THE RELATIONSHIP OF MAXIMAL LEG POWER AND SWING VELOCITY IN COLLEGIATE ATHLETES

by

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An Abstract of a thesis prospectus in partial fulfillment of the requirements in the Department of Nutrition and Kinesiology
University of Central Missouri

April, 2016
Abstract

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The purpose of this study was to evaluate the relationship between maximal leg power and swing velocity of each subject. Each subject completed one assessment to determine anthropometric measures, vertical jump, and swing velocity. Subject \((n=34)\) mean (±SD) age, height, and weight were 20.35 years (±1.34), 176.84 cm (±9.77), and 77.66 kg (±13.92), respectively. Mean measures for baseball \((n=17)\) and softball \((n=17)\) were 20.65 years (±1.22), 184.81 cm (±4.07), 88.28 kg (±9.83) and 20.06 years (±1.43), 168.87 cm (±6.74), 67.03 kg (±7.96), respectively. Vertical jump means for total population, baseball, and softball were 41.50 cm (±10.36), 49.89 cm (±6.05), and 33.11 cm (±5.92), respectively. Swing velocity means were 33.98 m/s (±4.93), 38.65 m/s (±1.39), and 29.56 m/s (±2.08), respectively. Pearson’s Correlation revealed a high \((r=0.823)\), moderate \((r=0.520)\), and non- \((r=0.036)\) linear relationships for sample, baseball, and softball players when measuring the relationship of vertical jump and swing velocity. Coefficient of determination was also calculated for each group and were \(R^2=0.677\), 0.270, and 0.001, respectively. Statistical evaluation revealed a strong relationship between vertical jump and swing velocity in collegiate athletes.
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CHAPTER I
NATURE AND SCOPE
OF THE STUDY

Successful performance in baseball or softball requires the ability to perform multiple skills of the game efficiently. The skills most critical to the game include fielding, throwing, and hitting. Improving these tasks is at the forefront of every coach and player. However, with the emergence in the popularity of hitting home runs in baseball and softball, successful hitting performance has steadily received the most attention. Successful hitting has been, and will continue to be interpreted differently among pundits of the game and is attributed to several factors. These factors include, but are not limited to, swing velocity, swing time, swing path, ball exit velocity, and decision time. Though several swings have been demonstrated as efficient, each swing contains a primary component: swing velocity. Swing velocity is characterized as the direct measure of the rate the bat travels through the hitter’s desired path (Szymanski, 2007).

Swing velocity is linked directly to noticeable improvements in hitting performance through two distinct factors. Primarily, increases in swing velocity allows the hitter to decipher whether or not he or she wants to swing at the ball. Secondly, the increase in swing velocity allows the bat to travel faster to the ball thus leading to an increase in ball exit velocity off the bat (Szymanski, DeRenne, & Spaniol, 2009). There is an abundance of literature regarding decision time and ball exit velocity (Szymanski, 2007). However, there is a paucity of research examining how to directly improve decision time and ball exit velocity.

Teams and coaches striving to improve hitting performance utilize periodized strength and conditioning programs and have noticed significant improvements (DeRenne, Hetzler, Buxtant, & Ho, 1996; Dodd & Alvar, 2007; Ebben, Hintz, & Simenz, 2005; Reyes, Dickin,
Dolny, & Crusat, 2010; Szymanski et al., 2007). Most of these strength and conditioning programs have examined hypertrophy or strength training and the residual effects on hitting performance. There is little data evaluating an athlete’s ability to produce power and its effects on baseball and softball performance. Literature reveals that with the improvement of power by means of strength and conditioning implementation sport performance improves (Baechle & Earle, 2000; Bompa & Haff, 2009; Young, Jenner, & Griffiths, 1998).

**Significance of Study**

Assessing the relationship between maximal leg power and swing velocity will allow professionals in the field to further interpret contributing factors to hitting performance. Establishing a relationship may provide evidence for manipulating strength and conditioning programs to enhance baseball and softball hitting performance. Focusing training could provide a competitive edge for the teams who implement power training into their softball and baseball programs. However, a lack of evidence exists between power and swing velocity. The results of this investigation may provide evidence to establish a relationship between leg power and swing velocity.

**Purpose of Study**

The purpose of this investigation is to examine the strength of association of maximal leg power and swing velocity. Primarily, the research team investigated lower body power by means of vertical jump and its relationship to swing velocity. Evaluating the direct relation between maximal leg power and swing velocity in more depth could allow strength and conditioning professionals in the sport to develop and implement more sound programs to enhance hitting performance.
Hypothesis

It was hypothesized that maximal leg power and swing velocity will display a significant positive relationship.

Delimitations

The investigation was delimited to:

1. current players on the University of Central Missouri baseball and softball teams;
2. subjects with previous strength and conditioning experience; and
3. one thirty-minute session to assess anthropometric measures, vertical jump, and swing velocity.

Limitations

The investigation was limited by:

1. Qualisys motion capture technology accurately measuring each swing and vertical jump trial;
2. the Kistler force plate accurately measuring the time in air of each vertical jump trial; and
3. subjects reporting to the assessment without undergoing any workouts/practice immediately prior to the testing session.

Assumptions

It was assumed that:

1. each subject performed the vertical jump assessment to their maximum ability;
2. each subject performed the swing velocity assessment to their maximum ability;
3. the software utilized to collect vertical jump trials provided the most accurate measure for each trial;
4. the software utilized to collect swing velocity trials provided the most accurate measure for each trial; and

5. each subject utilized the same bat as they would in a game.

**Definition of Terms**

1. Batting tee: An implement used for batting practice in which the desired height can be adjusted.

2. General programming: Exercises that are composed primarily of compound multi-joint movements directed towards movements encountered during the sport (Szymanski, 2007).

3. Resistance training: a form of physical activity that is designed to improve muscular fitness by exercising a muscle or a muscle group against external resistance.

4. Swing velocity: The direct measure of the rate the bat travels through the hitter’s desired path (Szymanski, 2007).

5. Loading phase: The batter shifts his or her weight to their back foot, retracts their upper body limbs, and attempts to analyze the ball in the pitcher’s hand (Welch, Banks, Cook, & Draovitch, 1995).

6. Muscular power: The rate at which a muscle or group of muscles can perform an activity (Baechle & Earle, 2000).

7. Muscular strength: The amount of force exerted by a muscle or group of muscles (Baechle & Earle, 2000).

8. Periodization: A systematic planning of athletic or physical training in an attempt to perform maximally (Bompa & Hoff, 2009).
9. Plyometrics: A rapid action which employs a countermovement to stimulate the stretch-shortening cycle in attempt to generate power (Baechle & Earle, 2000).

