they are applicable to specific sport skills (McArdle, Katch, & Katch, 1994). A limited amount of research has actually been conducted to test the outcomes of plyometric training on the skilled baseball movements (Newton & McEvoy, 1994). Most of the existing body of research on plyometrics has been focused on the lower body, while upper-body and trunk exercises have not been evaluated nearly as much (McEvoy & Newton, 1998).

Research on the effects of medicine ball training on throwing velocity among baseball players has been conducted, with conflicting results. Newton and McEvoy's (1994) study on the effect of medicine ball training versus weight training on baseball throw velocity found that medicine ball training did not increase throw velocity, while McEvoy and Newton's (1998) study of the effects of ballistic resistance training on throwing speed did see a significant increase in throw velocity among medicine ball trained participants in their study. Although many similar properties concerning trunk rotation apply to both throwing and hitting a baseball, the primary focus of the current study is on the involvement of the muscles of the midsection during the baseball swing, and whether medicine ball training that targets those muscles can have a positive effect on bat speed.

Bat speed has been touted as "the single most important measure of how well you swing the bat" (Schilling, 2003). Since the batter only has a few tenths of a second in which to recognize the pitch, decide whether or not to swing, initiate his swing, and connect with the ball, any means to increase the time the batter has to react would be invaluable to his success. With a faster bat, the batter can have longer to react to the ball without compromising his response time, and thus, his success (Hughes, et al, 2004). Simply put, by late hitting legend Ted Williams, "The longer a batter can wait on a pitch, the less chance there is that he will be fooled" (Williams & Underwood, 1986).

Apart from timing, bat speed also has a significant impact on how far the ball travels when struck. It serves to reason that the faster the bat is moving, the farther a ball will fly (Schilling, 2003). More specifically, as Adair discusses in his text, an 85-mile per hour pitch struck with a bat speed of 65 mph will travel about 370 feet in the air. If it is struck with a bat speed of 70 mph, it will travel an estimated 400 feet. If the swing velocity is increased to 75 mph, the ball will land 425 feet away (Adair, 2002). Bat speed, then, has the ability to turn "warning track power" into "bullpen power", and "bullpen power" into "bleacher power". We have established, now, that bat speed is very important. Next, it is essential to understand the mechanisms by which the hitter generates bat velocity through an analysis of his body's movement throughout the hitting motion.

While the lower body is essential in generating power in a baseball swing (Bishop & McFarland, 1993), the trunk is also a key element in that it must transmit the power generated by the legs to the upper body. Murphy and Forney (1997), as well as Coleman (2000) agree that over 50 percent of the force produced in the hitting and throwing motions in baseball is attributable to the action of the midsection. Coleman states "a strong trunk lets you transfer all or most of the force generated by the hips and legs to the shoulder, arm, wrist, and hand" (2000). Once again, Ted Williams tells us "cocking the hips...is at the root of batting power". He goes on to say that the way a batter brings his hips into his swing is in direct proportion to the power generated. In his extensive, lifelong study of hitters and hitting, Williams concludes that he "never saw a hitter that didn't have a good hip-cock" (Williams & Underwood, 1986).

Shapiro finds in his analysis of the baseball swing that the torque generated during maximum acceleration can be attributed to the rotation of the hips, trunk, and shoulders (Shapiro, 1979). Miller agrees that, in the baseball swing, "power is supplied by the rotation of the hips" (1984). Additionally, the speed at which a player's body rotates during the swinging motion in baseball comes from the muscles of the trunk (Price, 2004).

The trunk muscles also act to stabilize the body during the movements associated with baseball, including hitting, throwing, running, and fielding, and are a major factor in balance (Price, 2004), as well as in the ability of a player to check swings, and to resist the impact of sliding and collisions that often occur on the field (Coleman, 2000; Price, 2004). In those capacities, having a well-trained midsection is essential to injury prevention in baseball.

Hence, the practical value of trunk training is most evident. To further understand the importance of the trunk from a scientific standpoint, one must understand the kinetic chain principle as it applies to the skill of hitting a baseball. Practically the entire body is involved in producing the force needed to drive a baseball into the bleachers (Allman, 1987). The power supplied comes from the successive coiling and explosion of the legs, trunk, and arms (Klatt, 1992). A hitter's ability to utilize this kinetic chain principle to generate bat speed depends very heavily on the interaction of those three body segments (Welch, Banks, Cook, & Draovich, 1995). The summation of torque that originates in the legs is passed on to the upper extremities through the trunk (Hughes, et al., 2004).

In the baseball swing, kinetic energy is transferred to the ball in the form of heat, distortion of the ball, friction, bat vibration, and distance traveled by the ball, the nature of these summed forces is that a great deal of force must be generated to impart them (Adair, 2002). The initial force in a swing is produced from the stride of the lead foot, followed by rotation of the hips, trunk rotation, and finally the action of the shoulders, arms, wrists, and hands (Klatt, 1992). A tremendous amount of rotational energy is generated during this chain of events, all within mere tenths of a second (Adair, 2002). The function of the midsection during this power production process is to transfer the power generated by the legs to the upper extremities (Newton & McEvoy, 1994). Without a strong trunk, the massive force produced by the legs and hips would not be applied into the player's swing (Price, 2004). Furthermore, a weakness in any body segment will limit the player's ability to pass any power generated along the kinetic chain and into the ball (Ruot, 1987).

To better understand this process, the swing can be broken down still further. Upon external rotation of the lead hip around the lead leg (left side in a right handed batter, right side in a left handed batter), the shoulders lag behind, which creates a stretch across the anterior torso. The hips continue to rotate with the rear leg pushing by way of hip and knee extension in combination with forceful plantar flexion of the back foot. The torso then begins to unwind, releasing its stored energy. The stretch across the anterior torso has been translated into powerful contractile force of the lead side internal obliques, and the external obliques of the trailing side (Garhammer, 1983). Essentially, this sequence of body segment rotation permits the kinetic chain to incorporate the muscles of the trunk through preload, or coiling, also known as eccentric contraction (Klatt, 1992 ; Welch et al., 1995). The faster this eccentric contraction occurs, the greater contractile force is available for the concentric movement of the muscles involved (Chu, 1983, 1999).

This stretch and contract action of the muscles of the trunk is a direct result of the function of the muscle spindles and Golgi tendons within skeletal muscle. These proprioceptive units monitor muscle tension, static length, pressure, and rate of stretch, and send this information to the central nervous system, which causes the muscle to rapidly contract (Chu & Plummer, 1984; Chu, 1983). Plyometric exercises train this reflex and allow the athlete to better capitalize upon it in the execution of sport-specific movements.

Plyometric training links speed and strength to produce more explosive types of movement (Chu & Plummer, 1984) by using explosive, ballistic movements against resistance at the fastest velocity possible (McEvoy & Newton, 1998). This type of training encompasses a genre of exercises that involve the rapid stretch, or eccentric contraction, of a muscle, followed by immediate and rapid concentric contraction of the muscle for the purposes of causing a forceful movement over a brief period of time. According to basic physics, the ability to produce force per unit of time is referred to as power—one of the most desirable characteristics for a baseball player (Chu, 1983). Plyometric training uses the natural tendency of a muscle to rebound when stretched (Chu, 1999) in combination with the recruitment of fast-twitch (Type IIB) muscle fibers while exerting maximum force at a velocity close to or at the same speed as competitive skills to produce a training effect (DeRenne, 1987).

In plyometric training, the elastic components of muscles are stretched rapidly through the application of overload force (McArdle, et al., 1994), initiating the stretch reflex for the rebound phase of the exercise, which, as previously mentioned, causes the stretched muscle to contract forcefully in a powerful movement. Plyometric training develops the involved components of the nervous system so that they will respond with maximum force during the stretch reflex reaction by switching rapidly from eccentric to concentric contraction (Murphy & Forney, 1997).

This study will test the effects of plyometric training done with a medicine ball. According to Coop DeRenne, "Plyometrics and use of rubber medicine balls are effective in developing hip and trunk rotation and initiating upper body action, thus contributing to bat speed" (1992). Medicine ball training has been found to be an effective plyometric implement for the upper body. Medicine ball exercises that involve the quick catch and release of the implement capitalize on the stretch reflex in the chest, shoulders, arms, and back. Catch and throw drills that cause rotation of the trunk cause the same response from the musculature in that body segment (Chu, 1999). For those reasons, the medicine ball is an effective tool for developing explosive power in the upper body and torso, whose importance to batting has already been discussed. Furthermore, maximal power production is essential to hitting a baseball, and training with a medicine ball trains the body's capacity to produce force quickly (Potteiger, et al., 1992).

It has been found that weight training can significantly improve certain variables related to sport performance (Potteiger, et al., 1992). However, it is important to add that there is a pronounced positive training effect when elements of the conditioning exercise are similar to elements of the primary activity (DeRenne, 1987). Medicine ball training is unique in that it allows sport-specific training by being able to replicate the various angles of movement encountered in athletic activity (Murphy & Forney, 1997). Additionally, medicine ball training allows the athlete to go through the range of motion of the primary sport activity, and to do so at a speed similar to that encountered in competition (DeRenne, 1992).

Medicine ball training is also very efficient, self-paced, and non-competitive. It combines speed, strength, endurance, and rhythm, and yields notable results very quickly. Combined with the unique capacity to duplicate myriad sport-specific movement, medicine ball training would appear to be a very effective tool for any coach or athlete (Lorette, 1985). In Szymanski's study of 12 weeks of medicine ball training with periodized strength training in baseball players, he found that hip, torso, and arm rotational strength increased among the medicine ball-trained group than those trained only with weights (2004). It would appear, then, that medicine ball training does have a positive effect on the muscles of the trunk, but the question remains whether or not those strength gains have an immediate impact on the baseball swing.

Having established the value of training that incorporates medicine ball exercises, an adequate training program must then be designed. It is important to keep in mind in the design of a program, first, that baseball is a power sport. Second, it must be understood that strength is not power, nor is speed power. It is the combination of speed and strength that generates power (Schilling, 2003). According to hitting coach Jim Lefebvre, training programs must have specific goals in mind (1983). Certainly, swinging a bat with greater velocity ought to be a goal of any baseball training program. Under this thinking, the muscles used in swinging a baseball bat must be trained in a high-velocity, explosive manner (Slavik, 2004). It has been found, after all, that power training, such as medicine ball training, may be a more effective means of promoting increases in bat speed than weight training (Bishop & McFarland, 1993).

