UNIVERSITY OF CENTRAL OKLAHOMA

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Jackson College of Graduate Studies

# A STUDY OF MOVEMENT IN SITTING-VOLLEYBALL

A THESIS

SUBMITTED TO THE GRADUATE FACULTY

in partial fulfillment of the requirements

for the degree of

MASTER OF SCIENCE

by

Maggie Zerger

Kinesiology and Health Studies

University of Central Oklahoma

Edmond, OK

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Committee Chairperson

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Committee Member

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I would like to thank the women of the United State Paralympic Sitting-Volleyball team. To my committee for their guidance during this process I am eternally grateful. Dr. Michelle Gray, your patience and tenacity has made this thesis what it is, my greatest work to date. Dr. Debbie Traywick, I have appreciated your thoughtful insight. Dr. Cynthia Murray, the queen of statistics, I would never have finished the results without you.

# DEDICATION

This thesis is dedicated to Lola. In the time since you have been gone, I have been away from the game. Now the love that we shared for the game has brought me back from despair and given direction where I was once faltering. It was your infectious loves of the game that I have once again succumb to and embraced. A hit is a hit, regardless of who delivers.

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## Abstract

The present investigation focused on movement in the game of sitting-volleyball with the US Paralympic Team. The purpose of the study was to assess the effectiveness of lateral, forward, and posterior hand placement and open and closed body position on speed of movement of sitting-volleyball players. The United States Paralympic Women's volleyball team volunteered for the study. The team was in training at the time. All subjects were studied at the University of Central Oklahoma Wellness Center located in Edmond, Oklahoma. All trials were filmed on a regulation sitting-volleyball court that was designated by the UCO Paralympic Training Coordinator. The independent variables for movement at the net in the two meter trials were open and closed body position and direction. Open body position was defined as the player's body facing the sideline with their shoulder to the net, when moving parallel to the net for two meters. Closed body position was defined as the player's body facing the net as they moved laterally for two meters. Hand placement and direction were the independent variables for the six meter movement trials. Forward and backward were defined as moving facing the sideline in front of them and then behind them. Hand position was defined as anterior, lateral and posterior. Anterior placement was in front of the hips on the floor on the left and right side of the body. Lateral hand placement was on the floor even with the hips on each side of the body. Posterior hand placement was behind the hips on each side respectively. The dependent variable for both the six and two meter trials was the time it took for the player to reach the given distance. For the two meter trial conducted at the net, breaking the plane of the net was the beginning and end point. A Brower Timing System (Draper, UT) was used to measure time for two and six meter trials. Each variable was filmed using a

compact digital Sony Compact Digital (Tokyo, Japan) video camera and analyzed using Dartfish 4.5.2 (Alpharetta, Georgia) software. A rear court view was used for filming at a height of one meter. A two-factorial analysis of variance (2 X 2 ANOVA) was performed for the two meter trial at the net – open and closed movement times for center to sideline and sideline to center. A three-factorial analysis of variance (3 X 2 ANOVA) was performed for the six meter trials – anterior, lateral, and posterior hand positions for forward and backward movement times. Statistically significant differences were seen between open versus closed body position when moving from the center of the court to the sideline ($p \leq 0.05$). This result has been hypothesized to be linked with the pattern of amputation among the subjects and individual movement characteristics. No statistically significant differences were seen between hand positions with regard to direction. However, the lack of statistical significance for the remaining research questions does not fully explain what was found by the study. Sample size could have attributed to insignificant findings.

# CHAPTER ONE

## Introduction

Movement in sitting-volleyball can be the greatest challenge a player may face in the game. Sitting players most commonly remain in contact with the floor by sliding on their posterior (Davis, 2002, p 95). Where ground reaction force is minimal in the standing game (Wakeling, Tscharner, Nigg, & Stergiou, 2001), the sitting player must use the smaller muscle groups of the arms to move a larger area that is in contact with the playing surface to overcome inertia. Latissimus dorsi, trapezius, abdominal, and hip flexor muscles serve not only as stabilizer of the trunk, but also as primary movers (Seelen and Vuurman, 1991). Muscle strength, endurance, and fatigue threshold have a great impact on the sitting or standing player's overall game. The presence or lack of lower extremities can function as an advantage or disadvantage based on the player's ability to adapt and move in the game environment. Hand placement, balance, and powerful arm strokes are needed to overcome the opposing force. Although movement is an integral part of the sitting-volleyball game. Literature does not yet exist on the topic of sitting-volleyball and movement.