10. Preparatory phase: When the batter assumes his or her position within the batter’s box and awaits delivery of the pitch (Hughes, Lyons, & Mayo, 2004; Monteleone & Crisfield, 1999).

11. Special programming: This modality combines generalized and specific training within the same training cycle in an attempt to achieve maximal performance (Baechle & Earle, 2000; Bompa & Haff, 2009).

12. Specific programming: Programs designed to maximize applicability from resistance training to sports participation (Baechle & Earle, 2000).

13. Stride phase: The batter remove the lead foot from the ground, thus allocating their weight to the back leg. Once the front foot is lifted from the ground, the direction the foot is moved is dependent upon the batter’s initial stance (Monteleone & Crisfield, 1999).

14. Swing phase: Bringing the hands forward through the ball, internally rotating the hind hip, externally rotating the front hip, and bringing the bat through while leading with the hands (Monteleone & Crisfield, 1999).
CHAPTER II
REVIEW OF RELATED LITERATURE

Purpose

Baseball and softball coaches across all levels of play continuously search for ways to enhance hitting performance. Most research to date has investigated various warm-up routines and the effects on subsequent hitting performance. Similarly, there is an increased awareness for research investigating the effects strength and conditioning programs on hitting performance. Acute and chronic manipulations in training each contain their own focus for enhancing performance; however, there still is not a methodology proven to be most effective in improving hitting performance. Though a multitude of differences exists across the softball and baseball population, the common proposition amongst professionals in the field are the mechanics of the swing and attributes associated with swing velocity. Nonetheless, this review of literature is organized into the following sections: 1) swing analysis, 2) swing velocity, 3) attempts to enhance swing velocity, and 4) assessment of power via vertical jump.

Swing Analysis

At first glance, there are several differences noticed across each skill level between swings. Although there may be nuances initially noticed, every swing contains several main components or phases. The components of the swing have been under continuous evaluation and literature designated these phases as: preparatory phase, loading phase, stride phase, and swing phase (Escamilla et al., 2009a).

Preparatory phase. The batter initiates this sequence by proceeding through all of his or her post-warm-up routines once in the batter’s box. Following the routine in the box, the batter
will then assume their optimal grip on the bat. Alignment of proximal interphalangeal joints allows the batter to achieve optimal hand placement at the time of bat to ball contact (Hughes et al., 2004; Monteleone & Crisfield, 1999).

During the preparatory phase the batter chooses to align themselves in relation to the pitcher however they choose. Within the entire population of baseball and softball athletes, no two batting stances are completely identical. However, a majority of hitters assume a stance relatively close to placing their feet shoulder width apart (Nicholls, Elliot, Miller, & Koh, 2003). Comparable ideas are shared throughout the current body of literature in regards to assuming a shoulder width base (Escamilla et al., 2009b, Flyger, Button, & Rishiraj, 2006; Welch et al., 1995). These ideas are mainly bolstered by the precedents of sustaining balance throughout the swing and for a less dramatic shift of weight during the loading phase (Milanovich & Nesbit, 2014).

Similar to the lower body, a multitude of differences are noticed when comparing hitters’ upper body positions during the stance. The position of the upper body is based on personal preference; however, once the loading phase is initiated mechanics are almost completely identical (Milanovich & Nesbit, 2014). Although several placements of upper body limbs have proved to work for different hitters, a study examining bat path revealed different paths of the bat may require significantly more or less muscle action to initiate the loading and swing phases (Flyger et al., 2006).

Finally, the head placement for all baseball and softball players is primarily looking directly at the pitcher. Though many of the aforementioned variables within the stance can affect the placement of the head, a majority of the batters place their chins on or next to the anterior midaxillary line (Monteleone & Chrisfield, 1999).
**Loading phase.** Once the pitcher begins the motion to deliver the pitch, the batter then shifts their weight to the back foot, retracts their upper body limbs, and attempts to analyze the ball in the pitcher’s hand. The culmination of the weight shift, retraction of upper limbs, and analysis of pitch allows the hitter to be in a loaded position in order to generate the greatest amount of velocity and power (Milanovich & Nesbit, 2014).

Once the batter initiates the transfer of weight from a balanced position toward the back foot, this causes a kinetic chain of events to transpire. As the batters weight is loaded to the hind leg, the hands have a similar pattern and are positioned further back. The main premise behind the loading phase is to create potential energy to be utilized when transitioning to the next phase. Previously, an investigation had described these events as the preservation of a stretch reflex to generate peak power for the swing (Montleone & Crisfield, 1999).

One should be cautious when examining the loading phase. This phase closely resembles a coiled spring, storing energy to be released at the opportune time. However, if the batter mistakenly rotates his or her body, this could lead to increased swing time, decreased swing velocity, and have the potential energy dissipated as the stride phase commences (Escamilla et al., 2009b; Welch et al., 1995).

**Stride phase.** The primary goal behind the stride phase is to establish the weight shift and analyze the task relevant cues prior to the swing (Teichler, 2010). Once the pitcher releases the ball, the batter will shift from the loading phase to the stride phase. The batter removes their lead foot from the ground thus allocating their weight to the back leg. Once the front foot is lifted from the ground, the direction the foot is moved is dependent upon the batters initial stance (Monteleone & Crisfield, 1999). The duration of this step is different among hitters. Some choose to have a high leg kick, while others prefer to have a subtle movement. Success has been
attained through either mode, but literature directs novice athletes to implement a short and low stride to decrease any negligible effects (Flyger et al., 2006; Monteleone & Crisfield, 1999).

**Swing phase.** The final phase of the swing ensues the moment the hands are carried forward. At this time the potential energy is engendered and displays kinetic energy characteristics as the hands move forward initiating the back hips internal rotation. As the hind hip rotates internally the front hip rotates externally to transfer the kinetic energy forward towards the ball. Simultaneously, the hands are carried in a downward slope towards the ball. These first three movements are consistently noticed across all populations swinging a bat (Welch et al., 1995).

However, the following mechanics of the upper body are what distinguishes hitting performance. Once the hands are thrust forward, two actions must occur in order to initiate successful hitting. First, the back elbow must remain tucked towards the midaxillary line. This allows the hitter’s bat to have a more direct and precise path to the ball, delivering a short and compact swing. When examining the direct path of the back elbow, noticeable differences have been revealed for swing velocity and swing time (Escamilla et al., 2009b).