As previously discussed, many baseball training regimens fail to place enough emphasis on explosive, power movements (Bishop & McFarland, 1993). The fact remains, though, that ballistic movement is absolutely necessary for sport-specific strength to develop among baseball players and should be done with greater frequency (Burgener & Abruzzo, 1989; Coleman 2000). Furthermore, baseball players often lack core strength, and exercises, including those done with a medicine ball, should be used to develop requisite strength in the trunk muscles. The development of strength in the core muscles is essential to swinging a bat, as well as to other baseball activities (Murphy & Forney, 1997; Slavik, 2004). Thus, a trunk-specific training regimen that includes the use of medicine balls should lead to specific adaptations in the athletes trained that will lead to increased sport performance, and reduced chance of injury (Coleman, 2000; Dyrin, 2001).

As a final consideration in the training of high school athletes, coaches must consider whether it is worth their limited time to train their athletes in ways that supplement the skills of the sport, yet are not specifically those skills. A high school baseball coach may find that his time is better spent on batting and fielding practice than physical, total-body conditioning. It has been found, though, that high school athletes exhibit a positive response to resistance training (Szymanski, Szymanski, Molloy & Pascoe, 2004). Further, male pubescent athletes have been found to retain nearly 99 percent of lower body strength gains, and actually increase upper body strength gains by way of a submaximal in-season strength maintenance program. Essentially, the players will not lose what they gain, even if the training is tapered during the competitive season (DeRenne, Hetzler, Buxton, & Ho, 1996). The effects of strengthening the physique of the high school athlete, then, should net a season less plagued by injury, and more on track toward continual improvement in athletic performance.

In the design of the training program, a few more principles must also be considered. First of all, it is known that Type IIB muscle fibers are responsible for high-speed movements. These fibers allow the athlete to move quickly and explosively, and can be trained to be the first muscle fibers recruited in a movement (Chu, 1996). This adaptation comes from neurological patterns formed during training that is performed at speeds that are close to or greater than the speed at which the skill being trained must be performed. This training effect reflects the principle of specificity, especially when the exercises are performed in ranges of motion that approximate the specific skills of the sport (DeRenne, 1992).

It is also known that high-intensity training facilitates these neurological adaptations that lead to an increase capacity to recruit Type IIB muscle fibers, so it serves to reason that exercises ought to be performed in a low-repetition, high-intensity manner in order to produce a maximum training effect (Baker, Wilson, & Carlyon, 1994; Miller, 1984; Szymanski, et al., 2004). Additionally, it has been found that non-specific training with heavy resistance can actually decrease bat velocity because these types of exercises must be performed slowly, at far less than competitive speeds, in order to avoid injury (Hughes, et al., 2004). One way to achieve the requisite intensity of training with a lighter load and a much faster movement through the prescribed range of motion is with power-focused training with medicine balls.

When training with medicine balls, specifically, it is crucial to emphasize that the movements be executed as quickly as possible, while still maintaining control and balance to avoid injury. Quickness through the range of motion will cause a more rapid stretch and rebound of the muscles being trained, which is essential to producing a training effect (DeRenne, 1992; Murphy & Forney, 1997). In fact, the rate of stretch may actually be more important than the length of the stretch in producing desired results. Also, coaches must allow proper rest in between exercises in order for the necessary intensity to be maintained during each effort. Finally, the coach must emphasize that as little time as possible be spent in transitioning from the eccentric to the concentric phase of the exercise. The only lag time will be from the neurological effort it takes to change the actions of a group of muscles, and not from any conscious hesitation by the athlete (Murphy & Forney, 1997).

In establishing a protocol for a medicine ball training program, there are several matters of importance involved in determining how many sets, repetitions, and so forth the athletes must complete to elicit a positive training effect. First of all, it is suggested that athletes begin with a single, timed set of each exercise and eventually progress toward the completion of several sets of three to four exercises in a session (O'Connor & King, 1999). It is also recommended that rest between exercises must be in excess of one minute, or the muscles will switch from anaerobic to aerobic means of contraction, which allows only submaximal effort, which would be counterintuitive to the goals of a power-oriented workout (Chu, 1996).

For the exercises themselves, a four to six-pound medicine ball should be used so that athletes can perform the movements quickly and explosively (Coleman, 2000). Plyometric exercises, such as those done with a medicine ball, should not be performed more than twice per week to allow optimal time for recovery from the highly demanding and intense routines (Bishop & McFarland, 1993; Seabourne, 2000). It is of further importance to note that the number of repetitions may be less important than the quality of the repetitions executed, and that medicine ball training should be used as a supplement to other training aspects, not as a replacement for them (Lorette, 1985).

Certainly, baseball is a complex sport that involves many complex movements, such as swinging a bat. In fact, Paul Kirkpatrick, a physicist at Stanford University identifies thirteen independent variables that are in effect when a batter swings at a pitch. Since he can err on both the positive and negative side of each of these variables, some twenty-six means to failure exist whenever the bat addresses the ball (Allman, 1987). So, by no means is any one exercise, or even set of exercises, enough to prepare a player completely for competitive play. It is possible, though, to prepare a player both more and better for the game. In order to achieve the goal of better-prepared athletes, coaches must take a step back, and make an objective assessment of their training procedures in terms of their foundation, how specific they are to the demands of the sport, and what the players can hope to accomplish as a result of the training. It is time that coaches and players alike begin treating baseball according to its nature as a powerful, explosive sport, and to take an approach to training that is founded in math more than myth, and research more than intuition. This study aims to be a stepping-stone toward a more scientific approach to training for the game of baseball.

III. Procedures

A. The Setting

All testing and training took place at the Ortega Middle School Auxiliary Gymnasium in Alamosa, Colorado at an elevation of 7,544 feet above sea level. Use of this facility was previously arranged through the Alamosa High School baseball program.

B. Population

Participants in this study were high school baseball players from ages 14-18 years from Alamosa, Colorado and the surrounding area. Players had from 0 to 3 years of experience of playing baseball at the competitive high school level. An initial population of 23 athletes participated in this study. It should be noted that 3 athletes dropped out of the baseball program during the course of this experiment. The young men who stopped participating did so because of the time constraints, and therefore increased academic demands, of the high school baseball season, or simply out of a desire to no longer play baseball. No participants were excused from the study due to injury, absence, or any other reason. Two of the athletes who left were assigned to the control group, and one to the experimental group. This netted an experimental population of 11, and a control population of 9.

C. Research Design

1. Nature of Study: This study is a research experiment design.
2. Methods of procedure
    a. A meeting was held with the parents of the Alamosa High School baseball players who were to be involved to answer any questions they may have, and to obtain parental consent (See Appendix 4A & B). Those who were not in attendance were sent a letter of information, along with the parental consent form, and were instructed to phone the researcher if they had any questions or concerns.
    b. After consent was obtained, subjects were assigned to one of two groups in a stratified random sample by experience level. Those with 0 years of playing experience were randomly assigned to either the experimental or control group in an amount equal to n/2. Those with 1, 2, or 3 years of experience were similarly bifurcated. It should be noted that, since only one participant had 3 years of experience, he was grouped with the 2-year group for assignment purposes.
    c. The control group performed all conditioning and activities related to normal baseball practice as determined by the coaching staff. The experimental group performed all activities of practice, but also

performed 6 trunk-specific medicine ball exercises on two separate days per week for six weeks. The subjects performed 3 exercises on Day 1, and 3 exercises on Day 2. See Appendices 1, 2, and 3 for exercises.

d. Both groups were instructed in the techniques to be used in the pre-test as described below. Each subject practiced these methods and was given the opportunity to any questions before beginning.

e. Both groups performed a pre-test that included:

   i. A determination of their pre-treatment bat velocity using a BatMaxx 5500 machine in the following Bat Velocity Test. Subjects hit a ball off of a batting tee into a net while the BatMaxx 5500 tracked the immediate pre-contact instantaneous velocity of their swing. Subjects were instructed to align themselves in such a manner as to strike the ball with the "sweet spot" of the bat, an area defined as an area 4 to 6 inches from the distal end of the bat, and indicated by part of the logo on the bat used. Subjects took as many swings as necessary to produce 5 usable swings, with no subject requiring more than 6 swings. The mean of 5 useable swings was used as their pre-test score. Swings were only counted if solid contact was made, and the tee was not struck during the swing, and a clear reading was received on the instrument. Five minutes of rest was given before the second test.

ii. Subjects then performed a 30-Second Abdominal Crunch Test to determine their pre-treatment linear abdominal muscle strength. Subjects lay on the floor with two tape lines on it that were 3 inches apart. Subjects were instructed to lie in supine position with arms straight down at their sides, their knees bent to approximately 90 degrees of flexion, so the feet were flat on the floor, and their fingertips on the tape line nearest to them. Over the course of 30 seconds, the subjects performed an abdominal crunch so as to move their fingertips to the line furthest from them, then return to their starting position and repeat until exhaustion, or until "time" is called. Five minutes of rest was given before the third test.

iii. Finally, subjects performed a 15-Second Medicine Ball Standing Twist Test with a six-pound ball to determine their pre-treatment rotational abdominal muscle strength. Subjects stood with feet at shoulder width and their heels on a line six inches from a mat that has been affixed to the wall for protection. Subjects began by holding a medicine ball directly in front of them with straight arms. Their elbows were flexed approximately 15-20 degrees from straight, and shoulders were flexed to between 75 and 90 degrees. Subjects then rotated their trunk quickly such that the medicine ball touched the matted wall behind them on their right side, then rotated their trunk in the opposite direction such that the medicine ball touched the matted wall behind them on their left side. Subjects were instructed to complete this exercise in a quick and controlled manner, and to execute as many repetitions as they could in 15 seconds, or until exhaustion. Each time the medicine ball touched the pad was counted as one repetition. The number of repetitions was recorded as each subject's pretest score.

f. At the next meeting, the experimental group was instructed in the proper methods and techniques for the prescribed exercises that they would be performing. Each subject performed 1-3 practice repetitions for each exercise to gain an understanding of what was expected.

