ABSTRACT

ANALYSIS OF HIP AND SHOULDER ROTATION AND LINEAR BALL VELOCITY IN THE TRANSVERSE PLANE DURING A HANDBALL POWER SERVE

The purpose of this research was to analyze angular velocities of the hip and shoulders in the transverse plane and resultant linear velocity of the ball during a handball power serve. There has been little research of any type in court handball and no known research reports involving the biomechanics of handball. Eighteen trained, competitive handball players, from the professional division to the B class amateur division, served 10 legal serves in a mock court setup. The serve patterns were digitized and angular velocities of hip and shoulder rotation were compared to ball velocities. The primary findings showed that hip rotation preceded shoulder rotation, the shoulders rotated at a higher angular velocity than the hips (429.796 deg/sec ±154.067, 801.237 deg/sec ±130.254 respectively), and better players achieved higher maximum and average linear ball velocities. Hip rotation was not significantly correlated with ball velocity, but shoulder rotation had a significant positive correlation (r = .206) to ball velocity. This study is the first to confirm the kinetic chain pattern within the handball power serve and to accumulate kinematic data on handball power serves.

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May 2012
ANALYSIS OF HIP AND SHOULDER ROTATION AND LINEAR BALL VELOCITY IN THE TRANSVERSE PLANE DURING A HANDBALL POWER SERVE

by

Adam Coronado

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Arts in Kinesiology in the College of Health and Human Services California State University, Fresno
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CHAPTER 1: INTRODUCTION

Handball is a court sport played throughout the United States. It is the oldest game played with a ball in which either hand or fist may be used to hit the ball (USHA, n.d.). The United States Handball Association (USHA) named handball “The Perfect Game,” because of the simple equipment needs and the difficult nature of playing the sport. Players are drawn to handball because it is an intense, fast-paced game that requires agility, speed, endurance, and ambidexterity (Graetzer, Shultz, Chen, & Jones, 1994). Even though handball requires a relatively high level of fitness and complex movements, (e.g., hitting the ball with either hand), research into the sport is minimal and the biomechanics of human movement of handball is undocumented. This study was designed to investigate the kinematics of the handball power serve.

Handball brings a challenge to the lives of many recreational athletes, but can also appeal to prime athletes of other sports in their off-season. The hand-eye coordination and various athletic challenges in handball create a sport that athletes use to stay in shape during the off-season (Ballard, 2011). Jake Plummer, a former NFL quarterback, used handball to keep up his cardiovascular endurance and footwork during the off season (Ballard, 2011). Baseball player Babe Ruth used handball during his early years in New York to stay in shape during the off-season (Montville, 2006). The challenge of handball appeals to a variety of people from differing athletic backgrounds. Actors like Ed O’Neill of Married with Children and Modern Family fame played handball (USHA, n.d.).

Handball manages to garner the attention of some famous athletes and numerous local players, but is still an obscure sport to the general public. Contemporary sports like baseball, football, or golf are more common within
society, and there is a large market for new information on mechanics, equipment, or apparel. Research tends to focus on these sports to make improvements on existing knowledge with the possibility of prestige or monetary compensation for the next big improvement. With the improvement in high definition television and web casting, handball is beginning to reach more of the general public. The United States Handball Association (USHA) and the World Players of Handball (WPH) are focused on marketing handball to the general public. As the number of amateur players begins to grow, research into handball also needs to expand. This study aims to begin a foundation of information on the biomechanics of handball, more specifically in the swing. The movement of the handball swing is visually similar to other ballistic sport movements: e.g., baseball pitch, baseball swing, golf swing, and the tennis forehand. The handball swing requires a complex movement that incorporates the theory of the kinetic chain to generate force from the legs up through the trunk and ending in the hand. The kinetics or external force applied to the handball requires the research to focus on the corresponding kinematics or pattern of movement with respect to time. The baseball pitch requires muscular fitness, coordination, and flexibility (Stodden, Fleisig, McLean, & Andrews, 2005; Wilk, Meister, Fleisig, & Andrews, 2000). The handball swing requires a similar complex motion in overhead, sidearm, and underarm strikes, but with equal skill from both hands. As a result, handball players are subject to a high amount of joint stress to the upper and lower body, based on the need to be efficient with their non-dominant side as well as their dominant side.

Research into the biomechanics of a handball strike is integral to understanding the velocities, muscle activation, movement patterns, and stresses placed on the tissue and joints of the body. Biomechanics research in throwing and striking sports (e.g., baseball, tennis, and golf) suggest that proper mechanics,
probable injury sites, and proper fitness programs can be understood and
developed (Davis et al., 2009; Meister, 2000; Wilk et al., 2000). Handball strikes
cross multiple movement planes, so that isolating and filming handball swings
during play is difficult. To begin investigative research in handball, it was
determined that a handball strike needed to be both simple to replicate among
multiple participants and required a high degree of strength and coordination. The
handball power serve was selected, because this specific handball swing takes
place in a 5-foot wide server’s box, the small area decreases set-up time and
calibration of cameras due to a participant’s physical size and/or serving style.
The handball power serve meets the criteria for coordination and strength, because
the server must strike the ball at the knees and with enough force to clear the fault
line, 20 feet from the front wall, to be a legal serve.

The serve in handball is an integral part of the game. It is the initial strike
of the game, and like tennis, provides an advantage to the server from the start.
The serve in handball is the only time the ball has little to no linear motion and the
server has a 5-foot box to generate the power to put the ball in play. The handball
power serve is one of the first serves a handball player learns and remains a tool in
their game for the rest of their playing careers. As the name implies, a handball
power serve is focused on high velocity and low trajectory. In this part of the
game, following Newton’s second law of motion, the server must provide all the
force to accelerate the handball. As a result, the power serve places a substantial
stress to the muscles and joints of the server and is considered the most fatiguing
stroke in the game.

The handball power serve follows the concept of the kinetic chain. A server
strives to successfully exploit the kinetic chain to provide maximum velocity with
appropriate sequence and timing of movements. Parameters of the kinetic chain
needed to produce these results are sequential increases in rotational velocities of each segment in the chain with appropriate timing between maximum rotations to allow a transfer of momentum to the next adjoining link. Like a pitcher’s fastball, the purpose of the power serve is to strike a high velocity serve that provides the receiver a short amount of time to setup, select a shot, and execute the action. The faster the power serve the less time their opponent will have to react. Ideally, the server will hit a power serve to either side of the court with such high velocity and low trajectory that the ball will bounce twice in the returnee’s box before it reaches the back wall. If the serve is hit too softly an opponent will have time to react. If the serve is too high it will careen off the back wall and their opponent will now be in a favorable position. So like baseball, a well hit power serve sets up the other serves to be more effective to keep an opponent from predicting a serve. The importance of the power serve at all levels of play is well established within the sport. Investigation is needed to quantify the parameters of the kinetic chain in a handball power serve to develop standardized instruction.

**Purpose**

The purpose of this study was to measure the angular velocity within the transverse plane of shoulder and hip rotations during a handball power serve. This study also analyzed and correlated these angular velocities to the linear velocity of the ball.