Though the general population has misconstrued the meanings of the swing velocity and swing time, there is a profound difference. Swing velocity is a direct measure of the rate the bat travels through the hitter’s desired path, where swing time is a measure of how quickly the bat travels from the initiation of the swing to the contact of the ball (Szymanski, 2007). Furthermore, a high swing velocity does not necessarily mean a fast swing time (Lund & Heefner, 2013). Typically, higher swing velocities are associated with power hitters. Typically, these hitters possess longer levers and more musculature than hitters with a fast swing time (Welch et al., 1995).
The second crucial element is the extension of the front arm through contact of the ball (Escamilla et al., 2009b). This aspect of the swing allows the complete transfer of stored energy to be released to the ball at contact. Kinematic investigations have revealed that carrying the front arm as close to fully extended as possible is strongly associated with increased ball exit velocity (Milanovich & Nesbit, 2014).

**Swing Velocity**

Swing velocity is described as the rate at which the bat travels through the zone and makes contact with the ball. Literature has revealed swing velocity as a crucial element to successful hitting (Szymanski et al., 2012). Enhancing swing velocity is one of several ways that a hitter can improve hitting performance. Several sources evaluating the attributes associated with successful hitting have deemed swing velocity as the most pivotal (Adair, 1995; Hines & McBee, 1985; Polk, 1978; Robson, 2003). An abundance of attempts have been made to enhance this variable, leading to improved hitting performance, and is evaluated later in this review. These attempts include, but are not limited to, various warm-up routines, warm-up implements, and resistance training protocols.

Measuring this variable has been evaluated in a multitude of ways. Velocity has been determined using motion analysis with infrared detectors (Liu, Liu, Kao, & Shiang, 2001; Southard & Groomer, 2003; Stuempfle, Crawford, Petrie, & Kirkpatrick, 2004; Szymanski et al., 2007b; Szymanski et al., 2010), video evaluation (Reyes et al., 2010), chronograph technology (Szymanski et al., 2006; Szymanski et al., 2011a, 2012; Wilson et al., 2012) electromyographically (Pillmeier, Litzenberger, & Sabo, 2012) and photoelectric sensors (Montoya, Brown, Coburn, & Zinder, 2009; Reyes & Dolny, 2009). Although many different
devices have been used to assess swing velocity, there has not been an investigation examining the accuracy of these measures.

The two primary mechanisms that are directly responsible for improving hitting performance from increased swing velocity include increased decision time and increased exit velocity. During an at bat a baseball hitter has between 0.4167 to 0.4688 seconds before the ball reaches the plate. In less than half a second, the batter must do three things in order to have the highest chance of successful hitting. These three tasks are deciphering what type of pitch is thrown, determining the velocity of the pitch, and determining the location of the pitch (Szymanski et al., 2009).

The brief amount of time the hitter must complete these tasks is referred to as decision time (Hay, 1985). Decision time varies from competition and age level; however, two attributes of successful hitting, timing and accuracy, could be enhanced with increased decision time (Breen, 1967; Welch et al., 1995). Timing the pitch correctly and accurately assessing the location allows the hitter to impart the most amount of force possible on the ball by contacting the pitch with the sweet spot of the bat (Brody, 1986).

The final variable is increased batted-ball velocity. Batted-ball velocity is synonymous with ball exit velocity. This variable is best described as the rate at which the ball bounces off the bat (Lund & Heefner, 2013). Higher batted-ball velocity is highly associated with successful power hitters (Hoffman, Vazquez, Pichardo, & Tenenbaum, 2009). The majority of the research conducted thus far has looked to examine bat composition and weight and the effects on exit velocity; however, that is outside the scope of this investigation (Crisco, Greenwald, Blume, & Penna, 2002; Greenwald, Penna, & Crisco, 2001; Nicholls, Miller, & Elliot, 2006).
Previously, an in-depth review of the physics associated with baseball was conducted. The review suggests that if a baseball or softball player could swing a heavier bat equal to or faster than their normal bat, or if the hitter could swing their standard bat faster, the exit velocity increased due to larger momentum transfer to the ball. Batted-ball velocity is directly affected by increased decision time. If decision time is increased, then the likelihood of batted-ball velocity will be increased (Adair, 1995).

**Attempts to Enhance Swing Velocity**

Previously mentioned, swing velocity has been characterized as one of the most crucial elements in successful hitting (Szymanski et al., 2012). Thus, the attempt to enhance swing velocity has been repetitively examined in order to improve this variable. An abundance of research has been conducted examining various warm-up procedures to improve swing velocity, such as the use of an additional swing weight, a lighter than normal bat, swing parachutes, and many more (Montoya et al., 2009; Reyes & Dolny, 2009; Reyes et al., 2010; Southard & Groomer, 2003; Szymanski et al., 2011a, 2012; Wilson et al., 2012). In similar fashion, prevalence of long-term attempts has increased in literature (DeRenne, 1987; DeRenne et al., 1996; Dodd & Alvar, 2007; Stuempfle et al., 2004; Szymanski & DeRenne, 2010; Szymanski et al., 2006, 2007b, 2010b). These attempts focused on using periodized strength and conditioning programs to enhance swing velocity.

**Warm-up procedures to enhance swing velocity.** Most of these attempts were aimed at examining various warm-up protocols on subsequent hitting performance. The attempts have included differing moments of inertia bats, heavy bats, light bats, and other implements commonly manufactured (Montoya et al., 2009; Reyes & Dolny, 2009; Reyes et al., 2010; Southard & Groomer, 2003; Szymanski et al., 2011a, 2012; Wilson et al., 2012). The notion
behind these attempts is each batter has a certain amount of time on deck prior to engaging in the live at bat. If swing velocity may be acutely enhanced, this may lead to more successful hitting performance during the live at bat.

*Light implement.* Achieving supramaximal swing velocities from light implements as a warm-up modality for baseball and softball players is becoming increasingly popular. The primary theory behind utilizing this warm-up modality is post-activation potentiation (PAP). Post-activation potentiation is a circumstance that occurs when a powerful force exerted by muscles directly effects the subsequent contractions in a beneficial manner (Reyes & Dolny, 2009). Swinging lighter than normal bats could allow a hitter to achieve a supramaximal swing velocity. Once the hitter achieves the supramaximal swing velocity, motor unit recruitment increases, which is associated with an increase in muscular power, thus creating an increase in bat velocity (Young et al., 1998).