Volleyball requires a great deal of movement. Getting into position requires precise, efficient movement (Kwak, Jin, Hwang, and Yoon, 1989; Gonzalez, Urena, Garcia, Martin, and Navarro, 2005; and Nall, 2007). There are differing opinions on how to move towards the ball on defense and offense. Insufficient movement resulting in an errant pass can result in a side out or handing the opponent a free ball, a ball floated into the opposing team's court. In the steps to successful blocking, movement must occur first (Nall, 2007; Giovannazi, 2006). A successful dig occurs only when a player correctly reads the hit from the opponent and they are able to move to cut off the angle of the hit. Libero and defensive specialists, those who are most responsible for “digging” the ball, must move into position based on the angle of the block. A block that is successful results in the defensive players moving to cover the area of the court the block is taking away from the opponent (Gonzalez et al., 2005; and Nall, 2007). Attack-hits, balls that are struck and driven downward from the net, are most effective when the player moves under the ball placed by the setter. There are few skills in volleyball that do not require the player to move.

The present investigation focused on movement not just in the backcourt, but at the net as well. Movement at the net is essential as players must move to follow play of the ball. Blocking offers the opportunity to end the point quickly, without the need to dig or attack-hit (Lawler, 2006). If players are not able to move quickly to respond to the block, the point will end unfavorably (Sandorfi, 2000). Even when the block does not result in the ball dropping into the opponent’s court, reducing the pace of the opponent’s hit can make the dig possible and at times easier (Nall, 2007). This requires movement frequently and at a fast pace in both standing and sitting volleyball.

In standing volleyball, keeping the body in position to move is important to respond to the game. A unique challenge of sitting volleyball over standing volleyball is moving with the hands where movement in standing volleyball is done by the feet and the ball is played with the hands. Sitting-volleyball requires that the player move their body as well as play the ball with their arms and hands. Smaller muscle groups are then responsible for movement of the same body mass. Once the player gets to the point at which they desire to reach, they must now play the ball with their hands. Double duty for the arms and hands make initial movement to the ready position even more important. The researchers believed that the sitting player has to put just as much emphasis on where to place their hands to move as the standing player does for their feet. The optimal position for hands is unknown.

## PURPOSE

The purpose of the study was to assess the effectiveness of lateral, forward, and posterior hand placement on movement of sitting-volleyball players.

## STATEMENT OF THE PROBLEM

There are no studies from which to answer the question of what is the optimal position of the hands to begin movement in sitting-volleyball players

## RESEARCH QUESTIONS

1. Is there a significant difference between mean movement times with regard to body position (open and closed)?
    - 1a. For the <u>center-to-side</u> direction, is there a significant difference between mean movement times with regard to body position (open and closed)?
    - 1b. For the <u>side-to-center</u> direction, is there a significant difference between mean movement times with regard to body position (open and closed)?
2. Is there a significant difference between mean movement times with regard to direction (center-to-side and side-to-center)?
    - 2a. For the <u>open</u> body position, is there a significant difference between mean movement times with regard to direction (center-to-side and side-to-center)?

2b. For the closed body position, is there a significant difference between mean movement times with regard to direction (center-to-side and side-to-center)?

3. Is there a significant difference between mean movement times with regard to hand position (anterior, lateral, and posterior)?

3a. For the forward direction, is there a significant difference between mean movement times with regard to hand position (anterior, lateral, and posterior)?

3b. For the backward direction, is there a significant difference between mean movement times with regard to hand position (anterior, lateral, and posterior)?

4. Is there a significant difference between mean movement times with regard to direction (forward and backward)?

4a. For the anterior hand position, is there a significant difference between mean movement times with regard to direction (forward and backward)?

4b. For the lateral hand position, is there a significant difference between mean movement times with regard to direction (forward and backward)?

4c. For the posterior hand position, is there a significant difference between mean movement times with regard to direction (forward and backward)?

## LIMITATIONS

1. Only female Paralympic sitting-volleyball athletes who trained at the University of Central were available to volunteer for the study.