**Research Questions**

1. Does hip rotation precede shoulder rotation during a handball power serve?
2. Does the shoulder rotate at a higher velocity than the hips?
3. Will better players achieve higher hip and shoulder angular velocities?
4. Is there a positive relationship between hip and shoulder angular velocity and linear velocity of the ball?

**Hypothesis**
1. Hip rotation will precede shoulder rotation during a handball power serve.
2. The shoulder will rotate at a higher angular velocity than the hips.
3. Better players will achieve higher linear ball velocities.
4. Faster hip and shoulder rotation will be associated with faster ball velocity.

**Significance of Study**
The results of this study could improve instruction of proper mechanics in handball. Understanding the kinetic chain in a handball power serve can lead to early detection of mechanical errors, early development of effective movement patterns in younger players, or development of new techniques. Proper mechanics can lead to a higher quality of play and reduction in injury occurrence (Aguinaldo, Buttermore, & Chambers, 2007; Aguinaldo & Chambers, 2009; Fleisig, Barrentine, Zheng, Escamilla, & Andrews, 1999; Gulgin, Armstrong, & Gribble, 2009; Stodden et al., 2005; Stodden, Fleisig, McLean, Lyman, & Andrews, 2001; Werner et al., 2010; Wilk et al., 2000.) If the hypotheses are supported then current research in other sports (baseball, golf, or tennis) may be applied to handball instruction and mechanics.
Delimitations
1. The subjects were male handball players between the ages of 18 and 40.
2. The handball players were right handed (Werner et al., 2010).
3. The handball players were currently competing in Professional, Qualifier, Open, A, or B level divisions.
4. Data was only counted on legal serves.

Limitations
1. The study assumed the subjects were putting forth a competitive effort.
2. Variations in individual mechanical performance of the power serve could not be controlled.
3. The study assumed that each player was at an adequate state of practice to produce an effective power serve.

Definition of Terms
For the purpose of this study, these terms are defined as follows:
1. Angular Velocity – rate of change in the angular position or orientation of a line segment, calculated as \( \omega = \theta/\Delta t \), where \( \omega \) represents angular velocity, \( \theta \) represents angular displacement, and \( \Delta t \) is the change in time (Hall, 1999).
2. Biomechanics – application of mechanical principles in the study of living organisms (Hall, 1999).
3. Court Dimensions - 40 feet long, 20 feet wide, and 20 feet tall. The server is set-up in the service box between 15 and 20 feet from the front wall (USHA).
4. Kinematics – study of the description of motion, including considerations of space and time (Hall, 1999).


6. Kinetic Chain – The concept of energy being generated from the lower larger segments of the body and that energy being transferred up the body maintaining the momentum energy and building upon it. The end result is to transfer all the stored energy to the most distal segment i.e., the hand (Wilk et al., 2000).

7. Moment of Inertia – inertial property for rotating bodies representing resistance to angular acceleration; based on both mass and the distance the mass is distributed from the axis of rotation (Hall, 1999).

8. Newton’s Second Law of Motion – A force applied to a body causes an acceleration of that body of a magnitude proportional to the force, in the direction of the force, and inversely proportional to the body’s mass, represented as \( F = ma \), or Force = (Mass) * (Acceleration) (Hall, 1999).

9. Newton’s Second Law of Motion (Angular terms) – A net torque produces angular acceleration of a body that is directly proportional to the magnitude of the torque, in the same direction as the torque, and inversely proportional to the body’s moment of inertia, represented as: \( T = I\alpha \) (Hall, 1999).

10. Server’s Box – Front service line is 15 feet from the front wall, the back service line or short line is 20 feet from the front wall. Both the front and back service lines are 20 feet wide (USHA).
11. Torque – the rotary effect of a force about an axis of rotation, measured as the product of the force and the perpendicular distance between the force’s line of action and the axis, represented as $T = Fd$ (Hall, 1999).

12. Transverse Plane – plane in which horizontal body and body segment movements occur when the body is in an erect standing position (Hall, 1999).
CHAPTER 2: REVIEW OF LITERATURE

Handball is an “open-type sport,” that incorporates locations of objects and players in a dynamic environment; another example of this type of sport is tennis. In contrast a “closed-sport” is characterized by a limited number of visual cues for the player to assess, like weightlifting. The number of variables, for example ball position, opponent position, and fatigue, involved in an “open” sport increases the difficulty in mastering the sport. In handball, anticipation and decision-making are key elements in returning a serve, overall playing strategy, and all other aspects of the game. In an attempt to focus upon one aspect of the sport, the subject of the proposed study is the handball power serve, because an effective power serve is a great offensive advantage to the server. Handball players are taught to watch their opponent’s serve and look for visual cues relative to the type and placement of serve. The higher caliber player can focus on several cues early in the serve to gain an advantage in making an effective return. The handball power serve is the fastball in a handball player’s repertoire of serves. Just like the fastball in baseball, an effective power serve will set-up other “off-speed” serves to keep an opponent from anticipating an individual serve. This variety of techniques will provide the server with opportunities to “Ace” their opponent or create a rally ending opportunity on a weak return of serve.

The handball power serve is a complex ballistic movement that requires strength, power, and coordination to execute effectively. The difficulty in executing a power serve lies in the power and timing necessary to hit the ball at a low trajectory with high velocity. Handball players frequently refer to the power serve as a high-energy serve. It is common for handball players to lose a lot of velocity on their serves in later stages of a tournament. The main reason for this
loss in velocity exhibited by most tournament players is “fatigue.” The causes and solutions to this fatigue could be inefficient mechanics, lack of physical preparation or both. It is known that efficient pitchers can maximize output (ball velocity) with the least cost (joint load) (Aguinaldo & Chambers, 2009). A handball player that can become more efficient with his or her power serve will capitalize on the advantage of a power serve over extended matches or tournament play. Although there is plenty of research in biomechanics and joint loads in other sports, there is a comparative lack of research in handball. The following review of literature is based on a variety of sports that share some similarities in the mechanics of handball.

**Kinetic Chain**

The initial investigation of a handball power serve is related to the basic physics of the movement. In handball, the hand that strikes the handball rotates through the transverse plane (Hall, 1999). This movement occurs perpendicular to the longitudinal axis of the body. This rotation produces an angular displacement ($\Theta$) of the hand from the start of the serve to impact of the handball. Ball speed is directly related to the angular velocity of the arm and hand. Angular velocity ($\omega$) is determined by the angular displacement divided by time from the start of the forward motion of the hand to ball impact. The angular velocity is a result of angular acceleration of the hand in the transverse plane. Angular acceleration ($\dot{\omega}$) is determined by taking the change in angular velocity over the change in time. Because the handball power serve is a movement about the longitudinal axis, it is acceptable to describe the angular velocity as a rotational velocity. At the point of impact between the server’s hand and the handball the rotational velocity peaks and angular acceleration of the hand declines as the ball travels on a path
tangential to the curve of the hand. The resultant linear velocity imparted upon the handball is the end purpose of the power serve.