The second reason behind this modality is the concept of specificity. Specificity, by definition, is characterized by training in a specific manner to produce specific adaptations on the body or training outcome (Baechle & Earle, 2000). When using a lighter than normal bat, hitters are able to achieve swing velocities much faster than compared to their normal weighted bat. When forcing the hitter to swing at a supramaximal velocities this translates to an increase in subsequent swinging velocity when using their normal bat. The primary notion behind this technique is that training to swing an implement as fast as you may allow a hitter to swing the implement faster. However, there are less detrimental kinematic effects compared to using heavier implements that force a hitter to have a slower more gradual swing, thus leading to altered mechanics and swing path (Reyes & Dolny, 2009).
Nonetheless, the use of a lighter than normal bat when warming up on deck has also received a great deal of scrutiny. The related literature has developed consistent results determining that when hitters consistently swing lighter than normal bats, achieving a supramaximal velocity, the swing pattern is altered when returning to normal bat weight (Liu et al., 2011). Additionally, the general consensus is this primarily occurs due to the back elbow not remaining tucked to the torso during the middle phase of the swing. Allowing the elbow to become distant from the torso can negatively impact overall hitting performance. Keeping the back elbow tucked allows the hitter to have a more efficient bat path when swinging (Szymanski et al., 2009).

Recently, research has revealed an improvement of subsequent swing velocity when utilizing a lighter than normal implement to warm up. The implements examined have included broom sticks, polymerized vinyl chloride (PVC) pipes, plastic bats, aluminum bats, and wood bats (Liu et al., 2011; Montoya et al., 2009; Reyes & Dolny, 2009; Szymanski et al., 2011a, 2012; Wilson et al., 2012).

Furthermore, the effects of warm-ups with various weighted bats on subsequent normal bat velocity were examined. The study consisted of nineteen recreational baseball players and each was randomly assigned to one of three experimental groups; the groups consisted of a light bat (LB), normal bat (NB), or heavy bat (HB). The subjects were asked to take warm-up swings with their designated implement and then complete maximal velocity swings with their normal bat. The conclusion of the study revealed the LB and NB groups both revealed significantly different velocities when compared to the HB group (Montoya et al., 2009).

**Heavy implement.** The prevalence of using multiple bats, weighted bats, or weighted implements to add to the bat while warming up on deck for baseball and softball players
increases. This tradition, routinely refuted, will continue to be passed down to each generation. The most common implement utilized is the donut ring (Montoya et al., 2009). Most players believe this accessory assists in stretching and loosening the pivotal muscles utilized when swinging a bat. The primary ideology behind the utilization of a heavy bat or donut is the “kinesthetic illusion”. This occurs when the hitters believe they are actually swinging faster after utilizing the heavier implement. Many hitters acknowledge the fact that they are not actually swinging with a higher velocity, but contain the perception of swinging faster and harder, giving them confidence in game situations (Szymanski & DeRenne, 2010).

Furthermore, the kinesthetic illusion has been evaluated in other sports. To date, no articles have reported improvements in performance. However, each of the subjects felt as if their performance had improved, thus exploiting the illusion. Many articles directed the kinesthetic illusion to having more of a mental effect than a physical effect on swing velocity. Nonetheless, there is no research indicating that there is an improvement in subsequent swing velocity after performing a warm-up with heavier than normal implements (Southard & Groomer, 2003).

Similar to the lighter than normal implement, the heavier implements can display a PAP phenomenon. Research has revealed that when using near maximal intensities and loads subsequent efforts elicit the same amount of work, even when altering loads (Young et al., 1998). When a hitter performs maximal effort swings with the added weight, the amount of motor units recruited is increased. Once returning to the normal weighted bat the same amount of motor units are utilized to swing the bat. With an increase in motor unit recruitment and a significantly lower bat weight, the hitter hopes to increase their bat velocity by displaying same amount of velocity and strength needed for a heavier bat (Szymanski et al., 2011a).
The utilization of heavier than normal bats while warming up continues to be heavily disputed. Almost identical to the lighter than normal implement warm-up, heavier than normal implements have the capability to negatively impact the hitters swing. When using a heavier than normal bat, the hitter’s non-related musculature compensates for the lack of hitting musculature in order to get the bat through its normal path. The hindering effects are more noticeable with the upper body rather than the lower body (Escamilla et al., 2009b). The lower body can handle the increase in the amount of weight; however, the upper body, especially the limbs, cannot take the increase in weight. This leads to a negligible effect on the hitter’s kinematics and swing path (Milanovich & Nesbit, 2014).

**Periodized training to enhance swing velocity.** With the increase in awareness of how physical attributes relate to successful sport performance, the primary focus has shifted in strength and conditioning programs designed for baseball and softball players. General consensus reveals that enhancing a batter’s strength and power shows similar increases in swing velocity. These increases have been examined and noticed from prepubescent to professional athletes (DeRenne et al., 1996; Fry et al., 2011; Hoffman et al., 2009).

Various strength and conditioning programs have revealed success for enhancing swing velocity. These programs can be categorized into general, specific, and special training programs (Baechle & Earle, 2000; Bompa & Haff, 2009; Szymanski, 2007). General programs aim to increase or enhance the skeletal muscle contraction capabilities. These exercises are composed primarily of compound multi-joint movements targeting large and powerful muscles (Szymanski, 2007). Specific programs coincide highly with the principle of specific adaptation to imposed demands, or SAID principle. These movements are directed towards movements encountered during the sport. The last modality of training implemented is specialized training. This
implementation combines generalized and specific training within the same training cycle. This phase of training is used typically when athletes are trying to taper or peak for optimal sport performance. This consists of periods of training that are directed towards power development and fatigue management (Baechle & Earle, 2000; Bompa & Haff, 2009).

Currently, strength training programs directed for baseball and softball have focused on training for hypertrophy and strength adaptation by increasing muscular size and contractile capabilities. These programs suggest the use of free weights and barbells to develop bat power and velocity (Ebben, Fotsch, & Hartz, 2006). Strength training programs that involve the use of free weights while implementing compound exercises tend to create a more profound stimulus when compared to isolation and single-joint movements (Baechle & Earle, 2000). Programs that are directed toward multi-joint compound movements have revealed significant increases in swing velocity (Szymanski et al., 2007). One source noticed that compound lower body exercises, such as squat variations, lunge variations, and power clean variations, tend to result in the most significant improvements (Ebben et al., 2005).

Recently, an investigation evaluated the relationship between physiological variables and bat velocity. This investigation utilized strength training three days a week for twelve weeks. The program consisted of six to eight compound exercises each day. Pre- and posttest differences were recorded in each physiological variable assessed. Each subject in the resistance training group revealed an increase in bat velocity (Szymanski et al., 2010b).