The researcher personally observed each subject and provided cues and feedback on their form and technique so as to limit potential for injury due to improper execution of the exercises.

g. For the next six weeks, subjects performed 3 of 6 exercises on one day of the week, and the other 3 exercises on another day of the week with at least one full day of rest in between. The exercises were paired as noted in the Appendices, and subjects completed one exercise from each pair on training days. Subjects performed as many repetitions of each exercise as they could in 15 seconds with 2 minutes rest in between sets. Two sets were completed for each exercise each day, totaling six sets per session. Continual feedback and cues were given during this time to limit risk of injury due to improper form or technique.

h. After six weeks of training, subjects completed a post-treatment test consisting of the same exercises performed in the pre-test described above.

3. Protection measures

   a. Each subject had a pre-season physical on file with the Alamosa High School Athletic Department that attested to his ability to participate in sports and related activities, including any limitations.

b. Each participant and his parents were informed of the risks and benefits of the exercises involved, and parents were asked to decide if their child had any physical limitations to participating in such training.

c. The researcher instructed all participants in proper techniques both before and during the exercises to ensure proper form and technique were employed.

d. The researcher observed all exercises being performed and provided corrective cues and feedback that ensured proper form and technique.

e. Subjects were instructed to cease exercise if they experienced any pain. Any pain was evaluated by the subject, parent(s) or guardian, and a physician before participation resumed.

4. Consent and Assent

a. Consent was obtained from the parent or legal guardian of all subjects involved in this study. The parent or legal guardian was the only appropriate consenting agent for this study. Parental consent was even obtained for those subjects who were 18 years of age.

b. Information regarding risks and benefits was disseminated to both subjects and parents or legal guardians in person, via a letter, or a combination of these means so that the consent of the parent or guardian and the participant was informed.

c. Please see Informed Consent Form and Parent/Guardian Information letter (Appendix 4A and 4B).

D. Internal Validity

The internal validity of this study may have been affected by illness or injury, especially among those in the experimental group. If the subjects missed training sessions, particularly when considering the relatively short time frame of this study, training effects could have been less pronounced, or eliminated all together. For that reason, subjects who missed more than two training sessions were excused from the study, but could complete the post-test for their own information. What is more, failure on the part of the subject to perform the exercises as prescribed could have, and may in duplicate experiments, resulted in lessened training effects. Also, during either of the testing phases, any of the subjects could have been suffering from injury, illness, or fatigue that could have had a skewing effect on their test scores. On the contrary, a player may have just been having an outstanding day on either testing occasion, and perhaps performed better than he would on any other occasion. In order to control for these variables, participants who sustained any injury that severely limited or eliminated participation in the study were excused without penalty. Fatigue was controlled for by only training twice per week, thus allowing optimal recovery time. All subjects were encouraged and instructed to do their very best during both the pre- and post-tests, and to perform each repetition as a maximal effort.

Additionally, subjects may have participated in activities outside of normal practice, even though they were asked not to, that could have had a bearing on the results of the study. Subjects could have engaged in weight training or other activities to increase their overall strength, which could have skewed results positively, or such weight training could have produce an effect that actually skewed results in the negative direction by causing decreased bat speed. Participants could have also engaged in outside activities that were not sport-specific, and that may have produced contraindicative results. In order to control outside factors such as this, subjects were instructed to maintain their normal level of activity, and to not exercise any more or less than they already were. Furthermore, all subjects were told not to engage in medicine ball training outside of practice, whether they were in the experimental group or the control group. This hopefully kept those in the control group from mimicking the exercises performed by the experimental group on their own. The desire of the control group to participate in the exercises was addressed by not stating the proposed connection between medicine ball training and bat speed directly. However, this could have been inferred from the pre-test/post-test conditions, and any casual observation of the training protocol. In an effort to control for this inference, the tests, exercises, and baseball activities were treated as separate elements being evaluated, and not portrayed as having a correlation. No relationship between the treatment and bat speed was mentioned until the results of the study were analyzed.

Individual motivation may have also been a limiting factor in this study. Those with a greater level of motivation may have been apt to work harder during the training sessions, thus yielding better results than the norm. Conversely, those who are were less motivated may have not worked so hard, which may have eliminated any training effect, especially as the exercises used in this study place a very high degree of emphasis on speed and intensity. Therefore, the researcher was the primary facilitator and observer of all exercises. The researcher gave encouraging and motivational prompts to elicit a best effort on each test and exercise.

E. External Validity

Due to the non-random nature of the population targeted in this study, the results have very limited validity to external groups. The results are only readily applicable to the male baseball players in the Alamosa High School baseball program, ages 14 to 18 years, who have from 0 to 3 years of high school baseball experience. The sample was selected out of convenience, and is not necessarily representative of the normal population.

F. Instrumentation

A BatMaxx 5500 was used to calculate instantaneous bat velocity. This device is manufactured by TechnaSport, LLC and produces a pair of vertical laser beams that, when interrupted, resulted in a calculation of the instantaneous speed of the part of the object passing through the beam. The speed of the object was displayed in miles per hour. TechnaSport, LLC can be contacted at P.O Box 981; Lakeville, MN 55044, or via their web site at www.technasport.com.

Subjects used a six-pound, vinyl-cover, sand-weighted medicine ball that is 21-inches in circumference in all testing and exercise procedures requiring the use of such an implement. In this particular investigation, the medicine balls used were all produced by Century Fitness, 1705 National Boulevard; Midwest City, OK 73110-7942; www.centuryfitness.com.

For the Bat Speed Test, all subjects swung a 32-inch, 29-ounce Easton Triple 8 CXN Connexion Z-Core aluminum baseball bat. The batting tee was set to a height of 32 inches for each participant, which the researcher deemed to be a uniform height that fell in the center of the strike zone (between the bottom of the elbows and the crease of the hip) for all participants.

G. Treatment of Data

A simple Analysis of Variance (ANOVA) was done on pre-treatment test data to determine whether any significant difference existed in the results of the 30-Second Abdominal Crunch Test, 15-Second Standing Medicine Ball Twist Test, and Bat Speed Test between the control and experimental groups before treatment.

Another simple ANOVA was performed after post-treatment data were collected to determine if there was a post-treatment difference between the experimental and control groups.

A Dependent t-Test was done for data sets within each group to determine whether or not statistically significant differences existed in the pre- and post-test scores for each group.

The raw data for the pre- and post-tests for Abdominal Crunches, Trunk Rotation, and Bat Speed are located in Appendix 5A and 5B.

The alpha level was set at $p \leq .01$ for all data in an effort to increase the power of the study, and to limit the likelihood of Type I error.

IV. Results

A. Pre-Test

For the 30-Second Abdominal Crunch Test, the experimental group averaged 41.82 repetitions in the prescribed period, with a standard deviation (s) of +/- 7.95, and scores ranging from 32 to 56. The control group had an average of 41.67 repetitions, with a standard deviation of 3.91, and scores varying between 37 and 48. A simple Analysis of Variance (ANOVA) showed no statistically significant difference between the experimental and control groups, as can be seen in Appendix 6A.

For the 15-Second Standing Medicine Ball Twist Test, the experimental group had a mean of 24.82 repetitions (s=0.75). The score in this test for the experimental group ranged from 24 to 26. The mean of the control group was 23 repetitions (s=1.41), and scores ranged from 20 to 24. According to a simple ANOVA, there was a significant difference existing between the groups ($p \leq .01$), as can be seen in Appendix 7A.

In the Bat Speed Test, the mean of the experimental group was 59.95 MPH (s=6.16), and scores varied between 53.18 MPH and 70.58 MPH. The control group averaged 61.40 MPH (s=6.48), and bat speeds ranged from a low of 51.4 MPH to 68.94 MPH. A simple ANOVA on pre-test data showed no statistically significant difference between the two groups, as shown in Appendix 8A.

B. Post-Test

In the post-treatment Abdominal Crunch Test, the experimental group averaged 48.64 repetitions (s=10.14), and a range of scores from 41 to 69. The control group's post-test results averaged to 49.44 repetitions (s=9.5) and scores from 41 to 68 repetitions. A simple ANOVA conducted on post-treatment data for the Abdominal Crunch Test showed no statistically significant difference between the groups, as is shown in Appendix 6B.

The results of the post-treatment 15-second Medicine Ball Standing Twist Test showed the experimental group to have a mean of 30.27 repetitions (s=3.44), and a range between 25 and 38. The control group had a mean of 25.78 repetitions (s=2.95), and scores from 21 to 29. A simple ANOVA showed a significant difference between the groups for the post-treatment test scores, as can be seen in Appendix 7B.

The post-treatment Bat Speed Test mean for the experimental group was 63.78 MPH (s=8.01), with bat speeds ranging from 52.22 MPH to 79.46 MPH. The control group's bat speed mean for the post-test was 63.60 MPH (s=9.15). Their bat speeds ranged from 49.1 MPH to 77.94 MPH. A simple ANOVA on post-treatment data indicated no significant difference between the two groups, as is evidenced in Appendix 8B.

C. Pre- vs. Post-Test Comparison

Appendix 6C shows that pre- and post-test scores in the Abdominal Crunch Test increased by an average of 6.82 repetitions in the experimental group, and also increased by an average of 6.78 repetitions in the control group. Both groups, based on the number of additional repetitions compared to pre-test data, increased their abdominal crunch output by 16.3 percent.

In the Dependent t-Test analyzing pre- vs. post-treatment Abdominal Crunch Test scores, it was shown that there was a statistically significant increase in test scores for the experimental group, $p < .01$. While the control group did not net a statistically significant increase at the .01 level, the increase was shown to be significant at $p < .05$, as is noted in Appendix 6D.

In Appendix 7C, differences between pre-treatment and post-treatment Trunk Rotation Tests are noted. The experimental group improved by an average of 5.45 repetitions, while the control group improved by 2.56 repetitions. In considering the number of additional repetitions in comparison to pre-treatment data, the experimental group was shown to have increased their output by 21.95 percent, and the control group was shown to have improved by 11.13 percent.

A Dependent t-Test taking into account pre- and post-treatment Trunk Rotation Test scores showed that the experimental group did net a statistically significant increase. Among the control group scores, there was not a significant difference noted between pre- and post-test scores, as is shown in Appendix 7D.

As shown in Appendix 8C, the experimental group's bat speed increased by an average of 3.83 MPH, while the control group's increased by 2.20 MPH.

Comparatively, the experimental group increased by 6.39 percent of their pre-treatment bat speed mean, while the control group increased bat speed by 3.60 percent.

According to a Dependent t-Test on pre- and post-test bat speeds, there was not a statistically significant increase in bat speed, $p < .01$. However, it should be noted that the increase in bat speed for the experimental group was significant at the .05 level. The increase in bat speed for the control group was also not statistically significant at the .01 level, nor was it significant at the .05 level of confidence, as is depicted in Appendix 8D.