To generate the rotational acceleration of a segment at a joint, the human body utilizes muscular tension to produce a net torque about the joint. The magnitude of the rotational acceleration is proportional to net torque generated about a joint. The human body is capable of summing up and accumulating series or torques about joints, conserving and transferring the force generated, by earlier momentum through the later moments to the hand or striking implement. The theory that describes this movement is known by many terms: summation of forces, kinetic link, or the kinetic chain (Bunn, 1972; Northtrip, Logan, & McKinney, 1983; Putnam, 1993; Welch, Banks, Cook, & Draovitch, 1995; Wilk et al., 2000). It is based on multiple throwing and striking sports that describe the kinetic chain as a sequential pattern of movement of individual body segments generating and transferring energy from the proximal segments and culminating at the distal segment of the intended action (Landlinger, Landlinger, Stoggl, Wagner, & Muller, 2010; Okuda, Gribble, & Armstrong, 2010; Takahashi, Elliott, & Noffal, 1996; Wilk et al., 2000). For example, in the golf swing, the club head is the last segment to be moved, thus has the fastest angular velocity, so the ideal golf swing is initiated by motion of the pelvis, followed by the upper trunk, upper extremity, and finally the golf club (Okuda et al., 2010).

The kinetic chain has been extensively researched in the baseball pitch. Understanding the kinetic chain has lead to advancements in pitching mechanics and strength training. For example, the rotator cuff has received a considerable amount of research, because of the high occurrence of injuries in pitchers (Fleisig, 1996; Jobe & Bradley, 1988; Meister, 2000). Researchers discovered that improper mechanics of pitching lead to a high amount of stress to the shoulder
joint, which is exacerbated by poor conditioning of those stressed muscles (Meister, 2000). Today, the rehabilitation and preventative medicine for baseball pitching concentrates on non-invasive therapy such as, stretching, flexibility exercises, and strength training (Braun, Kokmeyer, & Millett, 2009). This non-invasive therapy strengthens weak links in the kinetic chain of a pitcher decreasing stress to muscles and joints (Braun et al., 2009). Because the handball power serve is a strenuous effort that is repeated numerous times throughout a game, research into the kinetic chain of the power serve may lead to specific non-invasive techniques being applied to handball players.

Strengthening the weak links of the kinetic chain is one way a pitcher can increase his velocity (Wilk et al., 2000). A handball player or pitcher who can increase his velocity with little extraneous stress to their muscles and joints can play for an extended period of time. Additional methods of increasing velocity are a more effective transfer of momentum in the kinetic chain (Stodden et al., 2005); and by increasing muscle mass, which increases the joint forces and torques (Fleisig et al., 1999). These research findings relate to hypothesis 4; faster hip and shoulder rotations will result in faster velocities.

This thesis targeted the hip and shoulder rotation, because these body segments are integral to the generation and transfer of energy. The hip and shoulder rotation represent a significant portion of the kinetic chain, because of the mass of the segments and their anatomical link to the hand (Hall, 1999; Putnam, 1993). Trunk rotation is a positive link in the kinetic chain, because of its mass, (e.g. ~70% of body mass) and influence on shoulder rotation (Landlinger et al., 2010; Winter, 1990). Handball players have a limited serving box, 5 feet wide, so to generate high velocities the trunk must rotate first and then transfer of energy must be coordinated into the shoulder rotation. A baseball player has the same
dilemma; they need to generate high bat speeds within the confines of the batter’s box. In baseball batting there is a noticeable preload in the swing, this is initiated by the hip segment first and then transfers to the shoulder segment, which allows the incorporation of the upper extremity in the movement (Welch et al., 1995). In the baseball pitch, golf swing, and baseball swing the kinetic chain is evident and consistent. The handball power serve encompasses these same movements.

**Importance of Mechanics**

The handball power serve requires a certain skill set to execute. Longevity in the sport requires players to hone and tailor their skills to execute a power serve with high velocity and efficiency. The kinetic chain is foundational to the technique of generating power in the movement. Mechanics are the physical movements that allow players to achieve these velocities with consistency. For example, a baseball pitcher learns to lead with the hips during a pitch to incorporate the pelvis into their throwing motion (Davis et al., 2009). In mainstream sports like baseball, golf, and tennis a considerable amount of research has revealed and described fundamental mechanics in which to instruct amateur players (Davis et al., 2009; Fleisig et al., 1999; Meister, 2000; Meister et al., 2011; Stodden et al., 2005). Proper instruction allows amateur players to make efficient use of their practice time. These players can learn their sport quickly, produce quality play earlier, and reduce their injury occurrence. Handball is a difficult sport to learn; players spend a vast amount of time learning to play on their own through trial and error. It is common for handball players to play three times a week for a few hours each day with little or no conditioning in-between. For baseball pitchers the overriding risk of injury is in overuse (Olsen, Fleisig, Dun, Loftice, & Andrews, 2006). Overuse and improper mechanics will have a
negative effect on a handball players’ longevity in the sport (Davis et al., 2009). Handball players are currently at higher risk for injury based on the amount of playing time and possibility of improper mechanics. Research in baseball pitching has demonstrated a correlation in common pitching mechanical errors on joint stress and efficiency (Davis et al., 2009).

The proposed research focuses on hip and shoulder rotation in the handball power serve. Research suggests that improper timing of trunk rotation in a baseball pitch results in an increased joint load to the shoulder, which may lead to an increase rate of injury (Aguinaldo et al., 2007). Research into handball can lead to increased awareness on possible mechanical errors, while suggesting and implementing a fundamental base in instructional mechanics to new players.

**Coordinated Effort**

In the previous paragraphs the handball power serve was broken down into the elements of the kinetic chain and the mechanics necessary to execute the sequential kinetic chain movements. This section discusses the importance of coordinating these two processes to generate force efficiently and to apply that force effectively. It is still to be determined what are the actual angular velocities the hip and shoulders generate during the handball power serve, because the handball power serve is similar to a baseball pitch in terms of mechanics, intensity, and occurrence of injuries. It is reasonable to examine the effects of coordination in a baseball pitch. The importance of a coordinated effort in pitching is evident in the fact that force loads generated by pitchers approach ultimate failure for some soft tissue e.g., muscle tendons and ligaments (Braun et al., 2009). Coordination and timing are imperative to keep these loads within safe limits. Research has found that proper timing of the trunk in baseball pitchers
decreases the joint load on the shoulder, by allowing the conservation of momentum from the trunk through the shoulder (Aguinaldo et al., 2007). This research provided a sample of the forces generated from a handball power serve and the timing needed to hit an effective power serve. The results can lead to an emphasis in form, timing, and reducing stress to the soft tissue, which could reduce the occurrence of injuries.