Furthermore, programs implementing isolation exercises or exercises using machines have revealed minimal effects. The common notion that forearm strength and bat velocity are highly related has been investigated multiple times (Giardina, Leslie, Raridon, & Zimmer, 1997; Hughes et al., 2004; Szymanski et al., 2006). The primary mechanism behind this premise is that
with the increase in total strength there is a concomitant increase in forearm strength, specifically grip strength. This is where the misconception of forearm strength and swing velocity was engendered. Examining the effect of small muscle training (forearm, wrist, and hand muscles) on baseball hitting performance has been examined extensively. The most recent study revealed that there were no significant improvements noted between pre- and posttest groups (Szymanski & DeRenne, 2010).

Plyometric exercise programs have also received increased attention. Plyometric exercises have been noted to be merely similar to hitting. Specifically a quick and explosive movement executed with as much power as possible. Thus far, programs utilizing lower body plyometric exercises have resulted in improvements of power (Ebben et al., 2005, 2006; Klatt, 1992). Exercises directly related to improving this variable are box jumps, broad jumps, cone jumps and lateral bounds (Bishop & McFarland, 1993; Chu, 1998).

Non-traditional exercise programs have also attempted to enhance bat velocity. An investigation examined the effects of vibration training and exercise order on bat velocity. The only related result of the investigation with the current investigation was leg strength and bat velocity display a significant relationship, leading to the conclusion that improving leg strength could enhance bat speed (Reyes et al., 2010).

An additional investigation examined the effects of hydro-resistance training on swing velocity. This constituted of subjects swinging bats in shoulder deep water as the other group performed swings on dry land. Significant decreases were reported for both the dry land and submerged group. The investigators speculated that decreases were imposed from accessory resistance training programs. However, an additional reason could be that the submerged group
didn’t abide by the specificity principle. Thus, swings underwater could have additionally been altered in a negligible manner attributed to swing mechanics (Stuempfle et al., 2004).

**Assessment of Power via Vertical Jump**

Power has been delegated a pivotal attribute to sport performance for quite some time (Shetty, 2002). Power can be determined by examining the amount of time it takes to execute a certain activity or calculating the sum of force and velocity (Muehlbauer, Gollhofer, & Granacher, 2013). Generally, these activities are very quick in duration, ranging from less than a second to several minutes (Coburn, 2012). Though power can be calculated for events lasting several minutes, multiple sources have reported that using lighter weights while directing focus on the rate at which a certain task is executed displays the most power generated (Baechle & Earle, 2000; Bompa & Hoff, 2009). Nonetheless, power measurement can provide sport participants pivotal information regarding successful sport performance (Shetty, 2002).

The selected modality for assessing power for this investigation is the vertical jump. This method is versatile, simple, and relatively easy for participants to complete (Buckthorpe, Morris, & Folland, 2012; Burr, Jamnik, Dogra, & Gledhill, 2007). Vertical jump has been deemed an efficient measure for measuring sport attributes back to the early 1900s (Sargent, 1921). In agreement to the aforementioned study, a similar investigation revealed vertical jump height is highly related to maximal power (Dowling & Vamos, 1993). In relation to the proposed study; an investigation revealed a positive correlation ($r = 0.508$) between vertical jump and power while using a force plate (Considine & Sullivan, 1973). Vertical jump to assess maximal power was also selected to best replicate the demands of swinging a bat and is routinely used to assess performance within baseball and softball athletes (Ebben et al., 2005; Spaniol, 2009). The average swing takes about 300-500 milliseconds (Wilson et al., 2012). That duration establishes
baseball and softball swings to be completely anaerobic in nature. Therefore, a measure that allows similar imposed demands is the vertical jump. An older investigation revealed that when assessing power in aerobic and anaerobic athletes, that anaerobic athletes displayed more power when utilizing the vertical jump test when compared to 15 second jump test (Papunen, 1984). This bolsters the selection of the vertical jump as the measure utilized to quantify power for the athletes in this investigation.

In the selected population, vertical jump has been routinely used to distinguish differences between players. Results of a vertical jump investigation revealed that baseball players that were in the major leagues had significantly higher values when compared to their minor league counterparts. Additionally, the study revealed that a majority of the professional major league baseball teams utilize vertical jump as a performance measure (Ebben et al., 2005). Distinguishing professional and minor league players by way of vertical jump results could indicate a significant relationship between performance and vertical jump height (Hoffman et al., 2009).

However, a study from a few years ago attempted to evaluate the relationship between power and performance in collegiate softball players. This study opposes the previously mentioned investigations by determining power by means of vertical jump, and revealed no significant relation to softball performance. It should be noted that the sample size for this investigation was relatively small (n=10) in comparison to the aforementioned investigations that revealed significant relationships (Nimphius, McGuian, & Newton, 2010). Nonetheless, there is a paucity of literature investigating the relation of power with baseball and softball performance. To date, the prevalence of literature directed at examining throwing velocity to maximal power is more common than swing velocity and maximal power.
Other sports have contributed to the body of literature in regards to power and sport performance. Two investigations looked to examine the relation of power and soccer performance (Lopez-Segovia, Marques, Tillar, & Gonzalez-Badillo, 2011; Quagliarella, Sasanelli, Belgiovine, Moretti, & Moretti, 2011). One investigation looked to examine power output generated via vertical jump in prepubescent male soccer players, and revealed performance could not be estimated using a regression analysis (Quagliarella et al., 2011). However, a similar study determined that vertical jump is an important factor for predicting performance. This investigation suggested that vertical jump characteristics can be displayed in many aspects of soccer and other sports, which is plausible when discussing the relationship between variables (Lopez-Segovia et al., 2011). In congruence to the previously mentioned study, an additional investigation determined that power expression determined by vertical jump can be a profound indication of successful sport performance. The aforementioned investigation examined twelve male basketball athletes and determined that higher vertical jump resulted in higher in-game performance measures (Alemdaroğlu, 2012).

Summary

Though several attempts to enhance swing velocity have been made, there has been little research determining what variable is most associated with swing velocity. These variables include warm up routines, grip strength, upper-body strength/power, lower-body strength/power and several additional variables. However, the kinematics of a baseball swing exemplifies a powerful movement completed in very little time. Currently, the most efficient measure of power similar to swinging is the vertical jump and has been used to quantify and predict successful performance within the baseball and softball populations. By evaluating the relationship of vertical jump and swing velocity within the current study, training to improve swing velocity
could become more lucid by further examination of vertical jump and its relationship with swing velocity.
CHAPTER III
METHODOLOGY

The aim of this study was to determine the strength of association between maximal leg power and swing velocity. One session encompassed evaluating subjects’ anthropometric measures, maximal leg power, and maximal swing velocity. Statistical interpretation of the collected data evaluated the relationship between maximal leg power and swing velocity in collegiate athletes.