V. Discussion

Through the analysis of the data collected in this experiment, it has been shown that increases, significant or not, did occur for all dependent variables, which can likely be attributed to the nature of the conditioning and activities of baseball practice. Part of the normal practice conditioning routine incorporated leg-lifts, and crunches to target the *rectus abdominus* muscles. The rotational nature of both hitting and throwing, both done quite regularly in baseball practices, when paired with twisting crunches included in the normal conditioning routine were both likely contributors to the increases in trunk rotation test scores.

The increases in bat speed noted in both groups can be very simply linked to the SAID principle indicating specificity of activity as a primary factor for improvement in that activity, in this case, swinging a baseball bat. Due to the nature of the pre-test being at the very onset of the baseball practice season, increases in all three variables were very likely for both groups. In essence, they were bound to improve through the very activities of baseball practice. However, the hypotheses for this experiment stated that the group completing the medicine ball training regimen over the course of six weeks would make statistically significantly greater gains in all three dependent variable tests as compared to the control group, and these hypotheses will be discussed heretofore.

Upon statistical analysis of the data collected, similarities and differences between the experimental and control groups began to surface. In the Abdominal Crunch Test, both groups were found to have increased by approximately 6.8 repetitions, and a nearly identical 16.3 percent. While Dependent t-Tests showed significant increases for the experimental group at $p \leq .01$, and not so for the control group, the control group did show statistically significant increases at $p < .05$. Despite inconsistency in statistical interpretation, application of logic would dictate that both groups improved by an extraordinarily similar margin.

Since only one of the exercises done by the experimental group really targeted the *rectus abdominus* muscles recruited for the Abdominal Crunch Test, these results are far from shocking. It could also be supposed that, with abdominal crunches being a very common exercise, participants in this study may have engaged in this exercise on their own or through physical education classes in their high school curriculum, thus contributing to the increase in output for both groups.

In this case, we must accept the null hypothesis I, stating that medicine ball training does not have a statistically significant impact on linear abdominal strength. However, there may still be a value in using medicine ball exercises to target the *rectus abdominus* muscles. As stated in the literature review, the dynamic nature of baseball, as in so many other sports, places great and unique demands on the musculature of the body. The explosive nature of medicine ball exercises targeting the *rectus abdominus* may serve to train the muscles to have a greater capacity to resist impact of the participant with an object or implement, participant with the playing surface, or participant with another participant. Additionally, the *rectus abdominus* muscles serve to hold the body in an upright position during normal activity by supporting the hips and spine. In sports, the ability to stabilize one's body core could likely contribute to running speed, vertical jump, body control, and possibly resistance to injury.

Interestingly enough, the Abdominal Crunch Test has come to serve as an additional control in this research. The test results can be used indirectly to evidence the application of the SAID principle in the medicine ball exercises, as well as to show that increases in strength among the experimental group in the trunk rotation and bat speed tests were less likely to be due to their own predisposition to strength increases, and more likely can be attributed to the treatment condition. Had the control group not increased their test scores for the Abdominal Crunch Test, the argument could have been posed that these individuals' performance capacities had already peaked, and were therefore incapable of further increases.

In contrast to the Abdominal Crunch Test, the 15-second Medicine Ball Standing Twist Test results did show a statistically significant difference for the experimental group, but not so for the control group. As stated in the hypotheses for this experiment, it was believed that such an increase would occur as a result of the application of the independent variable. Once more, the SAID principle comes into play in the interpretation of these results. The medicine ball exercises in the experimental treatment most closely mimicked the 15-second Medicine Ball Standing Twist Test. The fact that the test and several of the treatments were very similar in load, duration, and intensity, not to mention the rotational movement itself boded well for an increase in Trunk Rotation Test scores for the experimental group.

The statistically significant increase for the experimental group leads to our rejecting the null hypothesis II, pertaining to the impact of trunk-specific medicine ball training on trunk rotation strength as indicated by the 15-second Medicine Ball Standing Twist Test. The training program seems to have had a positive effect on the experimental group's trunk rotation strength, at least as indicated by the 15-second Medicine Ball Standing Twist Test.

Injury prevention in sport is a close second to performance enhancement on the priorities list for many coaches. As stated previously, strong core muscles in the abdomen, lower back, and obliques allow the athlete to stabilize his hips, spine, and torso during the course of athletic activity. This will likely make an athlete less susceptible to injuries of these areas, as well as other areas of the body based on the kinetic chain principle. As an additional bonus, an athlete who is less concerned about injury because he is physically conditioned to participate in his activity to the fullest while still avoiding injury will be a more productive and happier player.

As already mentioned, performance is usually the number one objective of many coaches and athletes alike. There is a keen desire for skill improvement, and the ready application of training techniques in order to improve the skills concomitant to a sport. With respect to the sport of baseball, the key skill addressed in this research is the ability to produce force using a baseball bat, that is, to generate bat speed.

Upon analysis of the data collected, it became evident that neither control nor experimental group increased bat speed by a statistically significant margin at the .01 level of confidence. However, it also became evident that the experimental group's increases were statistically significant at $p \leq .05$, while the control group's were not so. While we would be compelled to accept null hypothesis III at $p \leq .01$, we may fail to accept the null hypothesis at $p \leq .05$. This significance at $p \leq .05$ merits further investigation as results consistent with those obtained in this experiment may indicate significance at $p \leq .01$ with a larger experimental population, or perhaps a longer course of treatment.

While there is mild evidence to suggest a relationship here between rotational trunk strength and bat speed here, the meaningfulness of the data comes into account when considering bat speed, and perhaps to a lesser degree for the other dependent variables tested. With hundredths of a second to react to a well-thrown fastball, the hitter must attempt to eek out any advantage he can give himself to contribute to his success. With an increase in bat speed of only a few miles per hour, the difference between fair and foul, safe and out, win and lose hangs in the balance. An increased capacity to generate bat speed is valuable in giving the hitter more time to read what pitch has been thrown, and thus to make a better informed decision on whether or not to swing, making him less likely to be fooled by a crafty pitcher. Since the experimental group netted an increase in bat speed of 6.39%, as compared to the control group's increase of 3.60%, there may be practical significance to the results of the present study, even if it may not be so statistically. Increasing an athlete's bat speed from 50 MPH to 53.195 MPH (6.39%), it serves to reason, would be more beneficial than increasing from 50 MPH to 51.800 MPH (3.6%). This difference in bat speed would give a batter that much more time to react to an incoming pitch and, all other factors being equal, give the batter more of a chance for success.

Granted, bat speed is a single component of the very lengthy equation that determines likelihood of success at the plate. Coordination, timing, confidence, previous experience, weather conditions, vision, educated guesses, and pure dumb luck all contribute to the success of a hitter. An extremely hard-hit ball may be hit right at a fielder for an out, while a softly hit ground ball may prove to be a "seeing-eyed single", or a soft line-drive to be a "Texas leaguer" that finds its way in between players for a base hit.

Regardless, though, good bat speed is a fine tool for any hitter to possess. For coaches and players, trunk-specific medicine ball training may prove of value as a means to increase bat speed. The exercises incorporated in this study were not only trunk-specific, but also baseball-specific as they were designed or included with the sport and its particular skills in mind. This study, it is hoped, will serve as a resource to coaches and players who desire to incorporate datadriven rationale in the selection of their sport-specific conditioning programs, and abandon superstition for science.

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Mr. Jerry Green, Athletic Director, Alamosa High School
Assistant Coaches Santiago Martinez, Brad Wilcox, Tony Kechter, and Matt Neuhold
The parents and players in the Alamosa High School Baseball Program

-also-

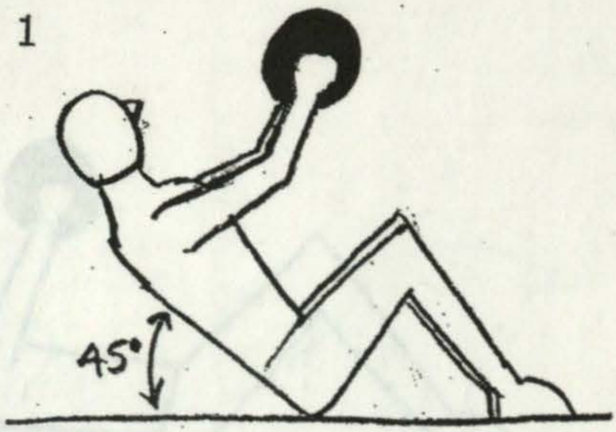
Dr. Tracey Robinson, Adams State College
Dr. Jeffrey Geiser, Adams State College
Ms. Cari Boe, M.A., Adams State College

--finally—

Very special thanks to Mandy Pittman

Appendix 1A:
Russian Twist

1



2

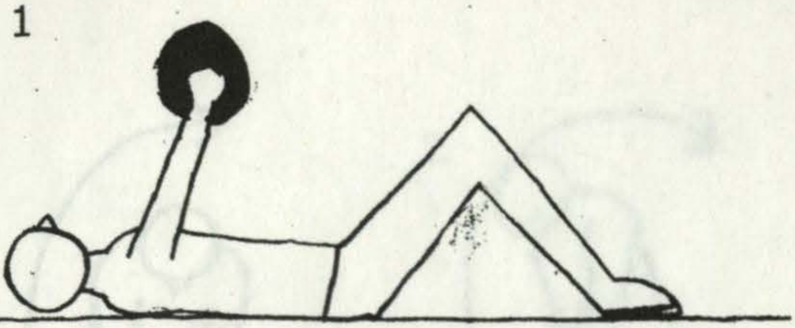
Twist to 90 degrees trunk rotation

3

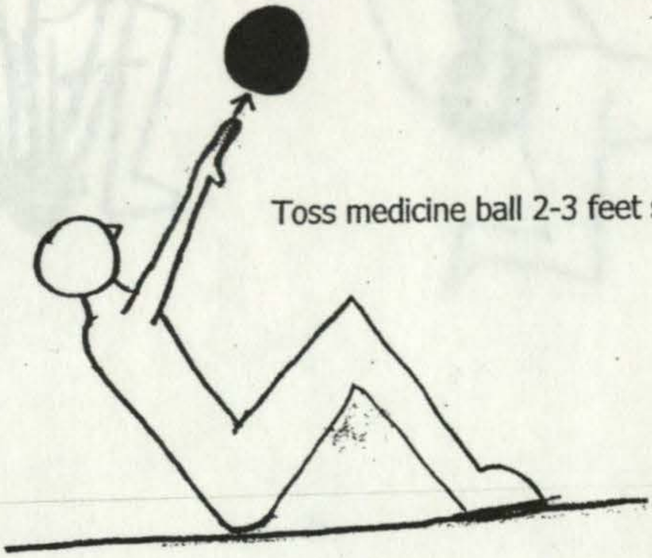
Quickly twist to 90 degrees trunk rotation
on opposite side and repeat