2. The trials were conducted outside of the competitive environment.

3. The number of participants was limited to 15.

4. The participants were only available one day per test conducted.

## DELIMITATIONS

1. The sample consisted of the US Paralympic Women's Sitting-Volleyball team.

2. The sample consisted of elite athletes and their performance may not reflect the general population.

3. The participant's performance may not represent their best due to undetermined factors of mental or physical fatigue.

## ASSUMPTIONS

1. Each participant exerted their maximum effort during all trials.

2. All previous injuries were reported before the trials occurred that might affect performance.

3. Each participant performed at the level they would in a competitive situation or game.

## DEFINITIONS

All definitions below, provided for the reader gain an understanding of volleyball, are from the USA Volleyball Domestic Competition Regulations 2007-2008 (Lenberg, 2007).

ATTACK BLOCK - Receiving team's player attempting an aggressive block a spiked ball.

ATTACKER - A player whom attempts to hit a ball aggressively and downward for an immediate point.

ATTACK LINE - A line two meters from the net that separates the front row players from the back row players.

BACKCOURT - The area from the end line to the attack line.

BLOCK - A defensive play by one or more players meant to deflect a spiked ball back to the court. It may be a combination of one, two, or three players jumping in front of the opposing spiker and contacting the spiked ball with the hands.

CLOSING THE BLOCK - The responsibility of the assisting blocker(s) to join the primary blocker and create an impenetrable block in which a ball cannot fit between the two individual blockers.

CROSS OVER STEP – Footwork technique that allow the left or right foot to move in front of the opposite foot to move at the nets

DOUBLE BLOCK - Two players working in unison to deflect an attacked ball at the net back to the hitter’s side.

HIT - To jump and strike the ball with an overhand, forceful shot.

HITTER - Also "spiker" or "attacker."

KEY - To predict a team's next play by observation of patterns or habits.

PENETRATION - The act of reaching across and breaking the plane of the net during blocking.

READY POSITION - The flexed, yet comfortable, posture a player assumes before moving to contact the ball.

SET - The tactical skill in which a ball is directed to a point where a player can spike it into the opponent's court.

SETTER - The player who has the second of three contacts of the ball who "sets" the ball with an "Overhand Pass" for a teammate to hit. The setter normally runs the offense.

SIDE OUT - Occurs when the receiving team successfully puts the ball away against the serving team, or when the serving team commits an unforced error, and the receiving team thus gains the right to serve.

SPIKE - Also hit or attack. A ball contacted with force by a player on the offensive team who intends to terminate the ball on the opponent's floor or off the opponent's blocker.

STUFF - A ball that is deflected back to the attacking team's floor by the opponent's blockers. A slang term for "block."

# SIGNIFICANCE OF STUDY

There are no studies from which to answer the proposed research questions. The greater issue of understanding sitting-volleyball is the impact this understanding will have on Paralympians, disabled children, and young adults who are future Paralympic hopefuls. Assessing the lateral, forward, and backward movement of sitting-volleyball players will contribute significantly to game techniques, training methods, player development, and general understanding of the game.

# CHAPTER TWO

## Review of Literature

Movement in sitting-volleyball can be a great challenge that a player may face. Movement is the logical beginning for applied research. Sitting players most commonly remain in contact with the floor by sliding on their posterior (Davis, 2002, p 95). The purpose of the study was to assess the lateral, forward, and backward movement of sitting-volleyball players. The study focused on movement not just in the backcourt, but at the net as well. Play at the net and in the backcourt requires movement frequently and at a fast pace. This is true of both standing and sitting volleyball. Sitting-volleyball requires that the players move their body and play the ball with their arms and hands. This double duty for the upper body makes movement even more important. The researchers believed that the sitting player has to put just as much emphasis on where to place their hands to move as the standing player does for their feet. The optimal hand or body position during active play is unknown. No studies were found in the literature that were directly related to the complete aspects of the study. However, in order to provide a background of information, related topics of speed, reaction time, cross-over step, slide step, and vision were reviewed.

### *Sitting-Volleyball*

Individuals with disabilities experience lasting consequences of their disability (Vute, 1992). These lasting effects are a lower level of social functioning, physical ability to tolerate work, and overall energy (Akasaka, Takakura, Okuma, Kusano, Suyama, Yamamoto, et al., 2003). Participating in sitting-volleyball improves these areas collectively (Vute, 1992). Vute (1992) recorded many reasons why individuals participate in sitting-volleyball. Breaking through barriers their disabilities have placed upon them, providing an opportunity for success, socialization opportunities with others, and a sense of joy and wellbeing were all outcomes of playing sitting volleyball (Vute, 1992). Playing volleyball requires a level of mastery of the technical, tactical, and mental elements of the game. Amputees are able to perform the game at a higher level than others who have lower limbs, resulting in a game well suited for them (Vute, 2005). Considering all of these factors, sitting-volleyball has a great physical benefit along with a social benefit.