The handball power serve is a movement that is performed in the transverse plane. Rotation in the transverse plane about the polar axis places a considerable amount of mechanical force on the lumbar spine, possibly contributing to lower back injuries (Tsai et al., 2010). Therefore, the timing of the kinetic chain during a skilled movement is imperative to transfer the momentum efficiently. If the movement among the adjacent link segments is too slow or too fast the generated force may not travel up the chain, instead it is dissipated among the soft tissue within the segments. This idea is evident in a baseball pitcher that “overthrows” or tries to put more effort on a pitch; this “maximum effort” tends to disrupt the kinetic chain pattern resulting in increasing joint stress, increasing fatigue, and an increasing probability of inaccurate pitches (Aguinaldo & Chambers, 2009; Meister, 2000). A handball power serve and a baseball fastball require high velocity and accuracy to be effective. Timing and coordination of both movements must be made with a controlled competitive effort to avoid disrupting the transfer of momentum and increasing unnecessary stress to joints.

This research investigated the timing pattern of numerous players of different skill levels, possibly revealing an optimum timing pattern in the handball power serve. In pitching, it has been determined that there were numerous timing patterns in the pitch that produced near maximum velocity, but only one timing pattern that produced the maximum velocity (Aguinaldo et al., 2007; Stodden et
A similar relation likely exists for the handball serve. Identifying a timing pattern in the handball power serve could potentially explain injuries related to the power serve and assist instructors in developing key factors to achieving high velocity serves.

The coordination in the handball power serve is closely related to the swing of a baseball bat. Both movements occur in the transverse plane and are quick and powerful actions that require proper sequence and timing to be effective. If the ball is struck too early in the kinetic chain sequence while the body segments are still accelerating, poor accuracy and decreased velocity will result; if the ball is struck too late in the kinetic chain sequence or past the optimal power zone the body segments will be decelerating resulting in decreased velocity and poor accuracy. The key segment in the baseball swing is the hip (Welch et al., 1995). The hip is the first of three primary segments in the baseball swing, shoulders and arms being the next two. As stated earlier the hip makes up a considerable portion of the human body mass and is the primary link between the lower extremities and upper extremities. In order for the kinetic chain to achieve the highest possible momentum, the hips need to begin rotating first followed by the shoulders and then arms. Since, the handball power serve is related to the baseball swing via the kinetic chain and generation of power within a small area. It is logical to test hypothesis number 1, hip rotation will precede shoulder rotation, to confirm the relationship between the handball power serve and baseball swing.

**Skilled Players**

It is a common sight to see youth, collegiate, and amateur players watch in awe at professional handball players. Amateur handball players of all ages strive in some way to mimic the effortless motion of these professionals. These elite
players are able to hit the handball at a high velocity, accurately, and consistently. The skill displayed during a professional match is inspiring to any sports enthusiast. The common downfall for amateur players is the timing and coordination of their swings. Amateurs frequently look “mechanical” or lack fluency when swinging, as opposed to the smooth motion of a professional (Lane, 1977). This research compared amateur players to elite players. It is reasoned that elite players will have a higher velocity, more accurate serve, and be more consistent than amateurs, all related to hypothesis number 3 (Davis et al., 2009; Fleisig et al., 1999). Because of the differences in performance, it is likely there will be differences in either swing mechanics or timing pattern of the kinetic chain. Identifying these differences and developing fundamental mechanics based on these differences will enable new handball players to be more successful in handball. Evidence that supports the previous sentence comes from baseball, which emphasizes the importance of proper pitching mechanics at a young age to be successful (Fleisig et al., 1999). Pitching mechanics between youth players and adult players are essentially the same, the only difference being in body size and muscle mass of the adult pitcher that leads to greater velocities and the associated joint stresses (Davis et al., 2009; Fleisig et al., 1999; Meister, 2000). Developing fundamental knowledge in handball swing mechanics will promote proper instruction for handball players at the beginning of their training.

A professional handball power serve looks smooth, because the coordination and timing in the body segments produces the optimal angular velocity at the correct moment of impact. The most common difference between amateur and elite players is the timing pattern. Amateur golfers achieved peak angular velocity about the hip sooner than professionals (Meister et al., 2011; Okuda et al., 2010). This early peak angular velocity would cause the peak
angular velocity in the striking implement to occur sooner, before ball impact, resulting in a decreased amount of force applied to the ball. In addition to the early peak angular velocity, the transfer of momentum would dissipate in the trunk segment versus being transferred up the torso to the upper extremity resulting in further reduction of force applied to the ball at impact. In another study, the maximum peak values of the pelvis were the same in amateur and elite tennis players; the key difference was the temporal occurrence of this peak velocity (Landlinger et al., 2010). This would indicate that elite and amateur players can generate the same force, but the elite players have mastered the timing of their kinetic chain so that max velocity coincided with the impact of the ball. This research compared the hip and shoulder rotations between amateur and professional handball players to possibly identify the timing difference in the power serve.

In striking sports such as tennis and golf, there is a mechanical difference in amateur and elite players’ relative pelvic and torso rotation (Landlinger et al., 2010; Meister et al., 2011). While the elite player does show a marked difference in timing, which inevitably leads to an increase in ball velocity, there is individual mechanical variability among the elite players (de Subijana & Navarro, 2010; Landlinger et al., 2010; Stodden et al., 2005). In pitching and tennis, elite players were able to achieve high velocities by utilizing different parts of the kinetic chain, higher trunk rotations or higher shoulder rotations, or by having a more effective transfer of momentum. When comparing elite players to amateur players gross differences in mechanics can lead to improvements in the amateur swing. The handball power serve is a complex movement that may have a general mechanical structure and timing pattern. However, a question that needs to be addressed is
whether elite handball players may develop a slightly modified swing to achieve their high velocity and efficiency.

The common link between the handball power serve and the mainstream sports of baseball, tennis, and golf is the kinetic chain. The kinetic chain is the summation of forces from segments proximal to distal. Because research in handball is limited it is essential to begin a foundation of knowledge based on a sound theory of kinematics. This research tested three hypotheses based in part on the kinetic chain (e.g., hypotheses 1, 2, and 4). As part of the process, this study investigated mechanics and timing of amateur and professional handball players. The rotational velocities and timing patterns were recorded and compared to ascertain specific differences between handball players. The overall importance of this proposed research is to increase the amount of knowledge to the handball community to possibly create new training techniques or strength and conditioning programs to benefit all handball players.
CHAPTER 3: METHODOLOGY

Research Design

This chapter presents the methodology to be utilized for this study. The purpose of this research was to compare the hip and shoulder rotations of a handball power serve in the transverse plane. To complete this study, currently competing handball players were asked to execute a power serve while being filmed. The subjects selected were asked to attend one session of filming at the South Gymnasium room 109 on the California State University, Fresno campus. Prior to testing, the subjects were briefed on the purpose of the experiment and the type of serve required for a positive test.