Appendix 1B:
Sit-up with Toss

1

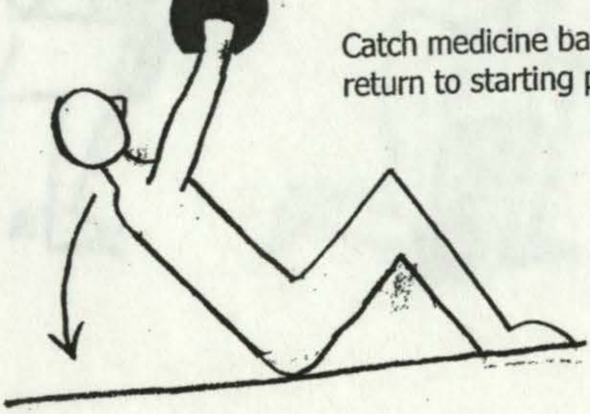


2



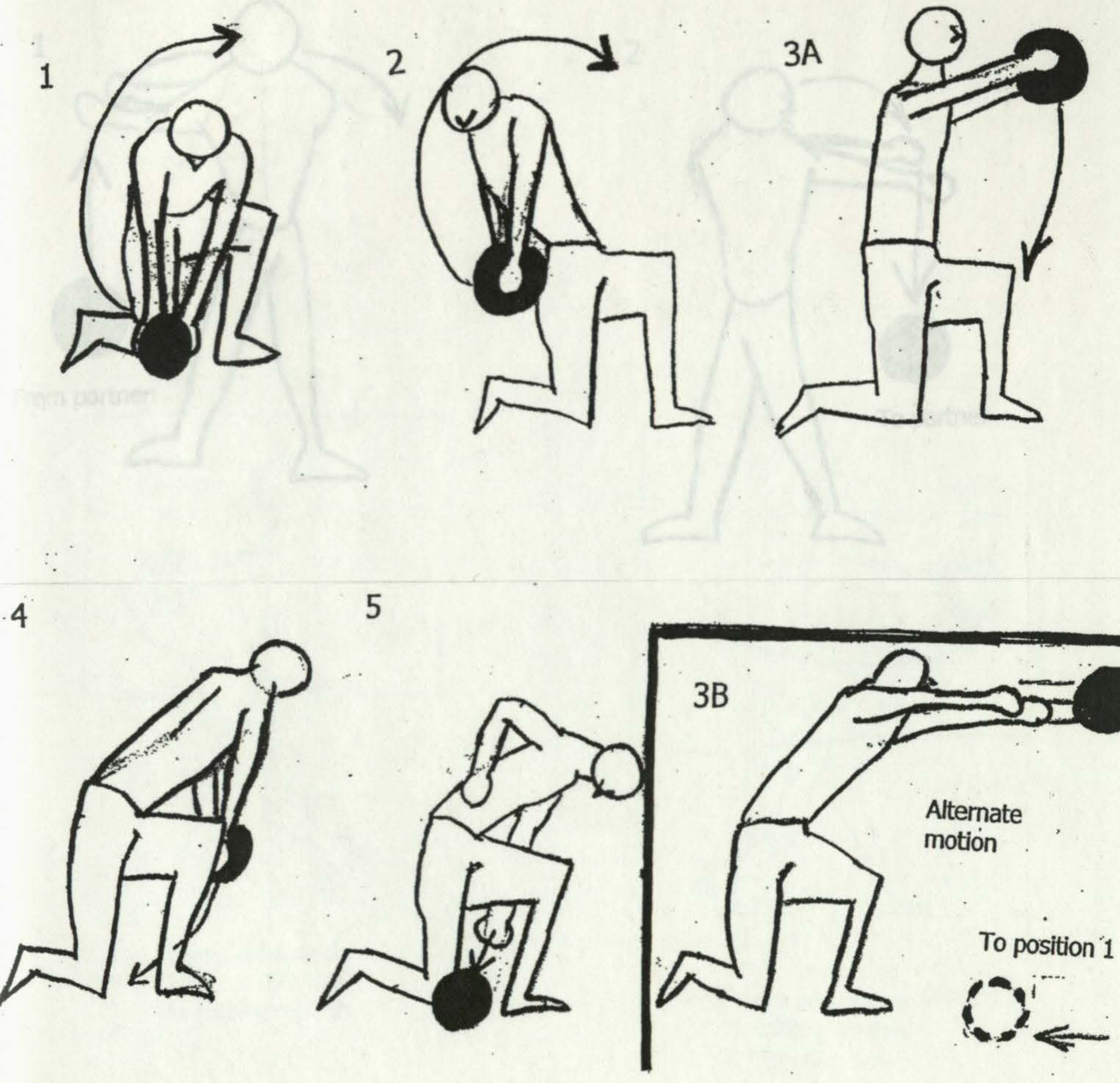
Toss medicine ball 2-3 feet straight up

3

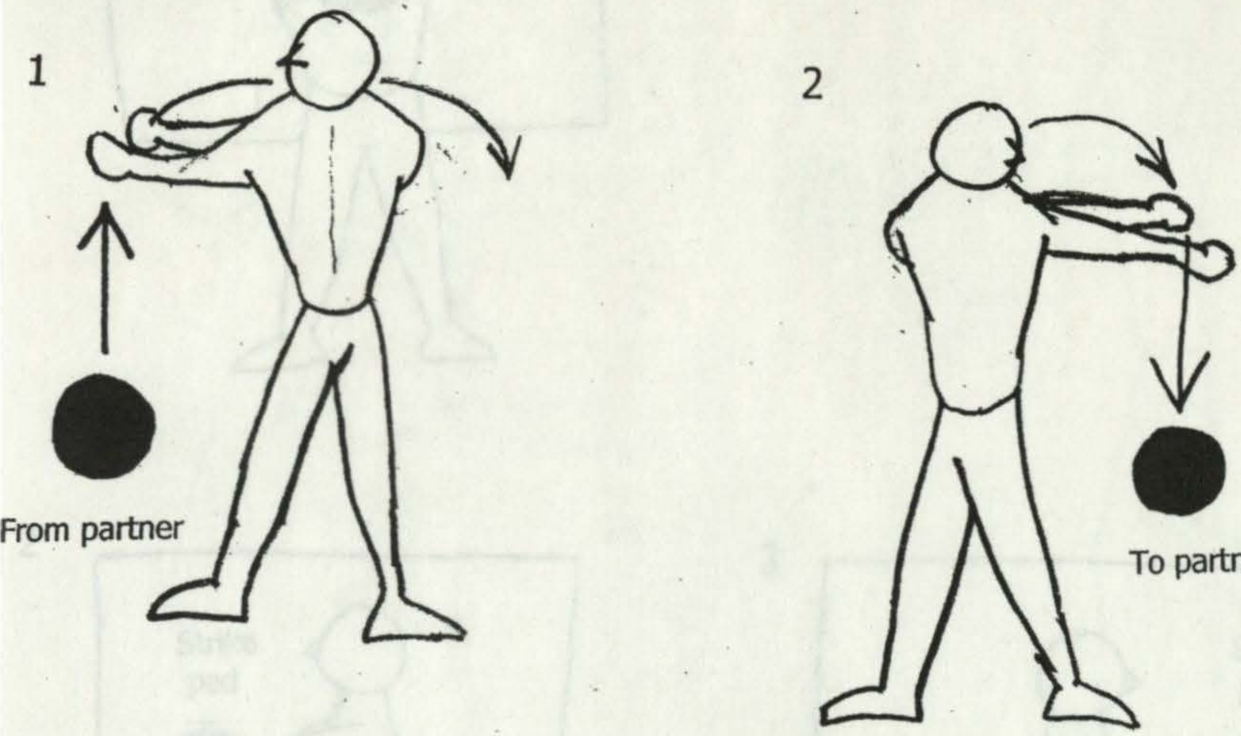


Catch medicine ball with arms extended and return to starting position

Appendix 2A:
Lumberjack or Lumberjack with Toss

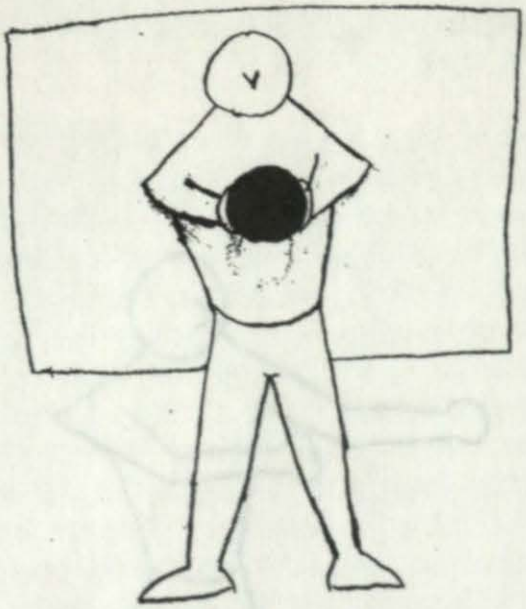


Appendix 2B:
Backward Toss with Partner

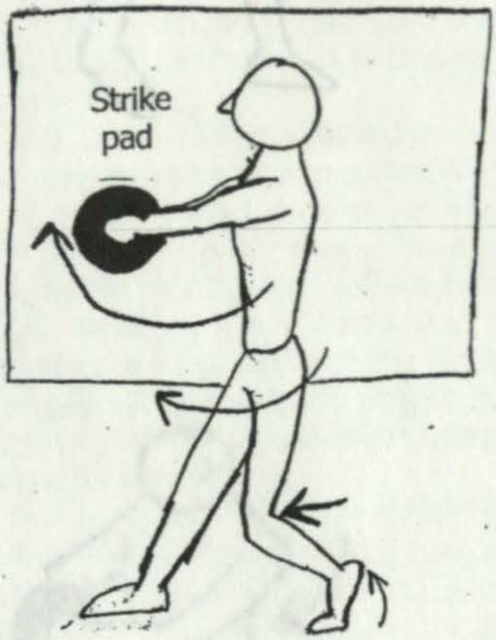


Appendix 3A:
Baseball-Simulating Standing Trunk Rotation with Padded Wall

1

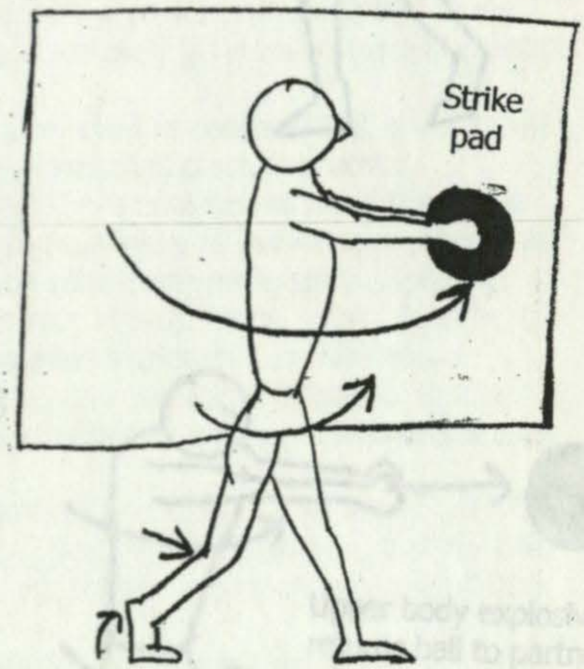


2



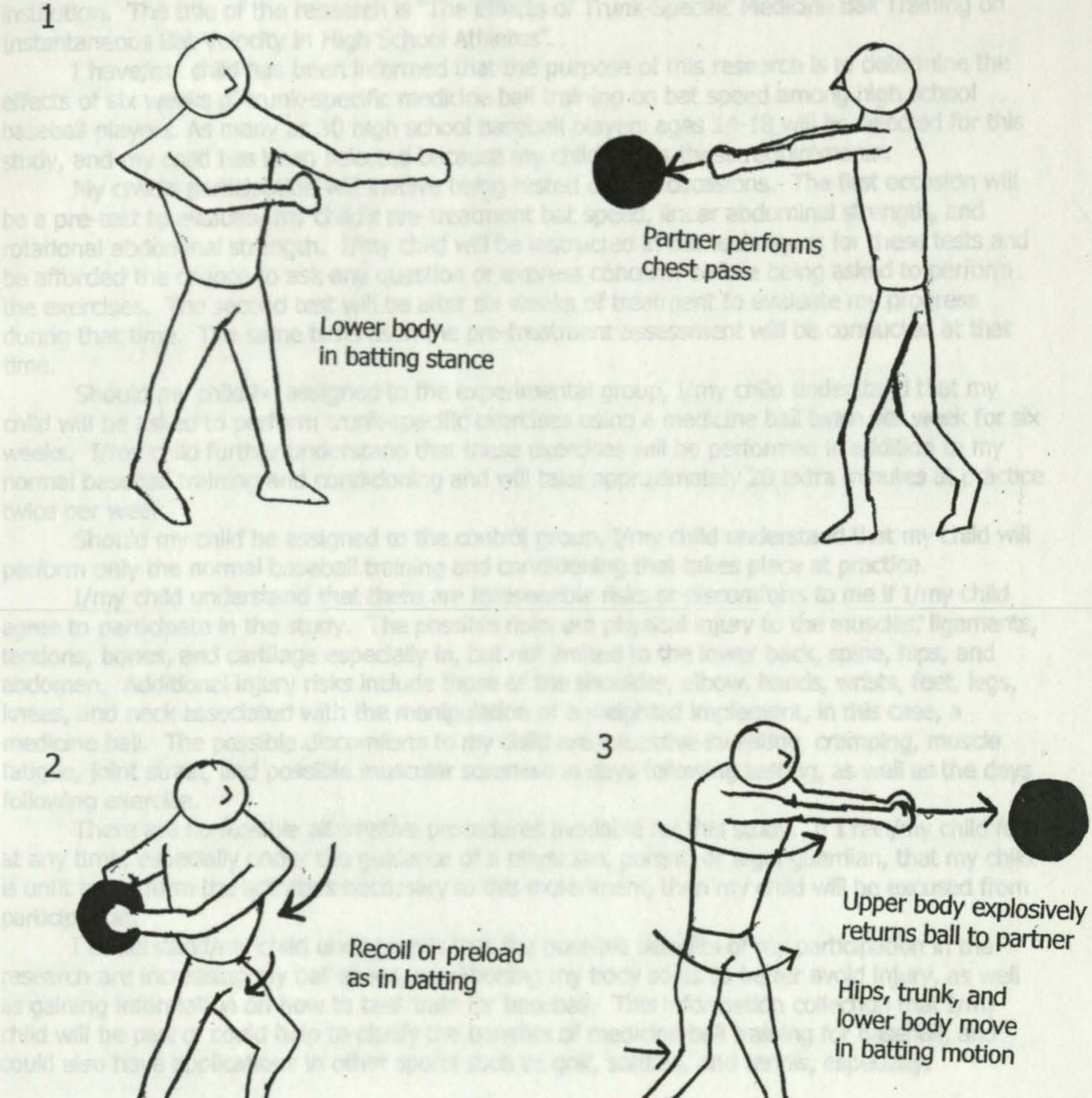
Hips, trunk, and lower body move in batting motion

3



Hips, trunk, and lower body move in batting motion to opposite side

Appendix 3B:
Batter's Drill with Partner Toss



Appendix 4A: Informed Consent

"The Effects of Trunk-Specific Medicine Ball Training on Instantaneous Bat Velocity in High School Athletes".

Mark Pittman, who is a graduate student in the Health and Physical Education program at Adams State College, has requested my/my child's participation in a research study at this institution. The title of the research is "The Effects of Trunk-Specific Medicine Ball Training on Instantaneous Bat Velocity in High School Athletes".

I have/my child has been informed that the purpose of this research is to determine the effects of six weeks of trunk-specific medicine ball training on bat speed among high school baseball players. As many as 30 high school baseball players ages 14-18 will be selected for this study, and my child has been selected because my child meets these requirements.

My child's participation will involve being tested on two occasions. The first occasion will be a pre-test to evaluate my child's pre-treatment bat speed, linear abdominal strength, and rotational abdominal strength. I/my child will be instructed in the techniques for these tests and be afforded the chance to ask any question or express concerns before being asked to perform the exercises. The second test will be after six weeks of treatment to evaluate my progress during that time. The same tests as in the pre-treatment assessment will be conducted at that time.

Should my child be assigned to the experimental group, I/my child understand that my child will be asked to perform trunk-specific exercises using a medicine ball twice per week for six weeks. I/my child further understand that these exercises will be performed in addition to my normal baseball training and conditioning and will take approximately 20 extra minutes at practice twice per week.

Should my child be assigned to the control group, I/my child understand that my child will perform only the normal baseball training and conditioning that takes place at practice.

I/my child understand that there are foreseeable risks or discomforts to me if I/my child agree to participate in the study. The possible risks are physical injury to the muscles, ligaments, tendons, bones, and cartilage especially in, but not limited to the lower back, spine, hips, and abdomen. Additional injury risks include those of the shoulder, elbow, hands, wrists, feet, legs, knees, and neck associated with the manipulation of a weighted implement, in this case, a medicine ball. The possible discomforts to my child are excessive sweating, cramping, muscle fatigue, joint strain, and possible muscular soreness in days following testing, as well as the days following exercise.

There are no feasible alternative procedures available for this study. If I feel/my child feels at any time, especially under the guidance of a physician, parent, or legal guardian, that my child is unfit to perform the activities necessary to this experiment, then my child will be excused from participation.