*Speed*

In standing volleyball moving for the ball using a crossover step, requires running (Giovanazzi, 2006). In examining the skill of moving to the ball to block, time should be analyzed at a time (Giovanazzi, 2006). Speed development is important in getting to the ball and winning points (Nall, 2007). Speed is vital to the game. These facts emphasize that moving quickly is key to winning points. There are two ways to accelerate: increasing length of stride and frequency. Strength is an important determinant of speed that needs to be increased to improve acceleration. Players in the standing game cross over and sprint, pivot and bound, or turn their body and bound (Nall, 2007). In standing volleyball, the posture that a player takes to sprint across court has a pronounced lean to play the ball (Nall, 2007). We suggest that these principles apply to the sitting-volleyball player. Instead of crossing over with their feet, the sitting player reaches across, turns, or slides their body by reaching with their arms and hands. The sitting volleyball player must focus as to where the best place to reach to or from to move quickly in the seated position.

In sitting-volleyball posture is vital to movement and specific levels of posture are needed for specific skills in standing volleyball (Kus, 2004, p 83). Low, medium, and high postures in sitting volleyball are distinguished by the position of the arms. Low posture would be dig just above floor level. Medium level posture would be a mid chest level or shoulder level dig. High body position would be distinguished by overhead plays such as a set or a tip or spike (Kus, 2004, p 83). Before contact with the ball, the player should be in the ready posture. This requires the player's position is loaded and ready to move or the pre-movement position.

Moving towards the ball efficiently begins with the foot farthest from the direction the player is moving in or the ball (Kus, 2004, p 84). Movement to the ball needs to occur prior to the ball reaching the ideal or optimal hitting position (Kus, 2004, p 85). The player's weight should be central to their stance to maintain balance (Kus, 2004, p 85). Team's must gain movement techniques first prior to working on speed of movement (Kus, 2004, p 85). Tempo at practice should be higher than game speed (Kus, 2004, p 85). Player errors such as moving too slowly requires that the player runs through the ball in order to make the play (Kus, 2004, p 85). Movement towards the ball at the proper pace occurs more often when the player focuses and makes anticipatory movement towards the ball with each touch prior to contact (Kus, 2004, p 85). Movement in most game situations is prior to contact with the ball (Kus, 2004, p 85). Thus fast and efficient movement is essential to the game of sitting-volleyball.

*Blocking*

Blocking is one of the most demanding skills in volleyball because of the need of quick, precise movements to the ball. To win at volleyball, a team must have effective outside hitters and blockers (Wall, 2006). Successful digs and blocks offer additional scoring opportunities. Winning the blocking battle, although import, can still result in a loss. Offense must be paired with defense to have a winning game. Points achieved by scoring in transition from defense to offense are more likely to decide a match than all other statistics (Wall, 2006). The key to successful transition is getting into position quickly to play the ball effectively. Transition is moving from one ready position to another (Wall, 2006). The defensive players behind the blocker must adjust to the hitter as well. Reading the hitter is a vital skill of the defensive player (Wilde, 2001). Moving to the open space provided by the block will lead to an optimal defensive position (Wilde, 2001).

In standing volleyball the player should be able to move towards and receive the passed ball in just a few steps (Shondell and Reynaud, 2002, p 179). In standing volleyball the blocker can either slide or perform a step over technique. In the step over, the hips turn away from the net but the player continues to follow the play visually. Before movement begins, the player should have a balanced body position (Shondell and Reynaud, 2002, p 245). When there are several quick sets taking place the blocker may commit to the hitter which can lead to lost points or slowing down the opponent's offensive play. This should result in the opponent's setter diverting the ball to other non-preferred hitters (Shondell and Reynaud, 2002, p 250). When using the commit blocker a stack blocker can move to the second hitter at the time the commit blocker covers the quick hitter. This helps form a defensive line for a stronger position at the net (Shondell and Reynaud, 2002, p 253).