Sample Population

The subjects for this research were male handball players that were currently competing at the B class level or above. The subjects were between the ages of 18 and 40. In a recent study, it was determined that there are mechanical differences between left and right handed pitchers, because of this possibility, all subjects were right-handed (Werner et al., 2010). The subject pool for this study consisted of 18 handball players. The breakdown of competitive divisions for which the players had qualified was 4 professional players, 2 qualifiers, 4 open, 5 A, and 3 B

Materials

For the purposes of this study the South Gymnasium room 109 was utilized. The South Gym room 109 was marked with court boundaries including a service box, see Figure 1. Three cameras were used to film the power serve. Two cameras were set up on 10-foot ladders anywhere from 6 to 10 feet from the server.
facing down at the server. The other camera was at ground level and was used to capture ball velocity. The overhead cameras were temporally synched with contact of the hand and ball. All three cameras filmed at 60 frames per second. The overhead cameras used the default shutter speed. The ground camera that was used to gather ball velocity data was set at 1/350th shutter speed. The researcher placed four white cardboard poster displays as a backdrop for the ground camera to create a white contrast for ease of digitizing the handball. Because the shoulders are anatomically wider than the hips, the researcher created a metallic hip harness that had two antennae pointing out away from the player. The antennae were used to digitize the hip rotation. Shoulder markers were placed on the acromion processes of both shoulders to digitize the shoulder rotation. There are currently three handballs in use in competition: USHA Red ACE, USHA 21, and Ektelon Premium Select. All handballs must pass a coefficient of restitution test to be considered for a tournament ball. The researcher elected to use the Ektelon Premium for all tests.

Independent Variable

The independent variable in this study was the handball power serve.

Dependent Variables

The dependent variables for this study were the angular velocities and timing patterns of the hips and shoulders during the power serve swing and ball linear velocity.
Experimental Protocol

The subjects were asked to read and sign the informed consent form prior to testing. The subjects were given at least a 10-minute warm-up prior to testing. It was acceptable for subjects to play one warm-up game prior to testing.

The court boundaries were identified to the subjects. The researcher placed a white tape marker perpendicular to the service zone back line. The subjects were asked to begin their serve at that marker to allow the researcher to center their position with the cameras. An audible cue was the signal for the server to begin their serve. The researcher placed a counter within the view of all cameras to indicate the number of total serves. The researcher kept a tally of legal serves and illegal serves with a series of ‘O’s or ‘X’s,’ respectively. The serve counted if it met certain criteria: it is a legal serve, the server accepted the serve as legal, and
the serve was struck at the waist or lower. The subjects were asked to serve ten competitive serves to be used for data collection.

**Expected Outcomes**

The hypothesis states hip rotation will be precede shoulder rotation during a handball serve, the shoulder will rotate at a higher angular velocity than the hips, better players will achieve higher velocities, and faster hip and shoulder rotation will be associated with faster ball velocity.
CHAPTER 4: RESULTS

This chapter encompasses a summary of the collected data of the study. References to the methodology are used to clarify the acquisition and presentation of the data. The total number of handball players participating in this research was 18 (n=18).

The research questions that guided this study were: (a) Does hip rotation precede shoulder rotation during a handball power serve? (b) Does the shoulder rotate at higher velocity than the hips? (c) Will better players achieve higher hip and shoulder angular velocities? (d) Is there a positive relationship between hip and shoulder angular velocity and linear velocity of the ball?

The first research question is related to the temporal sequence of hip and shoulder rotation during the handball power serve. Measuring and analyzing the temporal sequence centered on identification of the ball contact frame, as frame 0 or time 0. The number of frames before or after frame zero in which the maximum rotational velocity was achieved was noted. For example, in trial 1 of Table 1, the individual achieved maximum hip rotation at -4 or 4 frames prior to ball contact. The maximum shoulder rotation was noted at -2 or 2 frames prior to ball contact. Among this individual’s 10 trials, 9 had maximum hip rotation occurring first. In trial 4, hip and shoulder maximum velocities occurred in the same frame indicating a trial that is not consistent with the first research question. Table 2 illustrates the temporal results of all participants expressed in number of frames and also in seconds. The hip rotation preceded the shoulder rotation in 140 of 176 trials (79.6%).
Table 1

**Individual Data Sheet**

<table>
<thead>
<tr>
<th>Trial Number</th>
<th>Hip Rotation (Deg/s)</th>
<th>Frames From Ball Contact</th>
<th>Shoulder Rotation Deg/sec</th>
<th>Frames From Ball Contact</th>
<th>Ball Velocity (ms)</th>
<th>Ball Velocity (MPH)</th>
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<tr>
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<td>498.350</td>
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<td>900.253</td>
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<tr>
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<td>Shoulder Rotation (Deg/sec)</td>
<td>Frames From Ball Contact</td>
<td>Ball Velocity (ms)</td>
<td>Ball Velocity (MPH)</td>
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<td>906.877</td>
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<tr>
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<td>Trial 9</td>
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<td>917.107</td>
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<td>965.723</td>
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<td>956.735</td>
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<td>28.356</td>
<td>63.431</td>
</tr>
</tbody>
</table>
Table 2

**Temporal Conditions**

<table>
<thead>
<tr>
<th>Subject</th>
<th>Division</th>
<th>Average Hip Time Frames</th>
<th>Seconds</th>
<th>Average Shoulder Time Frames</th>
<th>Seconds</th>
<th>Trials Hips Led Shoulders</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>P</td>
<td>-2.9</td>
<td>-0.048</td>
<td>-1.7</td>
<td>-0.028</td>
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</tr>
<tr>
<td>2</td>
<td>Q</td>
<td>-4.7</td>
<td>-0.078</td>
<td>-1.2</td>
<td>-0.02</td>
<td>10 of 10</td>
</tr>
<tr>
<td>3</td>
<td>O</td>
<td>-4.2</td>
<td>-0.07</td>
<td>-4.2</td>
<td>-0.07</td>
<td>3 of 10*</td>
</tr>
<tr>
<td>4</td>
<td>P</td>
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<td>-0.055</td>
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<td>6</td>
<td>P</td>
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<td>-0.043</td>
<td>-1.5</td>
<td>-0.025</td>
<td>5 of 10**</td>
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<td>P</td>
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<td>-0.045</td>
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</tr>
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<td>3.4</td>
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<td>9</td>
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<td>-1.6</td>
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<td>11</td>
<td>B</td>
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<td>-0.067</td>
<td>-3.9</td>
<td>-0.065</td>
<td>4 of 10</td>
</tr>
<tr>
<td>12</td>
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<td>-0.5</td>
<td>-0.008</td>
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<tr>
<td>13</td>
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</tr>
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<td>14</td>
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<tr>
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<td>18</td>
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<td>-4.6</td>
<td>-0.077</td>
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</tr>
</tbody>
</table>

Total: Average Hip Time less than Shoulder time (83.3%) 15 of 18

Total: Majority of trials that the hips led shoulders (72.2%) 13 of 18

Total: Total Trials (79.6%) 140 of 176

Note: Ball Contact is designated frame 0 or time 0

* 5 of the 7 trials had maximum shoulder and hip rotation occur in the same frame

** 4 of the 5 trials had maximum shoulder and hip rotation occur in the same frame
In addition to examining all trials, the researcher assessed each individual performance. A normal kinetic chain pattern was identified as hips leading the shoulders. If a player achieved that pattern in the majority of their trials, it was considered a performance in compliance with the kinetic chain. Table 2 lists the players and the number of trails the hips led the shoulders. Player 4 only had 6 viable trials due to an error in filming on the first four trials. Thirteen of the 18 players (72.2%) had their hips leading the shoulders in the majority of their trials. Players 3 and 5 had a majority of their trials in non-compliance with the kinetic chain, their shoulders achieved maximum angular velocity prior to their hips. However, upon closer inspection of the raw data both players achieved maximum hip and shoulder rotational velocity in the same frame in the majority of their non-compliant trials (5 of 7 for player #3, 4 of 5 for player #5). The implication of this data is discussed in the following chapter.