I understand/my child understands that the possible benefits of my participation in the research are increasing my bat speed, conditioning my body so as to better avoid injury, as well as gaining information on how to best train for baseball. This information collection that I/my child will be part of could help to clarify the benefits of medicine ball training for baseball, and could also have applications in other sports such as golf, softball, and tennis, especially.

I understand/my child understands that the results of the research study may be published but that my name or identity will not be revealed. In order to maintain confidentiality of my child's records, Mark Pittman will assign my child an identification number for use in the collection of all data and information, and will limit access of the names of all participants to fellow colleagues who have direct involvement in the study. I understand/my child understands that when collected data are to be stored, it will be in a file cabinet in the personal residence of Mark Pittman to which only he has access. Any information stored on a computer will be protected so that only Mark Pittman has access.

I have/my child has been advised that the research in which my child will be participating does involve some risk because of the dynamic and physically demanding nature of the exercises to be performed. However, I am/my child is further advised that these exercises have been designed specifically to replicate the movements used in baseball and to train the specific muscles used in those movements.

I have/my child has been informed that I/my child will not be compensated for my child's participation.

I have/my child has been informed that any questions I have/my child has concerning the research study or participation in it, before or after my consent, will be answered by Mark Pittman, Box Adams 1120, Alamosa, CO 81102, 719-587-7542.

I understand/my child understands that in case of injury, if I have/my child has questions about my/my child's rights as a subject/participant in this research, or if I/my child feel(s) I have/my child has been placed at risk, I/my child can contact the Chair of the Human Subjects Research Review Committee at Adams State College, Dr. Kim Kelso at 719-587-7783. I may also contact Dr. Jeff Geiser at 719-587-7402, and Dr. Tracey Robinson at 719-587-7663, as they are the faculty advisers to Mark Pittman for this study.

I have/my child has read the above information. The nature, demands, risks, and benefits of the project have been explained to me. I/my child knowingly assume(s) the risks involved and understand that I/my child may withdraw my/my child's consent and discontinue participation at any time without penalty or loss of benefit to myself/my child. In signing this consent form, I am/my child is not waiving any legal claims, rights, or remedies. A copy of this consent form will be given to me/my child.

____

Subject's Signature Date

____

Parent or Guardian Signature Date

I certify that I have explained to the above individuals the nature and purpose, the potential benefits, and possible risks associated with participation in this research study, have answered any questions that have been raised, and have witnessed the above signature.

These elements of informed consent conform to the assurance given by Adams State College to the Department of Health, Physical Education, and Exercise to protect the rights of human subjects.

I have provided the subject/participant and the subject's parent or legal guardian a copy of this signed consent document.