In "read blocking" the read is not of the ball from the hitter but the ball as it leaves the setters hands (Lawler, 2006). Reading is often overlooked for time to focus on footwork and hand position. The hitter must be identified by the blocker based on the ball release from the setter. Additionally, the habits of a particular hitter should be known by the blocker. Blockers should verbally call out the set ball for direction. Initially, the blocker will have better results the longer they can focus on the setter. When the blocker looks at the setter, their peripheral vision should allow them to see the hitter. Once the blocker shifts towards the hitter, they are able to commit to the trajectory of the hit ball. Drills that train the blocker to move along the net and read the set will improve their game skills (Lawler, 2006). Moving is continuous in volleyball because of the reading of the opponent and flight of the ball.

Position of the blocker requires precision because where they are in relationship to the net determines success in many cases. A block should form a solid wall or barrier at the net with the players hands with the arms fully expended (Sandorfi, 2000). The block should be viewed as a shield and blockers need to move quickly into position to refrain from swatting at the ball. Their hands should be closer together for those with smaller hands and wider with large handed players. The thumbs should be a few inches apart and never touch to form the "wall." This hand position will for the largest barrier possible for the blocker. The position of the hitter to the net will aid the blocker in determining the timing of the block (Sandorfi, 2000).

*Movement*

There are fundamental differences of the temporal and spatial movements in response to the ball between the novice and expert player (Abernathy, 1989). Expert players are able to interpret information 83 to 167 milliseconds prior to contact by the setter (Abernathy, 1989). The more advanced the player the more they will be able to interpret and in turn, use this information. Sport specific motor performances can best be analyzed through the multiple disciplines (Kluka, Love, Kahlman, Hammack, and Wessan, 1996). The game of volleyball has the smallest playing area of any team sport, 72 square feet. Smaller playing areas create a congested area for players to move and react to each other and the ball. Tracking the movement of the ball can be difficult and the timing of movement can be even more difficult (Kluka, Love, Kahlman, et al., 1996). When taken together, these finding highlight the quickness of the sport of volleyball and how quick a player must be to succeed.

Ground reaction forces are different in the sitting game compared to the standing game. Pre-activation of the primary movement muscles occurs in anticipation of movement for both the standing and sitting player (Wakeling, et al., 2001). Walking or running contact with the ground creates a muscle reaction and results in contraction and movement (Wakeling, Tscharner, Nigg, and Stergiou, 2001). This results in muscular activation (Wakeling, et al., 2001). The difference from standing to sitting is the contact results in the activation in different muscle groups of different limbs.

*Movement of Disabled Athletes*

The pull of luge is very similar to that of the sitting volleyball player's arm stroke during floor movement (Hancock, 1988). This is a far reaching reference and indicative of the need for research that relates the standing game to the sitting game. In defining the movement of a player in arm movement, the terms stroke length, time, and frequency are used. This term has been used here to describe arm movements. Stroke length is distance from one complete stroke until the next (Chow, Milklikan, Carlton, Chae, and Morse, 2000). Stroke length is the distance covered in one stroke (Chow et al., 2000). Stroke time is the time needed to complete one full stroke (Chow et al., 2000). Stroke frequency is the reciprocal of the stroke (Chow et al., 2000). These statements to describe stroke length are the most readily understood terms to describe the arm movements of the sitting-volleyball player.

There are no existing studies in which the disabled athletes' movement is analyzed moving on a surface without an assistive device. Wheelchair movement is the primary movement assist device that has been studied. Movement of the arms in propelling a wheelchair forward is opposite that of the sitting-volleyball player's arm movements. Analysis of wheelchair movement of the disabled athlete does not apply to this topic except for backward movement. The sitting-volleyball player is at a significant mechanical disadvantage to the wheelchair athlete.

Finding the relationship between velocity parameters and force during wheelchair propulsion was the aim of the study (Hintzy, Tordi, Predine, Rouillon, and Belli, 2003). The authors observed 17 able bodied females (age 30.0±10.2). Data on each subject were collected on a wheelchair ergometer created by modifying a manual wheelchair and placing it on a treadmill. Force and velocity had a strong negative linear relationship ($r$ = -.969, $p$ = .01). Maximal power (1.28 Watts per kg) and optimal velocity (1.49 meters per second) were found to have a positive linear relationship ($r$ = .678, $p$ = .01). This is a finding consistent with arm cranking, 2.21 meters per second, and wheelchair propulsion, 4.39 meters per second (Hintzy, Tordi, Predine, et al., 2003). Force and velocity are dependent on the type of movement and basic biomechanical principles explain these differences. The large distance that can be covered with one arm stroke using a wheelchair is not comparable to that of the distance of one arm stroke while seated on a floor surface. Maximal force does apply and velocity is important in moving in sitting-volleyball.