The second research question focused on the shoulders rotating at a higher angular velocity than the hips. The researcher took the average of the three highest angular velocities achieved during a single trial and then averaged these across all trials. Table 1 shows the compiled data for a single player. Table 3 shows means for the entire sample. The mean maximum angular velocity for hip rotation was 429.796 deg/sec (±154.067) and mean maximum angular velocity for shoulder rotation was 801.237 deg/sec (±130.254). Table 4 presents a summary of the maximum angular velocities and associated linear ball velocity. The shoulders rotated at a higher angular velocity than the hips on average for each individual player.
The third research question was that better players would achieve higher ball velocities. The divisional hierarchy is listed as: professional (P), qualifier (Q), open (O), A, and B. The researcher focused on resultant linear velocity as the criterion variable for this research question. Table 4 indicates a natural break in maximum ball velocities between the fast group and the slow group and this natural break was more specifically between player #10 and player #9 of 3.533 MPH. Above this break, 8 players achieved velocities higher than 64 MPH, the divisions are listed as: (4P, 1Q, 2O, and 1A).
Table 4

*Results Summary*

<table>
<thead>
<tr>
<th>Subject</th>
<th>Division</th>
<th>Hip Average (deg/sec)</th>
<th>Shoulder Average (deg/sec)</th>
<th>Average Velocity (MPH)</th>
<th>Max Velocity (MPH)</th>
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</thead>
<tbody>
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<td>948.446</td>
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<td>62.369</td>
<td>69.030</td>
</tr>
<tr>
<td>7</td>
<td>P</td>
<td>299.399</td>
<td>729.102</td>
<td>61.155</td>
<td>67.696</td>
</tr>
<tr>
<td>8</td>
<td>O</td>
<td>184.070</td>
<td>774.103</td>
<td>63.534</td>
<td>67.274</td>
</tr>
<tr>
<td>9</td>
<td>Q</td>
<td>362.730</td>
<td>846.049</td>
<td>57.696</td>
<td>63.741</td>
</tr>
<tr>
<td>10</td>
<td>A</td>
<td>298.504</td>
<td>809.567</td>
<td>56.832</td>
<td>63.236</td>
</tr>
<tr>
<td>11</td>
<td>B</td>
<td>694.432</td>
<td>787.880</td>
<td>57.000</td>
<td>63.064</td>
</tr>
<tr>
<td>12</td>
<td>B</td>
<td>249.025</td>
<td>863.658</td>
<td>58.740</td>
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</tr>
<tr>
<td>13</td>
<td>O</td>
<td>441.166</td>
<td>696.229</td>
<td>57.274</td>
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<tr>
<td>14</td>
<td>O</td>
<td>568.672</td>
<td>909.176</td>
<td>53.542</td>
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<tr>
<td>15</td>
<td>A</td>
<td>415.825</td>
<td>860.068</td>
<td>54.885</td>
<td>61.442</td>
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<tr>
<td>16</td>
<td>A</td>
<td>362.029</td>
<td>629.777</td>
<td>56.575</td>
<td>60.766</td>
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<tr>
<td>17</td>
<td>A</td>
<td>419.100</td>
<td>692.068</td>
<td>55.479</td>
<td>58.722</td>
</tr>
<tr>
<td>18</td>
<td>B</td>
<td>275.330</td>
<td>603.170</td>
<td>50.552</td>
<td>56.790</td>
</tr>
</tbody>
</table>

**Mean** 429.796 801.237 58.986

Note. Arranged from highest maximum velocity to lowest
In addition to the maximum velocity, these same 8 players had higher average ball velocities than the mean ball velocity of the entire sample (58.987 MPH from Table 3). The 10 players hitting under 64 MPH are listed as (1Q, 2O, 4A, and 3B).

The final research question asked if faster hip and shoulder rotation would be associated with faster ball velocity. To answer this question a Pearson correlation was computed between hip rotation velocity and ball velocity, and between shoulder rotation velocity and ball velocity. The correlation between hip rotation and ball velocity showed low association ($r= .139$) and approached statistical significance (.066). The correlation between shoulder rotation and ball velocity showed a low positive correlation ($r= .205$) that was significant at the 0.01 level (Table 5).

Table 5

<table>
<thead>
<tr>
<th>Variable</th>
<th>Statistic</th>
<th>Ball Velocity</th>
<th>Hip Rotation</th>
<th>Shoulder Rotation</th>
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<td>Ball Velocity</td>
<td>Pearson Correlation</td>
<td>1</td>
<td>.139</td>
<td>.205**</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td></td>
<td>.066</td>
<td>.006</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td></td>
<td>176</td>
<td>176</td>
</tr>
<tr>
<td>Hip Rotation</td>
<td>Pearson Correlation</td>
<td></td>
<td>.139</td>
<td>.226**</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td></td>
<td>.066</td>
<td>.003</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td></td>
<td>176</td>
<td>176</td>
</tr>
<tr>
<td>Shoulder Rotation</td>
<td>Pearson Correlation</td>
<td></td>
<td>.205**</td>
<td>.226**</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed)</td>
<td></td>
<td>.006</td>
<td>.003</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td></td>
<td>176</td>
<td>176</td>
</tr>
</tbody>
</table>

**. Correlation is significant at the 0.01 level (2-tailed)
CHAPTER 5: DISCUSSION

The purpose of this chapter is to discuss the outcome of the research and the implications of the findings as they pertain to handball instruction and mechanics. However, the current research in the biomechanics of handball is limited, so this investigation is intended to be descriptive. The researcher kept the scope of the investigation within practical limits, but broad enough to answer certain questions about the mechanics of handball as well as provide a foundation for future research.

The investigation focused on a series of hypothesis based on the kinetic chain of movement. Three of the four hypotheses were confirmed using only descriptive methods including measurement of angular velocities of the hips and shoulders, the temporal pattern of these velocities relative to ball contact, linear velocity of the ball, and current division of the subject. The fourth hypothesis, faster hip and shoulder rotation will be associated with faster ball velocity, required a statistical correlation.