____

Signature of Investigator Date

Appendix 4B: Parent Information Letter

February 23, 2005

Dear Alamosa High School Baseball Parent:

My name is Mark Pittman, and I am one of the members of the coaching staff in the AHS baseball program. I am currently working on my Master of Arts degree in Health, Physical Education, and Recreation through Adams State College. I am in the final phase of my completion of this degree, but need you and your son's assistance to make the final step.

My culminating thesis is to investigate the variables of trunk-specific medicine ball training and bat speed. For this purpose, I intend to conduct an experiment with the members of the AHS baseball program. The process is outlined in detail in the accompanying form. Please read through that form, sign it, have your son sign it, and then have your son return it to me at practice as soon as possible. I will then make a copy of the form for you to retain, as stated in the final section of the document.

In terms of additional time commitment, I have estimated that the exercises to be done will take approximately an additional 11-12 minutes at practice twice per week for six weeks.

I know that some of the risks of injury I note in the accompanying form may be unnerving. Officially, I cannot guarantee that no injuries will occur. What I can assure you is that your son will be participating in activities that would normally be done at baseball practice. I have been performing the intended exercises myself for several months in order to verify both their safety and effectiveness, and believe that either case is true.

If you would like a copy of my research proposal, or diagrams of the exercises to be performed, please feel free to contact me at 587-7396. Also, do not hesitate to contact me at any time during the season if you have any questions or concerns regarding your son. I thank you in advance, and appreciate your cooperation.

Sincerely,

Mark J. Pittman
Adams State College &
Alamosa High School Baseball

Appendix 5A
Pretest Data Sheet

Pre-Test
Experimental Group

Subject	BS1	BS2	BS3	BS4	BS5	BS Mean	BS (X-M)^2	Crunch	CR (X-M)^2	MB Twist	MBT (X-M)^2
2	64.7	63.7	66.7	67.6	65.4	67.4	55.43479339	35	46.48760331	24	0.669421488
5	61	65.2	64.8	64.5	66.3	64.36	19.40802975	56	201.1239669	25	0.033057851
7	61.3	64.9	65.8	60.4	67.4	63.96	16.04366612	38	14.5785124	24	0.669421488
13	70.1	71	69.9	71.7	70.2	70.58	112.9002843	40	3.305785124	26	1.396694215
15	56.8	62.2	62.4	58.1	65.2	60.94	0.971120661	42	0.033057851	25	0.033057851
17	62	54.5	52.3	48.2	52.5	53.9	36.65752066	37	23.21487603	24	0.669421488
24	53	54.6	56	51.9	50.4	53.18	45.89446612	32	96.39669421	25	0.033057851
25	56.7	57	52.1	52.7	52.8	54.26	32.42784793	50	66.94214876	26	1.396694215
28	56.5	57.2	54.4	55.7	56	55.96	15.95639339	54	148.3966942	24	0.669421488
29	55.2	53.2	51.6	54.2	53.3	53.5	41.66115702	39	7.94214876	25	0.033057851
31	62.9	60.7	58.9	59	65.8	61.46	2.266393388	37	23.21487603	25	0.033057851
Mean	*SD*					59.9545455	*6.161344599*	41.81818	*7.94755537*	24.8181818	*0.750757194*

Control Group

1	49.2	51.8	53.4	55.8	46.8	51.4	100.0444494	44	5.444444444	23	0
4	59.5	60.8	59.8	58.6	56.2	58.98	5.867160494	37	21.77777778	22	1
8	67.1	74	56.8	56.2	61.1	63.04	2.682316049	48	40.11111111	23	0
9	74.6	68.4	65.8	63.7	66.5	67.8	40.93156049	44	5.444444444	23	0
12	63.3	62	58.9	62.4	62.2	61.76	0.128004938	39	7.111111111	24	1
14	55.1	57.3	64.4	58	57.4	58.44	8.774760494	39	7.111111111	25	4
21	62.1	65.9	70.5	71.8	74.4	68.94	56.81809383	46	18.77777778	20	9
22	67.9	69.2	70.3	68.5	68.6	68.9	56.2166716	38	13.44444444	23	0
30	51.8	54.7	52.6	55.6	51.1	53.36	64.67733827	40	2.777777778	24	1
Mean	*SD*					61.4022222	*6.48209414*	41.66667	*3.905124838*	23	*1.414213562*

Appendix 5B
Post-Test Data Sheet

Post-Test

Experimental Group

Subject	BS1	BS2	BS3	BS4	BS5	BS Mean	BS (X-M)^2	Crunch	CR (X-M)^2	MB Twist	MBT (X-M)^2
2	61.4	65	67.4	69.9	65.6	65.86	4.31128595	46	6.950413223	31	0.52892562
5	64	67.5	66.8	68	65.5	66.36	6.637649587	69	414.677686	38	59.7107438
7	63.1	64.5	63.6	65.2	63.8	64.04	0.065722314	41	58.31404959	28	5.165289256
13	66.4	70.7	78.9	76.2	74	73.24	89.42281322	43	31.76859504	31	0.52892562
15	76.2	78.3	81.3	80.8	80.7	79.46	245.7483769	50	1.859504132	29	1.619834711
17	69.9	70	66.6	65.4	66.9	67.76	15.81146777	54	28.76859504	30	0.074380165
24	55.3	54.7	54	54.2	59.7	55.58	67.29964959	41	58.31404959	27	10.7107438
25	63.8	57.3	57.2	59	59.9	59.44	18.86717686	48	0.404958678	33	7.438016529
28	59.6	56.3	55.5	55.1	56.3	56.56	52.18092231	64	236.0413223	32	2.983471074
29	52.4	52.6	51.8	53.1	51.2	52.22	133.717686	43	31.76859504	29	1.619834711
31	62.6	65.2	60.1	58	59.6	61.1	7.201904132	36	159.677686	25	27.80165289
Mean	*SD*					63.7836364	*8.00790019*	48.636364	*10.141723*	30.2727273	*3.437758255*

Control Group

1	54.7	49.1	48.8	46.3	46.6	49.1	210.1855605	60	111.4197531	24	3.160493827
4	57	56.8	58.3	57.9	56.8	57.36	38.9098716	40	89.19753086	23	7.716049383
8	60.1	59.8	63	63.7	70.6	63.44	0.024893827	68	344.308642	29	10.38271605
9	65.7	65.6	68.4	66	65.7	66.28	7.194316049	55	30.86419753	27	1.49382716
12	73.5	71.7	71.7	75.8	74.4	73.42	96.47604938	41	71.30864198	24	3.160493827
14	58.2	58.8	57.3	58.4	56.9	57.92	32.23716049	44	29.64197531	26	0.049382716
21	69.2	68.7	67.6	71.3	72	69.76	37.97298272	45	19.75308642	21	22.82716049
22	70.7	82.2	75.8	79.1	81.9	77.94	205.6993383	45	19.75308642	29	10.38271605
30	59.3	59.5	57.6	53.7	55.7	57.16	41.44498272	47	5.975308642	29	10.38271605
Mean	*SD*					63.5977778	*9.152493892*	49.444444	*9.501461876*	25.7777778	*2.948634335*

Pre-Test Abdominal Crunches ANOVA

Experimental Group

Subject	AC X	AC X^2
2	35	1225
5	56	3136
7	38	1444
13	40	1600
15	42	1764
17	37	1369
24	32	1024
25	50	2500
28	54	2916
29	39	1521
31	37	1369
Means:	41.8182	1806.181818
Sums:	460	19868

Control Group

Subject	AC X	AC X^2
1	44	1936
4	37	1369
8	48	2304
9	44	1936
12	39	1521
14	39	1521
21	46	2116
22	38	1444
30	40	1600
Means:	41.6667	1749.666667
Sums:	375	15747

Summary Table for ANOVA

	SS	df	MS	F
Between	0.114	1	0.114	0.003*
Within	753.636	18	41.869	
Total	753.75	19		

*p<.01 F(0.114, 41.869) = .003, p<.01
Critical value of F at p<.01, df (1,18) = 8.28

There appears to have been no significant difference between the Experimental and Control groups in the pre-test for abdominal crunches.

Post-Test Abdominal Crunches ANOVA

Experimental Group

Subject	SU X	SU X^2
2	46	2116
5	69	4761
7	41	1681
13	43	1849
15	50	2500
17	54	2916
24	41	1681
25	48	2304
28	64	4096
29	43	1849
31	36	1296
Means:	48.6364	2459
Sums:	535	27049

Control Group

Subject	SU X	SU X^2
1	60	3600
4	40	1600
8	68	4624
9	55	3025
12	41	1681
14	44	1936
21	45	2025
22	45	2025
30	47	2209
Means:	49.4444	2525
Sums:	445	22725

Summary Table for ANOVA

	SS	df	MS	F
Between	3.233	1	3.233	0.033*
Within	1750.77	18	97.265	
Total	1754	19		

*p<.01 F(3.233, 97.265) = .033, p<.01
Critical value of F at p<.01, df (1,18) = 8.28

There appears to have been no significant difference between the Experimental and Control groups in the post-test for abdominal crunches.

Dependent t-Test for Abdominal Crunch Test

Experimental Group

Subject	Crunch Pre	Crunch Post	Pre-Post (D)	D^2
2	35	46	11	121
5	56	69	13	169
7	38	41	3	9
13	40	43	3	9
15	42	50	8	64
17	37	54	17	289
24	32	41	9	81
25	50	48	-2	4
28	54	64	10	100
29	39	43	4	16
31	37	36	-1	1
Means:	41.8181818	48.63636364	6.818181818	78.45454545
Sums:	460	535	75	863

N=11 p<.01
df=10 critical value of t at df=10 is 2.764
t= 3.813

There was a statistically significant increase in abdominal crunch test scores for the experimental group.

Control Group

Subject	Crunch Pre	Crunch Post	Pre-Post (D)	D^2
1	44	60	16	256
4	37	40	3	9
8	48	68	20	400
9	44	55	11	121
12	39	41	2	4
14	39	44	5	25
21	46	42	-4	16
22	38	45	7	49
30	40	47	7	49
Means:	41.6666667	49.11111111	6.090909091	103.2222222
Sums:	375	442	54.81818182	929

N=9 p<.01
df=8 critical value of t at df=8 is 2.896
t= 2.119

There was not a statistically significant increase in abdominal crunch test scores for the control group.