Forces during movements are transferred through the shoulder to the trunk of the body. Shoulder complex muscles must all work together to propel the body and stabilize the shoulder during movement. Four healthy male subjects (Van der Helm and Veeger, 1996) were measured on the ergometer at -15, 0, 15, 30, and 60 degrees and attempted to prevent the rims of the wheelchair from turning backwards against the resistance of zero maximal voluntary moment and increasing in 10% increments until reaching 40% (Van der Helm and Veeger, 1996). Pressure on the shoulder joint in movement was greatest at hand position 0 and 15 degrees. The larger muscles of the shoulder need to be recruited to ensure the joint is stabilized during loads of all levels (Van der Helm and Veeger, 1996).

The ability of the player to maintain their balance as they move is important. If the player is unable to maintain their balance the optimal sequential transfer of energy will not take place. In a study of hip strength, lower limb amputees were found to have weaker abductor and extensor muscle groups. Croisier, Noorhout, Maquet, Camus, Hac, Feron, Lamotte, and Crielaard (2001) used isokinetic testing measures of 33 (19 transfemoral and 14 transtibial) amputees to determine the strength of the hip complex muscles of unilateral amputees. Significant weaknesses were found in the extensor and abductor muscle groups on the amputated side. This has a significant impact on the choice of prosthesis as well as physical therapy for use of the selected device. A t-test and a two-way ANOVA were conducted in the Croisier et al. study. Through these two tests, the differences were found to be bilateral and unrelated to time since amputation ($p$ = .05).

Stability of the trunk cannot be disregarded for its potential impact on movement. Kamper, Barin, Parniapour, Reger, and Weed (1999) analyzed the impact of an unstable surface with spinal cord injured subjects ($n$ = 13 males). Each subject was able to maintain a predetermined level of maintenance of posture before being twice subjected to the disturbance platform. Under the conditions of the disturbance platform, subjects were unable to maintain their body in an upright posture ($p$ = .05). This is similar to the lack of stability of the amputee athlete. The prosthesis is removed during game play or if the subject chooses to not have a prosthetic a lack of ancillary leg muscles aiding in balance are in absentia. Fewer muscles are dedicated to support of the trunk alone in the amputee.

Wakeling, et al. (2001) studied the reaction of the leg muscles response to ground strike. Using a pendulum device, the subjects were laid flat on their backs then swung feet first into a force plate. Substantial differences in multiple variances were seen in the activity measured by the EMG in all muscles analyzed (tibialis anterior, medial gastrocnemius, vastus medialis, biceps femoris). These muscles were speculated to control the impact of the ground force reaction and control balance ($p$ =.05). If there were to be an experiment on the sitting player, it could be presumed that the latissimus dorsi, bicps, triceps, and forearm muscles would be the muscles to control the impact of locomotion.

Seelen and Vuurman (1991) found that the latissimus dorsi and trapezius muscles are stabilizers for paraplegics in sitting postures. Although Seelen and Vuurman looked solely at paraplegics (11 = males, 4 = females) and not amputees, there are many similarities with amputees from a theoretical standpoint. Individuals who would have less or no control of the lower limbs or lack lower limbs would not be able to flex the legs to stabilize. This means that an individual with amputations would experience something similar to the spinal cord injured individual. Core strength and balance could be determined to be vital for agility and speed with muscles that are not true stabilizers or movers. This modification of roles can be directly attributed to amputation and does not exist in able bodied persons.

Predicting the force a muscle can produce offers insight into movement abilities. Muscle taking on more than one role is more likely to fatigue, especially if they are aerobic in nature (Gonzalez, Urena, Llop, Garcia, Martin, and Navarro, 200; Goosey-Tolfrey, Castle, and Webborn, 2006). Kaufman, An, Litchy, and Chaos (1991) stated that prediction of muscle forces cannot take place under maximal muscle stress, but can under minimal muscle activation. Prediction of muscle force could be used to determine the body composition issues for players that can slow them down. If the forces of the muscles are known, the amount of weight that can be moved and how fast can be calculated. This can be helpful in another important area, which is overcoming the ground reaction force.