The first hypothesis, hip rotation will precede shoulder rotation during a handball power serve, is based on the kinetic chain theory that explains that the human body is a series of links or segments that generate energy from the lower extremities sequentially through the hips, trunk, and out to the hand (Bunn, 1972; Northtrip et al., 1983; Putnam, 1993; Welch et al., 1995; Wilk et al., 2000). These segments produce energy and each consecutive segment in the chain can transfer its momentum to the next segment creating an accumulation of energy. The result is a substantial increase in force production at the most distal segment. According to our results, this hypothesis was confirmed in 72.2% of the subjects. The findings are consistent with the kinetic chain concept.
The second hypothesis, the shoulder will rotate at a higher angular velocity than the hips, further expands the validity of the kinetic chain within handball mechanics. In this study, all players during all trials demonstrated a higher angular velocity in the shoulders than hips with a mean hip rotation being 429.796 deg/sec (±154.067) and a mean shoulder rotation of 801.237 deg/sec (±130.254). The sequential increase in velocity during the handball power serve indicates compliance with the kinetic chain theory. An example of this is shown in Figure 2, which shows that maximum hip rotation occurs first followed by the maximum shoulder rotation. In accordance with the kinetic chain theory, the maximum shoulder rotation is higher than the maximum hip rotation.

Figure 2. Graphical representation of data
Note: Data taken from trial 5 of subject 1
The third hypothesis states that better players will achieve higher velocities. The sample population included a variety of players from different divisions. The mean ball velocity of all trials equated to 58.986 MPH. The 8 players that averaged higher than the mean were in the following divisions: 4 professional, 1 qualifier, 2 Open, and 1 A. The 10 players averaging lower than the mean included: 1 qualifier, 2 Open, 4 A, and 3 B. The same 8 players achieved the highest linear velocities of the ball (>64 MPH). The descriptive statistics are consistent with the hypothesis.

The final hypothesis states that hip and shoulder rotation will be directly associated with ball velocity. The correlations between these parameters netted a very low correlation between hip rotation and ball velocity, but a low positive correlation between shoulder rotation and ball velocity (r = .205), significant at the 0.01 level. The kinetic chain theory is a summation of all links in the system, and the methodology of this research was limited to the first two links in the kinetic chain of the handball power serve. However, as stated in chapter 2, trunk rotation is a positive link in the kinetic chain because of its mass and influence on shoulder rotation (Landlinger et al., 2010; Winter, 1990). In Table 5, there was a significant positive correlation between hip rotation and shoulder rotation (r = .226). The researcher believes the “critical” link in the kinetic chain for the handball serve must be one of later links, either shoulder joint, elbow, or wrist. The researcher also theorizes that each of these more distal links in the kinetic chain will have a higher correlation with ball velocity.

**Strengths of the Current Study**

The study was completed with a sample population of 18 (n=18) handball players. The sample population was distributed nearly evenly throughout all
divisions tested as reported in the previous chapter. The conditions of the testing were adhered to uniformly for each participant: adequate warm-up time, familiarization with testing equipment, mock court set-up, and testing procedures. The researcher imposed limitations were adhered to; all players were in a current competitive state, right-handed, and within the age restrictions. The researcher imposed a single “official” testing ball for the purpose of this research. The ball used was the Ektelon Premium Select, either a brand new ball opened the day of testing or a ball no older than 1 day with no official playing time.

Limitations

The potential limitations of the study were in the effort each player put forth in completing the performance. The player’s were asked to perform a competitive serve. However, the limitations of the methodology prevented filming in an actual handball court. Creating an environment that would facilitate a competitive performance would have allowed these players to reach a competitive mind set early in the performance.

The scope of the research is limited, because the researchers were unable to capture the entire kinetic chain of the handball serve. The servers’ upper arm, forearm, wrist, and hand cross multiple planes prior to striking the ball. At the time of this research, the equipment needed to film in multiple planes was not available. Because of this limitation, the researchers could not compare velocities throughout the more distal links of the kinetic chain for comparisons and correlations.

During testing, a personal comment made by a professional handball player stated that the ball temperature does have a noticeable effect on serve velocity. Without data on the coefficient of restitution of the handball at different
temperatures, the researcher was unable to determine by how much the temperature affects ball velocity.

**Implications**

The implications of this research revolve around understanding handball mechanics and generating new tools for instruction or reinforcing existing instructional tools. This research was done to create a foundation of handball kinematic data. For perspective Table 6 compares this study to the baseball swing, baseball pitch, football pass, and tennis serve. The handball power serve is comparable to these sports in regards to angular velocities. Training strategies from each sport should be investigated to further increase a handball coaches repertoire of exercises i.e., power from baseball pitching and batting, endurance from tennis. Because the kinetic chain is valid in handball mechanics, focus on leading with the hips, strengthening the core muscles to prevent fatigue, and utilizing warm-up routines or strength training programs can be integrated into handball instructional camps.

**Table 6**

*Comparisons of Angular Velocities*

<table>
<thead>
<tr>
<th>Study</th>
<th>Motion</th>
<th>Mean Hip Angular Rotation (deg/sec)</th>
<th>Mean Shoulder Angular Rotation (deg/sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wilk et al. (2000)</td>
<td>Baseball Pitching</td>
<td>660</td>
<td>1170</td>
</tr>
<tr>
<td>Welch (1995)</td>
<td>Football Passing</td>
<td>500</td>
<td>950</td>
</tr>
<tr>
<td>De Subijana (2009)</td>
<td>Baseball Swing</td>
<td>714</td>
<td>937</td>
</tr>
<tr>
<td>Current Study</td>
<td>Tennis Serve</td>
<td>440</td>
<td>870</td>
</tr>
<tr>
<td>Current Study</td>
<td>Handball Power Serve</td>
<td>429</td>
<td>801</td>
</tr>
</tbody>
</table>

Note. All studies except the current study were completed exclusively with elite players.
The average speed of the handball power serve was 59.432 MPH. Of the 4 professional players tested the slowest average velocity was 60.658 MPH. Professional handball players place an equal amount of focus on location of serve and actual velocity. The implication for up and coming handball players is to focus not only on speed, but also on accuracy and precision, which involves proper footwork and mechanics to achieve.

**Directions for Future Research**

During the process of filming and digitizing, it was noted in table 2 that players 3 and 6 had a number of serves in which the maximum hip and shoulder velocities occurred in the same frame. These players may be in compliance of the kinetic chain, but their timing may have been too close for measurement. The filming was done at a rate of 60 frames per second, future research should attempt to film handball serves with a higher frame rate to effectively digitize the movement.

Future research in handball can be focused on determining the angular velocities of the remaining links in the kinetic chain to determine the “critical” link and determine the forces generated by the segments. By completing the entire process, players will have data that will enable them to focus on strengthening the weak links within the chain.

The current study can be augmented with future research into the handball skip serve. This serve is based on the power serve, but with the purpose of imparting a spin on the ball. Comparing the angular velocities of the kinetic chain segments and resulting linear ball speed can determine if and what are the differences in the kinetics and kinematics between a straight power serve and a
skip serve. The purpose would be to analyze and compare the injury rate and fatigue of the skip serve to a baseball curveball.

Handball is a high-intensity exercise. Research could also be done on the mechanics in the power serve after an intense match, to ascertain the effects of fatigue upon a players’ performance including ball velocity, accuracy, and precision. This research could also determine the areas likely for injury due to errors in form.