Subjects

Recruiting for the current investigation commenced with the approval of the Institutional Review Board at the University of Central Missouri, Warrensburg, Missouri. Collegiate baseball and softball players from the University of Central Missouri participated in the investigation. Players labeled ‘pitcher only’ were excluded from the investigation. Each subject was instructed to use their preferred game bat. Subjects included both right and left-handed hitters; subjects who were ‘switch hitters’ were given the opportunity to swing from both sides of the plate. Additionally, all subjects had at least one year of previous periodized strength and conditioning experience and were injury free.

Data Collection Procedures

Prior to recruiting members of the University of Central Missouri baseball and softball teams, members of the investigation team requested permission to convene with the head coaches of the respective teams. During this meeting the investigation team elaborated about the direct application of the investigation and sought affirmation to work with the players. Following the approval from the teams’ coaches, subjects were asked to schedule one thirty-minute session.
to evaluate maximal leg power and swing velocity. Before each testing session, the Kistler force plate and Qualisys Motion Capture collection technology was calibrated. Upon arrival subjects were provided with a detailed description of the data collection procedures as well as the implications of the current study. Subjects were then required to sign an informed consent form to complete the study.

After subjects signed the informed consent form, anthropometric measures, including height and weight, were recorded and expressed as means (±SD). Subjects were then informed about the vertical jump measurement. Three vertical jumps were performed in the Biomechanics Laboratory at the University of Central Missouri. Each attempt took place on a Kistler force plate. Subjects were instructed how to perform each trial prior to beginning the assessment. Each subject performed a vertical jump trial and was then allowed as much time as needed between subsequent trials. Following the three vertical jump trials, subjects then completed the swing velocity assessment. The participants performed their routine warm-up before hitting in game like scenarios. After the subjects performed the routine warm-up, the lead investigator placed two infrared dots on the endcap of the subjects’ bat. Subjects were then instructed to take three swings at the ball placed on a batting tee. All subjects were allowed as much time as necessary between each swing trial. During each vertical jump and swing trial the movements were recorded and later evaluated for inclusion in further statistical analysis.

Instrumentation

Anthropometric measures. Height was assessed using a TECA stadiometer and recorded in centimeters. Weight was assessed using a BEFOUR digital scale and recorded in kilograms.
**Vertical jump.** Vertical jump was assessed using a Kistler force plate. Prior to measuring vertical jump the subjects were instructed to perform each trial positioned directly on the center of the force plate. Subjects were provided instructions on how to perform each trial and were instructed to give maximal effort for all three trials. After each trial, subjects were allowed as much time as necessary to perform a maximal effort in the subsequent trials. After the participants completed the jumps, the mean height was determined and used for data interpretation. Vertical jump height was calculated using Galileo’s free falling equation \( d_v = 4.9(t/2)^2 \). Each vertical jump height was recorded in meters.

**Swing velocity.** Swing velocity was assessed using Qualisys Motion Capture infrared technology. Prior to swing velocity assessment, subjects were informed to complete their on deck routine. Once the on deck routine was completed, two infrared dots were placed on the endcap of the subjects’ bat and a ball was placed on the batting tee at the desired height of the subjects. Subjects then completed three swings at maximal effort. Once the swing trials were completed the dots were removed from the subjects’ bat. After completion of the trials mean velocity was determined and used for data interpretation. Each swing trial was recorded in meters per second.

**Data Analysis**

Each vertical jump trial and swing trial was captured utilizing Kistler force plate and Qualisys infrared technology, respectively. The mean of each subject’s vertical jump and swing trials was determined. Once the means were determined, Pearson’s correlation coefficient was implemented to determine the relationship between vertical jump and swing velocity. Coefficient of determination was also utilized to determine the amount of variance that is shared between swing velocity and vertical jump.
CHAPTER IV
RESULTS

The methods of this study were designed to evaluate the hypothesis that maximal leg power and bat swing velocity contain a relationship in collegiate athletes. Three swing velocity and vertical jump measurements were obtained utilizing Qualisys motion capture technology for each subject and were later used for statistical interpretation and evaluation of the current hypothesis.

Subject Means

Subject \((n=34)\) mean \((\pm SD)\) age, height, and weight were 20.35 years \((\pm 1.34)\), 176.84 cm \((\pm 9.77)\), and 77.66 kg \((\pm 13.92)\), respectively. Mean measures for baseball \((n=17)\) and softball \((n=17)\) were 20.65 years \((\pm 1.22)\), 184.81 cm \((\pm 4.07)\), 88.28 kg \((\pm 9.83)\) and 20.06 years \((\pm 1.43)\), 168.87 cm \((\pm 6.74)\), 67.03 kg \((\pm 7.96)\), respectively. Vertical jump means for total population, baseball, and softball were 41.50 cm \((\pm 10.36)\), 49.89 cm \((\pm 6.05)\), and 33.11 cm \((\pm 5.92)\), respectively. Swing velocity means were 33.98 m/s \((\pm 4.93)\), 38.65 m/s \((\pm 1.39)\), and 29.56 m/s \((\pm 2.08)\), respectively. (see Tables 4.1-4.3).

Statistical Evaluation

Pearson’s correlation revealed a high \((r=0.823)\), moderate \((r=0.520)\), and non- \((r=0.036)\) linear relationships for total population, baseball, and softball players when measuring the relationship of vertical jump and swing velocity. Coefficient of determination was also calculated for each group and was \(R^2=0.677, 0.270, \) and \(0.001\), respectively (see Table 4.4).
Table 4.1

*Means for Total Sample (n=34)*

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<thead>
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<th>Std. Deviation</th>
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<tbody>
<tr>
<td>Age (yr)</td>
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<tr>
<td>Height (cm)</td>
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<tr>
<td>Weight (kg)</td>
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<tr>
<td>Vertical jump (cm)</td>
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<td>Swing velocity (m/s)</td>
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Table 4.2

*Baseball Players (n=17)*

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</thead>
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</tr>
<tr>
<td>Height (cm)</td>
<td>184.8</td>
</tr>
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<td>Weight (kg)</td>
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<td>Vertical jump (cm)</td>
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<td>Swing velocity (m/s)</td>
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Table 4.3

*Softball Players (n=17)*

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</thead>
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<tr>
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</tr>
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<td>Weight (kg)</td>
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<td>Vertical jump (cm)</td>
<td>33.1</td>
</tr>
<tr>
<td>Swing velocity (m/s)</td>
<td>29.6</td>
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</table>

Table 4.4

*Statistical Evaluation of Variables*

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<th></th>
<th>r</th>
<th>(R^2)</th>
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</thead>
<tbody>
<tr>
<td>Total sample (n=34)</td>
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<td>0.677</td>
</tr>
<tr>
<td>Baseball players (n=17)</td>
<td>0.520</td>
<td>0.270</td>
</tr>
<tr>
<td>Softball players (n=17)</td>
<td>0.036</td>
<td>0.001</td>
</tr>
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</table>
CHAPTER V
DISCUSSION

The primary objective of this study was to examine the relationship between maximal leg power and swing velocity. A strong relationship was discovered when examining the entire population; however, when evaluating baseball and softball individually a moderate and poor relationship were determined. The findings of this study indicate that maximal leg power could play a significant role in swing velocity. Moreover, maximal leg power could assume a significantly greater role in the hitting aspect of baseball when compared to softball.