These are all anomalies that if answered will benefit the game of sitting-volleyball. Volleyball, regardless of sitting or standing differentiation, requires movement and understanding of ball movement (Wright, Pleasants, and Gomez-Meza, 1990). Twelve NCAA Division I volleyball players with an average of 6.6 years of playing experience were compared to 12 novice level players with an average of .03 years of experience. While viewing film of expert players, experienced group members were able to distinguish the direction of the ball with 167 milliseconds (five frames of film) prior and post the setters contact. The experience players mean success proportional responses (*r* = .86) were significantly better than those of the novice group (*p* = .58).

*Injury*

The variety of shoulder injuries are almost always related to repetitive motions (Vlyshou, Spanomichos, Chatziioannou, Georganas, and Zavras, 2001). Vascular problems may occur in the form of embolisms of the humeral artery in the posterior circumflex. When found its pathology was related repeated overhead motions. Injuries such as this and impingements are related to muscular imbalances in the shoulder that can cause abnormal movement of the humeral head either superiorly or anteriorly (Jacobsen and Benson, 2001). Formations of ganglion cysts, labrum damage superiorly, and hemorrhage occur because of the repeated overhead motions and the abrupt stoppage of movement that occurs during the spike (Wang and Koehler, 1996). This is the same pathology as many other shoulder injuries, such as tendonitis, that occur in overhead or throwing sport players.

The incidence of overuse injuries averages at 0.6 injuries for 1000 playing or practicing hours in volleyball players of all ages (Verhagen, Van der Beek, Bouter, Bahr, and Van Mechlen, 2004). Shoulder overuse injuries are among the most common. Shoulder injuries as a whole are common in volleyball and those that are relevant to the sitting-volleyball player are also relevant to the standing player. The sitting players must move themselves using their arms and shoulders as well as use them to play the ball. Propulsion injuries of the shoulder happen when paraplegics use wheelchairs as resulting in eccentric and concentric-eccentric exercise in the shoulder complex (Mayer, Bilow, Horstmann, Martini, Niess, Rocker, and Dickhuth, 1999). It could also be presumed that amputees who use crutches as a mode of propulsion are also at similar risk. This is a cross-section of the players that participate in sitting–volleyball. Thus shoulder injuries are the primary focus in sitting volleyball players.

Preventing injuries is the proactive role of proper training. Because of the muscular imbalances that are common in volleyball players and the amputee/paraplegic individual, this should take on focus. Exercises that would result in muscular balances, in the rotator cuff and surrounding shoulder complex would help eliminate the origin or most injuries and chronic complaints. Briner and Lawrence (1997) stated that stabilizing exercises would help eliminate tendonitis in the shoulder of volleyball players. Any abnormalities should be address to help maintain balance (Briner and Lawrence, 1997). Analysis of the shoulder should involve a complete kinesiological exam because of the dynamic stress of sudden changes in movements involved in the sport (Kahn, Guillet, and Fanton, 2001). Focuses in training on range-of-motion, strengthening (open and closed chain), and eccentric exercises, when combined with proprioceptive neuromuscular facilitation, aid in results of balanced shoulder musculature (Ellenbecker and Davies, 2000; Kahn, et al. 2001).

Pressure on the shoulder is a problem for the sitting-volleyball player. Analyzing pressure in the shoulder is a critical measurement. Through a catheter inserted subacrominal position pressure measurements were continuously attained during six activities: resting in neutral rotation and adduction, active forward flexion, active abduction, adduction with maximum contraction, supporting the weight of the body on the arms while in the seated position, and active transfer from wheelchair to bed (Bayley, Cochran, and Sledge, 1987). Of 142 subjects, 94% of the subjects were confined to wheelchair but could transfer themselves (Bayley, et al., 1987). Subjects who complained of shoulder pain were more commonly those who had not exercised (Bayley, et al., 1987). Sixty five percent had torn a rotator cuff muscle (Bayley, et al., 1987). There was a lack of initial incident for categorization of rotator cuff injuries as chronic in nature and degenerative (Bayley, et al., 1987). Injury patterns of sitting-volleyball players needs to be conducted in the near future.

*Summary*

The review of literature illustrates the lack of research that is directly related to sitting-volleyball analysis of movement. Volleyball literature on game-related movement is exceptional. This applies to the sitting-volleyball player, but the literature that is available that applies to the shoulder, arm, and hand complex as primary movers of the body on a linear surface does not exist. The foundation of information that was found provides a solid impetus for the project.