Appendix 7A

Pre-Test Standing Medicine Ball Twist ANOVA

Experimental Group

Subject	R X	R X^2
2	24	576
5	25	625
7	24	576
13	26	676
15	25	625
17	24	576
24	25	625
25	26	676
28	24	576
29	25	625
31	25	625
Means:	24.81818	616.4545455
Sums:	273	6781

Control Group

Subject	R X	R X^2
1	23	529
4	22	484
8	23	529
9	23	529
12	24	576
14	25	625
21	20	400
22	23	529
30	24	576
Means:	23	530.7777778
Sums:	207	4777

Summary Table for ANOVA

	SS	df	MS	F
Between	16.364	1	16.364	13.614*
Within	21.636	18	1.202	
Total	38	19		

*p<.01 F(16.364, 1.202) = 13.614, p<.01
Critical value of F at p<.01, df (1,18) = 8.28

There appears to have been a significant difference between the Experimental and Control groups in the pre-test for trunk rotation .

Appendix 7B

Post-Test Standing Medicine Ball Twist ANOVA

Experimental Group

Subject	R X	R X^2
2	31	961
5	38	1444
7	28	784
13	31	961
15	29	841
17	30	900
24	27	729
25	33	1089
28	32	1024
29	29	841
31	25	625
Means:	30.27273	927.1818182
Sums:	333	10199

Control Group

Subject	R X	R X^2
1	24	576
4	23	529
8	29	841
9	27	729
12	24	576
14	26	676
21	21	441
22	29	841
30	29	841
Means:	25.77778	672.2222222
Sums:	232	6050

Summary Table for ANOVA

	SS	df	MS	F
Between	7825.612	1	7825.612	175.035*
Within	187.738	18	10.43	
Total	8013.35	19		

*p<.01 F(7825.612, 10.43) = 175.035, p<.01
Critical value of F at p<.01, df (1,18) = 8.28

There appears to have been a statistically significant difference between the Experimental and Control groups in the post-test for trunk rotation .

Appendix 7C

Pre- vs. Post-Test Comparison for Medicine Ball Twist Test

Experimental Group

Subject	Rot. Pre	Rot. Post	Diff.
2	24	31	7
5	25	38	13
7	24	28	4
13	26	31	5
15	25	29	4
17	24	30	6
24	25	27	2
25	26	33	7
28	24	32	8
29	25	29	4
31	25	25	0
Mean	24.818182	30.27273	5.45455

The experimental group had an average increase of 5.45 repetitions, or 21.95%.

Control Group

Subject	Rot. Pre	Rot. Post	Diff.
1	23	24	1
4	22	23	1
8	23	29	6
9	23	27	4
12	24	24	0
14	25	24	-1
21	20	21	1
22	23	29	6
30	24	29	5
Mean	23	25.55556	2.55556

The control group had an average increase of 2.56 repetitions or 11.13%.

Dependent t-Test for Standing Medicine Ball Twist Test

Experimental Group

Subject	Rot. Pre	Rot. Post	Pre-Post (D)	D^2
2	24	31	7	49
5	25	38	13	169
7	24	28	4	16
13	26	31	5	25
15	25	29	4	16
17	24	30	6	36
24	25	27	2	4
25	26	33	7	49
28	24	32	8	64
29	25	29	4	16
31	25	25	0	0
Means:	24.81818182	30.27272727	5.454545455	40.36363636
Sums:	273	333	60	444

N=11 p<.01
df=10 critical value of t at df=10 is 2.764
t= 2.821

There was a statistically significant increase in trunk rotation scores for the experimental group, averaging a gain of 21.95%.

Control Group

Subject	Rot. Pre	Rot. Post	Pre-Post (D)	D^2
1	23	24	1	1
4	22	23	1	1
8	23	29	6	36
9	23	27	4	16
12	24	24	0	0
14	25	24	-1	1
21	20	21	1	1
22	23	29	6	36
30	24	29	5	25
Means:	23	25.55555556	2.555555556	13
Sums:	207	230	23	117

N=9 p<.01
df=8 critical value of t at df=8 is 2.896
t=2.842

There was not a statistically significant increase in trunk rotation scores for the control group, averaging a gain of 11.13%.

Appendix 8A

Pre-Test Bat Speed ANOVA

Experimental Group

Subject	BS X	BS X^2
2	67.4	4542.76
5	64.36	4142.2096
7	63.96	4090.8816
13	70.58	4981.5364
15	60.94	3713.6836
17	53.9	2905.21
24	53.18	2828.1124
25	54.26	2944.1476
28	55.96	3131.5216
29	53.5	2862.25
31	61.46	3777.3316
Means:	59.95454545	3629.058582
Sums:	659.5	39919.6444

Control Group

Subject	BS X	BS X^2
1	51.4	2641.96
4	58.98	3478.6404
8	63.04	3974.0416
9	67.8	4596.84
12	61.76	3814.2976
14	58.44	3415.2336
21	68.94	4752.7236
22	68.9	4747.21
30	53.36	2847.2896
Means:	61.40222222	3807.581822
Sums:	552.62	34268.2364

Summary Table for ANOVA

	SS	df	MS	F
Between	10.374	1	10.374	0.259*
Within	719.761	18	39.987	
Total	726.135	19		

*p<.01 F(10.374, 39.987) = 0.259, p<.01
Critical value of F at p<.01, df (1,18) = 8.28

There appears to have been no significant difference between the Experimental and Control groups in the pre-test for bat speed .

Post-Test Bat Speed ANOVA

Experimental Group

Subject	BS X	BS X^2
2	65.86	4337.5396
5	66.36	4403.6496
7	64.04	4101.1216
13	73.24	5364.0976
15	79.46	6313.8916
17	67.76	4591.4176
24	55.58	3089.1364
25	59.44	3533.1136
28	56.56	3199.0336
29	52.22	2726.9284
31	61.1	3733.21
Means:	63.78363636	4126.649055
Sums:	701.62	45393.1396

Control Group

Subject	BS X	BS X^2
1	49.1	2410.81
4	57.36	3290.1696
8	63.44	4024.6336
9	66.28	4393.0384
12	73.42	5390.4964
14	57.92	3354.7264
21	69.76	4866.4576
22	77.94	6074.6436
30	57.16	3267.2656
Means:	63.59777778	4119.137911
Sums:	572.38	37072.2412

Summary Table for ANOVA

	SS	df	MS	F
Between	0.171	1	0.171	0.002*
Within	1311.41	18	73	
Total	1311.581	19		

*p<.01 F(0.171, 73) = 0.002, p<.01

Critical value of F at p<.01, df (1,18) = 8.28

There appears to have been no significant difference between the Experimental and Control groups in the post-test for bat speed .

Appendix 8C

Pre- vs. Post-Test Comparison for Bat Speed

Experimental Group

Subject	BS Pre	BS Post	Diff.
2	67.4	65.86	-1.54
5	64.36	66.36	2
7	63.96	64.04	0.08
13	70.58	73.24	2.66
15	60.94	79.46	18.52
17	53.9	67.76	13.86
24	53.18	55.58	2.4
25	54.26	59.44	5.18
28	55.96	56.56	0.6
29	53.5	52.22	-1.28
31	61.46	61.1	-0.36
Mean	59.9545	63.78364	3.829091

The experimental group had an average increase of 3.83MPH, or 6.39%.

Control Group

Subject	BS Pre	BS Post	Diff.
1	51.4	49.1	-2.3
4	58.98	57.36	-1.62
8	63.04	63.44	0.4
9	67.8	66.28	-1.52
12	61.76	73.42	11.66
14	58.44	57.92	-0.52
21	68.94	69.76	0.82
22	68.9	77.94	9.04
30	53.36	57.16	3.8
Mean	61.4022	63.59778	2.195556

The control group had an average increase of 2.20MPH, or 3.60%.

Dependent t-Test for Bat Speed

Experimental Group

Subject	BS Pre	BS Post	Pre-Post (D)	D^2
2	67.4	65.86	-1.54	2.3716
5	64.36	66.36	2	4
7	63.96	64.04	0.08	0.0064
13	70.58	73.24	2.66	7.0756
15	60.94	79.46	18.52	342.9904
17	53.9	67.76	13.86	192.0996
24	53.18	55.58	2.4	5.76
25	54.26	59.44	5.18	26.8324
28	55.96	56.56	0.6	0.36
29	53.5	52.22	-1.28	1.6384
31	61.46	61.1	-0.36	0.1296
Means:	59.95454545	63.78363636	3.829090909	53.024
Sums:	659.5	701.62	42.12	583.264

N=11 p<.01
df=10
t= 1.955**

The experimental group did not show a statistically significant increase in bat speed at the .01 level, where the critical value of "t" is 2.764.

***It should be noted that this "t" value is significant at the .05 level (CV=1.812).*

Control Group

Subject	BS Pre	BS Post	Pre-Post (D)	D^2
1	51.4	49.1	-2.3	5.29
4	58.98	57.36	-1.62	2.6244
8	63.04	63.44	0.4	0.16
9	67.8	66.28	-1.52	2.3104
12	61.76	73.42	11.66	135.9556
14	58.44	57.92	-0.52	0.2704
21	68.94	69.76	0.82	0.6724
22	68.9	77.94	9.04	81.7216
30	53.36	57.16	3.8	14.44
Means:	61.40222222	63.59777778	2.195555556	27.04942222
Sums:	552.62	572.38	19.76	243.4448

N=9 p<.01
df=8
t= 1.317

The control group did not show a statistically significant increase in bat speed at the .01 level, where the critical value of "t" is 2.896, or at the .05 level (CV=2.306).

Appendix 6C

Pre- vs. Post-Test Comparison for Abdominal Crunches

Experimental Group

Subject	Crunch Pre	Crunch Post	Diff.
2	35	46	11
5	56	69	13
7	38	41	3
13	40	43	3
15	42	50	8
17	37	54	17
24	32	41	9
25	50	48	-2
28	54	64	10
29	39	43	4
31	37	36	-1
Mean	41.8181818	48.63636364	6.81818

The experimental group had an average increase of 6.8 repetions, or 16.3%.

Control Group

Subject	Crunch Pre	Crunch Post	Diff.
1	44	60	16
4	37	40	3
8	48	68	20
9	44	55	11
12	39	41	2
14	39	40	1
21	46	42	-4
22	38	43	5
30	40	47	7
Mean	41.6666667	48.44444444	6.77778

The control group had an average increase of 6.78 repetitions, or 16.3%.