Although the baseball athletes displayed a stronger relationship between the two variables, utilizing a test that measures rotational or angular power may have displayed a stronger relationship in both groups. A vertical explosive movement doesn’t replicate the imposed demands for baseball in regards to hitting. However, a similar movement may be utilized when playing defense trying to catch a ball. Nonetheless, several pieces of literature have delegated the swing as a ‘highly rotational’ movement (Adair, 1995; Welch et al., 1995). Adhering to the principle of specificity would utilize a transverse plane measure to assess power and would be most similar to performing a swing thus providing a stronger relationship.

Within the literature two resistance training programs have utilized a similar movement in an attempt to replicate swing velocity. The movement is termed the medicine ball hitter’s throw (MBHT) and involves subjects assuming their batting stance while holding a medicine ball (1kg) at shoulder height with hands evenly spaced on the medicine ball. When the subject was ready they were instructed to duplicate a swinging motion as similar as possible to their swing
motion during games, then let go of the ball, attempting to throw it as far as possible. In the reviewed literature, this was the most identical movement assessed when measuring power associated with baseball and softball. This test has also undergone repeated day testing for statistically significant differences and revealed a statistically significant correlation ($r=0.96, p<0.001$) (Szymanski, Szymanski, Bradford, Schade, & Pascoe, 2007; Szymanski et al., 2007b). This procedure has been evaluated for both baseball and softball collegiate athletes and has displayed consistent measures of moderate associations with swing velocity ($r=0.66$) (Pare, 2008).

Although the entire sample revealed a strong correlation ($r=0.823$), once the population was divided into baseball and softball a weaker relationship was found ($r=0.520$ & $r=0.036$). The total sample revealed an expected relationship between vertical jump and swing velocity. However, to the best of the investigation team’s knowledge, this was the second study examining baseball and softball performance measures concurrently. The results of the similarly designed study revealed associations between strength measures and softball players, but not baseball players. Test selection may have been responsible for the different results between studies. That investigation utilized upper body measures where the current investigation utilized a lower body measure (Weimer, Halet, & Anderson, 2007).

To date, one investigation has examined the relationship between leg power and swing velocity in collegiate baseball athletes while using the vertical jump to quantify power in subjects. When assessing the relationship between vertical jump and bat velocity a moderate ($r=0.591$) relationship was determined. The relationship determined from that study was similar to the results associated with the baseball team in this study ($r=0.520$), thus bolstering the
relationship between vertical jump and swing velocity in collegiate baseball players (Spaniol, Bonnette, Melrose, & Bohling, 2006).

Currently, there are only three investigations outside this project examining the relationship between swing velocity and leg power in collegiate softball athletes (Albert, Szymanski, & Stanley, 2008; Tiechler, 2010; Till et al., 2011). In congruence to the findings of this study, none of those studies revealed significant relationships between leg power and swing velocity. In fact, two of the investigations utilized a similar movement to quantify leg power in its athletes and revealed similar correlation values to the current study (Tiechler, 2010; Till et al., 2011). These findings reinforce the notion that leg power isn’t associated with swing velocity in collegiate softball athletes.

The coefficients of determination values were also much higher than hypothesized. These values were calculated at \( R^2 = 0.677, 0.270, \) and \( 0.001 \) for the total sample, baseball athletes, and softball athletes, respectively. The sample as a whole makes sense; there was a trend that showed the lower the vertical jump lower swing velocity. Several investigations, regardless of baseball or softball, have deemed variables such as grip strength, upper-body strength, lower-body strength, lower-body power, lean body mass, torso rotational strength, angular hip velocity, and full body strength to be significantly related to bat swing velocity and all could have played a role in the amount of variance revealed between variables (Szymanski, 2007).

One assumption could be the baseball players had more lean body mass than the softball players and could generate higher swing velocities and vertical jumps. Although the measure of lean body mass was outside the scope of this study, previously conducted investigations have revealed that lean body mass plays a significant role in bat velocity. This relationship has been evaluated in baseball and softball populations and has consistently revealed moderate to strong
relationships ($r=0.51-0.89$) (Albert et al., 2008; Spaniol et al., 2009b). This could explain the stronger relation between variables for baseball rather than softball due to the belief that men tend to be larger, carry more lean mass, and display more absolute muscular power and strength (Baechle & Earle, 2000; Coburn & Malek, 2012; McArdle, Katch, & Katch, 2014). Perhaps the inclusion of measuring lean body mass may have displayed a stronger relationship, thus being a better predictor of swing velocity.

An additional reason for the differences noticed within the relationship of the variables could be the nature of the game. Softball has transitioned into a game of strategy and the notion of hitting for power is diminishing. Since the introduction of the slap hit in softball, the prevalence of hitters using this strategy has increased. The slap hit allows the batter to get a running start while swinging the bat, thus attempting to quicken the time from home plate to first base, thus allocating the focus to speed and agility instead of power for their offensive production. With a shift towards ‘small ball’ in the game of softball, baseball conversely reiterates the importance of hitting for power. Since the steroid era of baseball in the early 2000s, the demand for hitting home runs and offensive production has steadily increased. Furthermore, the emergence of strength and conditioning programs within each collegiate and professional organization have shifted their focus toward making their players as strong and powerful as possible in an attempt to improve offensive production and player development (Ebben, Hintz, & Simenz, 2005).

Though several different instruments have been used for kinematic analyses in collegiate baseball and softball athletes, Qualisys Motion Capture technology revealed nearly identical results to the reviewed literature. The bat swing velocity means for the investigations previously reviewed were determined to be 38.26m/s and 29.41m/s for baseball and softball players (Flyger
et al., 2006; Fry et al., 2011; Hughes et al., 2004; Spaniol et al., 2006; Szymanski et al., 2009, 2011; Teichler, 2010). This investigation yielded means for baseball and softball players at 38.65m/s and 29.56m/s, reinforcing that swing velocity trials were measured accurately and are consistent with previous investigations. However, when examining the values obtained for vertical jump from this investigation and comparing them with collegiate baseball and softball athlete norms, the values were much lower. The vertical jump means for baseball and softball from this study were 50.34±5.9cm and 33.11±5.92cm when compared to the norms determined at 58cm and 44cm (Baechle & Earle, 2000). One assumption hypothesized is that each athlete didn’t perform the vertical jump trials with maximal effort, leading to profound differences between means. An additional hypothesis could be that the measure utilized to obtain vertical jump may have been different than the procedure(s) to develop the normative values.