Research can also be undertaken to compare the mechanics between dominant and non-dominant hands. As a handball player progresses to the higher levels of competition, their non-dominant hand will targeted more often by their opponents. Success at these levels will depend on the ability of their non-dominant hand to hit effective shots.
REFERENCES


APPENDIX A: INFORMED CONSENT
Informed Consent

Title of Project: Analysis of hip and shoulder rotation and linear ball velocity in the transverse plane during a handball power serve

Principle Investigator: Tim Anderson, Ed.D. (Professor, Department of Kinesiology)
Co-Investigator: Adam Coronado, B.S. (Graduate Student, Department of Kinesiology)

The purpose of this study is to analyze angular velocities of hip and shoulder rotation in the transverse plane during a handball power serve. Angular velocities will be measured during a competitive effort, legal power serve.

If you decide to participate in this study, there will be 1 session lasting approximately 1 hour at either the South Gymnasium room 109 or at Centerpoint Athletic Club.

At this session you will informed of the testing procedures. Data will be collected on 10 power serves that are served at competitive effort and within the legal bounds of play. If the testing is conducted at Centerpoint Athletic Club, it will be conducted in a handball court. If the testing is done in South Gymnasium room 109, there will be a marked boundary of the service box and side and back boundaries will be marked and identified.
Prior to the testing session, you will be asked to refrain from participating in high level play for at least 24 hours. If you are injured prior to your test session, inform the investigators of the nature of the injury and probable recovery time. If you wish to continue with the study, the investigators will determine if there will be adequate recovery time to schedule another session date.

At the beginning of the testing session, you will be given ample time to warm up. The warm-up procedure will consist of your normal tournament warm-up. If session is held at Centerpoint Athletic Club a warm-up game will be allowed.

Any information that is obtained by this investigation is strictly confidential and will only be disclosed with your permission. If you give us permission by signing this document, results from this study will be made available to the general public through submission to scientific journals. It is the intent that publication of the results will add to the body of knowledge in the related fields of biomechanics.

Your decision whether or not to participate in this study will not affect your future relations with CSU Fresno. If you decide to participate you are free to withdraw your consent and to discontinue your participation at any time without penalty. The committee on the Protection of Human Subjects at CSU Fresno has reviewed and approved the procedures for the present study.

If you have any questions/comments regarding your participation in this investigation, please feel free to contact Dr. Tim Anderson (559) 278 – 2203.
You are making a decision whether or not to participate in this study; your signature indicates that you have decided to participate in this study having read the information above.

Participant’s Signature

Date

Investigator’s Signature

Date
APPENDIX B: PROTECTION OF HUMAN SUBJECTS
Ethics for Human Subject Approval

ANALYSIS OF HIP AND SHOULDER ROTATION AND LINEAR BALL VELOCITY IN THE TRANSVERSE PLANE DURING A HANDBALL POWER SERVE

Investigators:

Tim Anderson, Ed.D. (Professor, Department of Kinesiology)
Adam Coronado (Graduate Student, Department of Kinesiology)

Abstract

The purpose of this research is to analyze angular velocities of the hip and shoulders in the transverse plane during a handball power serve. There has been little research of any type in court handball, and to this date, there are no known research reports involving the biomechanics of handball. The handball power serve represents a competitive effort strike in a coordinated pattern, which adheres to the kinetic chain theory, based on the generation and transfer of energy from the lower limbs to the trunk and finally to the hand (Wilk, Meister, Fleisig, & Andrews, 2000). For this proposed study, 20 trained, competitive handball players, from the professional division to the B class amateur division, will be filmed hitting a power serve. The participants will serve 10 legal serves in a mock court setup or on a standard court. The participants’ serve patterns will be digitized and angular velocities of hip and shoulder rotation will be compared to ball velocities. It is hypothesized that hip rotation will precede shoulder rotation, the shoulder will rotate at a higher angular velocity than the hips, better players
will achieve higher velocities, and faster hip and shoulder rotation will be associated with faster ball velocity.

**Protocol**

**Purpose and Background:**

The purpose of this study is to analyze angular velocities of the hip and shoulder rotation in the transverse plane during a handball power serve.

Handball is a court sport played throughout the nation. The sport has not garnered the attention of the public, but has been around since the late 19th century. Due to this lack of public attention handball research is nearly non-existent. The present study is investigative research to initiate the foundation of data in handball research. It is descriptive in nature, and will also attempt to measure relationships between hip and shoulder rotation and ball speed. The handball power serve is an ideal choice for research based on the association of power and coordination. In addition, the handball power serve follows the kinetic chain theory. The theory that power is first generated from the lower limbs and is transferred up the body through the trunk to the hand (Wilk et al., 2000). The kinetic chain theory has been studied in baseball, football, and most recently golf mechanics. The implications of this research lies in developing proper form and mechanics, strength training, and temporal coordination for instructional use.
Because handball is a high-paced game that requires power, agility, and endurance (Graetzer, Shultz, Chen, & Jones, 1994), research into the kinematics of handball would be beneficial to trainers, coaches, and recreational players.

**Subjects:**

Twenty right-handed male handball players that are currently competing in tournaments will be recruited for participation in this study. All players will be screened for physical contraindications that would prevent them from executing a competitive effort power serve. Recent injuries that prove to inhibit play or competitive effort will cause a subject to be excluded from testing. Any subject currently under medication for pain, inflammation, or any other medical condition that will prevent a maximum effort without further injury to the subject will be excluded from testing.

**Methods:**

This investigation will require the subjects to test for one session. The equipment will be set-up in a handball court at Centerpoint Athletic Club in Fresno or in the South Gymnasium Room 109. The subjects will be briefed in-depth on the purpose of the investigation and given verbal explanation on a legal power serve (if testing is done in South Gymnasium Room 109), otherwise tournament effort serve in a handball court. At this time they will also read and sign an informed
consent form (attached). All benefits and risks will be verbally explained to the subjects.

The test will include a two-camera set-up. Camera 1 will be set-up either in the service box facing the server or just behind the service box. Final decision of these positions will be based on each participants serve mechanics. Camera 1 will be positioned 8 feet up to film from a downward angle. Camera 2 will be placed in a position to capture ball velocity prior to front wall strike.

When the participants are prepared to test, a number indicator will be placed in the frame to indicate serve number and following a legal serve another indicator will be placed in frame. The participants will be asked to complete 10 legal serves for the investigation.

**Potential Benefits:**

Benefits of participation include: (1) Film of each participants serve technique for their own records and training and (2) analysis of each participants shoulder and hip angular velocities including implications to strength training to improve performance.
Potential Risks:

The participants will be asked to perform 10 competitive effort serves. There is a potential for injury to the shoulder and elbow joints and muscle damage to body part involved in the strike, but this is the same risk they voluntarily encounter when they play handball.

Management of Risks:

The subjects will be allowed to warm-up in the testing area or play a one game warm up if two subjects are present at the same time. Effort will be taken to keep testing facilities warm to prevent the subjects from cooling down during reset of equipment. At any time, if the subject feels pain or discomfort the test will be terminated.
California State University, Fresno

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<tr>
<th>Adam Coronado</th>
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Date