An additional hypothesis for the differences associated with leg power and swing velocity may be related to swing time. It has been hypothesized that collegiate baseball and softball players have 450ms and 200ms to analyze the pitch and decide to swing before the pitched ball reaches the hitter (Flyger et al., 2006; Wilson et al., 2012). With that being said, a softball player may have a shorter swing time to be able to adjust to a pitch being received in almost half the time. The baseball players also may have recorded longer swings, which would assist in the development of maximum velocity. A previous investigation revealed the notion that decreased swing time is typically associated with a lower swing velocity, and longer swing times are coupled with a higher swing velocity (Lund & Heefner, 2005).

It must be noted that the schedule of testing could have also factored into testing of the athletes. Testing for both sports was started and finished within ten days; however, the testing was performed in season. Nonetheless, a previous investigation examined the length of season on
performance measures within the population and determined that best measures are taken prior to the season (Szymanski et al., 2010). Although the means of swing velocity in relation to similar projects were almost identical, those investigations did not specify when the assessments were completed. Furthermore, the players were instructed to participate in the scheduled assessments without undergoing any practice or weight training sessions beforehand. However, residual fatigue was not accounted for from previous travel, practice, games, or weight training sessions and could have contributed to the testing results.

Conclusion

The result of this study provides a significant relationship between maximal leg power and swing velocity in collegiate athletes. However, when the data was evaluated between baseball and softball, these variables provided a moderate relationship with baseball and no relationship with softball swing velocity.

Recommendations

Strength and conditioning professionals should direct programs toward increasing strength, power, and lean body mass to enhance offensive production and player development. Although college baseball players displayed a stronger relationship between variables in comparison to college softball players, both groups should focus on improving lean body mass since there is a consistent significant relationship displayed across both populations. Further investigations should be conducted within the collegiate softball population to determine which variables assume moderate to significant roles in swing velocity. Furthermore, future swing velocity investigations should also try to collect as much data from the swing as possible. This could include, but is not limited to, handle/hand velocity, barrel velocity, swing path, swing time, etc. This could potentially provide insight on the variance recorded between populations.
References


APPENDIX A
HUMAN SUBJECTS APPROVAL

10/5/2015

Ryan Miller

Dear Ryan Miller:

Your research project, 'The effects of various weighted bat warm up on bat swing velocity', was approved by the Human Subjects Review Committee on 10/2/2015. This approval is valid through 10/2/2016. Your informed consent is also approved until 10/2/2016.

Please note that you are required to notify the committee in writing of any changes in your research project and that you may not implement changes without prior approval of the committee. You must also notify the committee in writing of any change in the nature or the status of the risks of participating in this research project.

Should any adverse events occur in the course of your research (such as harm to a research participant), you must notify the committee in writing immediately. In the case of any adverse event, you are required to stop the research immediately unless stopping the research would cause more harm to the participants than continuing with it.

At the conclusion of your project, you will need to submit a completed Final/Renewal Report to this office via Blackboard. You must also submit the Final/Renewal Report if you wish to continue your research project beyond its initial expiration date.

If you have any questions, please feel free to contact me.

Sincerely,

Janice Putnam, Ph.D., RN
Research Compliance Officer
putnam@ucmo.edu
APPENDIX B
HUMAN SUBJECTS AMMENDMENT

11/30/2015

Ryan Miller

Dear Ryan Miller:

Your amendment for your project titled, 'The effects of various weighted bat warm up on bat swing velocity', was approved by the Human Subjects Review Committee on 11/30/2015. Your informed consent is also approved until 10/2/2016.

Please note that you are required to notify the committee in writing of any changes in your research project and that you may not implement changes without prior approval of the committee. You must also notify the committee in writing of any change in the nature or the status of the risks of participating in this research project.

Should any adverse events occur in the course of your research (such as harm to a research participant), you must notify the committee in writing immediately. In the case of any adverse event, you are required to stop the research immediately unless stopping the research would cause more harm to the participants than continuing with it.

At the conclusion of your project, you will need to submit a completed Final/Renewal Report to this office via Blackboard. You must also submit the Final/Renewal Report if you wish to continue your research project beyond its initial expiration date.

Sincerely,

Janice Putnam, Ph.D., RN
Research Compliance Officer
putnam@ucmo.edu

Protocol Number: 299
APPENDIX C
SUBJECT INFORMED CONSENT

CONSENT FORM

Identification of Researchers: This research is being done by Ryan Miller and Dr. Strohmeyer, a professor. We are with the Department of Nutrition and Kinesiology at the University of Central Missouri.

Purpose of the Study: Identify the relationship between maximal leg power and swing velocity.

Request for Participation: We are inviting you to participate in a study identify the relationship between maximal leg power and swing velocity. It is up to you whether you would like to participate. If you decide not to participate, you will not be penalized in any way. You can also decide to stop at any time without penalty. You may withdraw your data at the end of the study.

Exclusions: Subjects must be 18-23 years of age, and an active member of the University of Central Missouri baseball or softball team.

Description of Research Method: You will partake in one trial that will take no longer than 30 minutes. During this time, you will be asked to perform three swings with your normal bat dotted up using Qualisys Motion Analysis. Once the swing trials are complete you will perform three vertical jump trials positioned on the Kistler Force platform.

Privacy: All of the information we collect will be confidential. We will not share your information individually but only as an aggregate of the data collected as a group average. All data will be stored in a locked office in a locked file or password protected computer. Upon completion of the study destruction of electronic data and consent forms will follow the University of Central Missouri policy.

Explanation of Risks: No more risk associated with study than in everyday life. Each day players successfully hit baseballs without injury; there is no more risk than a typical baseball or softball practice.

Explanation of Benefits: You will benefit from participating in this study by learning your swing velocity. You will also further your knowledge about the relationship between leg power and swing velocity

Questions: If you have any questions about this study please contact Ryan Miller, I can be reached at rmmiller@ucmo.edu. If you have any questions about your rights as a research participant, please contact the Human Subjects Protection Program at (660) 543-4621.

I have read this letter and agree to participate.

Signature: _______________________________
Print Name: ______________________________
Date: ______________________________