# CHAPTER THREE

## Methodology

### *Introduction*

The purpose of the study was to assess the effectiveness of hand placement and body position on movement of sitting-volleyball players. The subjects were studied at the University of Central Oklahoma Wellness Center located in Edmond, Oklahoma. All trials were filmed on a regulation sitting-volleyball court that was designated by the UCO Paralympic Training Coordinator.

### *Subjects*

The United States Paralympic Women's sitting-volleyball team volunteered for the study. The team was in training at the time.

### *Variables*

The independent variables for movement at the net were body position (open or closed) and direction (center-to-side or side-to-center). Open body position was defined as the player's body facing the sideline when moving parallel to the net for two meters. Closed body position was defined as the player's body facing the net as they moved laterally for two meters. Hand placement (anterior, lateral, or posterior) and direction (forward or backward) were independent variables for the six meter movement trials. Forward and backward were defined as the movement of players when facing the sideline in front of them and then behind them. Hand position was defined as anterior, lateral and posterior. Anterior placement was in front of the hips on the floor on the left and right side of the body. Lateral hand placement was on the floor even with the hips on each side of the body. Posterior hand placement was behind the hips on each side, respectively.

The dependent variable for both the two and six meter trials was the time it took for the player to reach a given distance. The timing began with the initial movement of the player's hands and ended when the player reached the given end point. In the six meter trial this was breaking the plane of the meter line. For the two meter trial conducted at the net, breaking the two meter net plane was the end point.

Each variable was filmed using a compact digital Sony Compact Digital (Tokyo, Japan) video camera and analyzed using Dartfish 4.5.2 (Alpharetta, Georgia) software. The distances filmed were referenced using the width of the volleyball court (6 meters) as the reference measurement. Filming was completed on court level from the end line of a standard regulation sitting volleyball court. A rear court view was used for filming at a height of one meter.

*Procedures*

Timing of movement for the six meter trials was measured three times with Dartfish 4.5.2 TeamPro and using a Brower Timing Systems (Draper, Utah) Wireless Sprint System. A sensor gate was used to begin timing with the initial player movement. Once a player's contact with the sensor beam from the gate was broken, timing began and did not end until the player passed through a second sensor gate. In the six meter trial each player moved from one side line to another (6 meters). Each player moved in two directions - forward and backward. Trials were conducted using each of three hand positions (anterior, lateral, and posterior) for each direction. Players were instructed to move as quickly as possible during each trial.

Timing of movement for the two meter trials was measured twice with Dartfish 4.5.2 TeamPro and using a Brower Timing Systems (Draper, Utah) Wireless Sprint

System. A sensor gate was attached to the net at each sideline and was used to begin and end timing with the initial and final player movement. Each player began the trials with their arms up and hands facing the net in the blocking position. Once a player's hands contacted the sensor beam from the gate, timing began and did not end until the player moved two meters to a set marker in the blocking position facing the net.

*Statistical Analysis*

The times for hand and body position and direction combinations were analyzed using a two factor repeated measure design with SAS software (Cary, NC, version 9.1). P-values less than 0.05 were considered statistically significant.

# CHAPTER FOUR

## Results

*Introduction*

There were differences between movement times of individuals who moved with an open or closed body position from one position at the net to another regardless of direction. Statistically insignificant differences between forward and backward movement times of individuals who use a forward, lateral, or posterior hand positions were seen. A two-factorial analysis of variance (2 X 2 ANOVA) was performed for the two meter trial at the net – open and closed movement times for center to sideline and sideline to center. A two- factorial analysis of variance (2 X 3 ANOVA) was performed for the six meter trials – anterior, lateral, and posterior hand positions for forward and backward movement times. Times were recorded during the trials and were entered into SAS. Only one of these findings was significant statistically. On a level of volleyball significance, the findings were all valuable in understanding movement in the sitting game.

*Research Questions*

1. Is there a significant difference between mean movement times with regard to body position (open and closed)?

Questions 1, 1a, and 1b were the basis of the two meter trials. In question 1, a significant difference ($p$ = .1822) was not found between movement time with regard to body position (open and closed). In the open position (3.04 seconds) a range of 2.36 to 3.90 seconds were recorded. In the closed position (2.29 seconds) a range of 2.23 to 4.34

were recorded. The range of times recorded for the closed position was greater than that of the open position. These results are shown in Table 1.

Table 1.

Open Versus Closed

| Position | n | M | SD | Range |
|---|---|---|---|---|
| Open | 20 | 3.04 | .47 | 2.36 - 3.90 |
| Closed | 20 | 2.29 | .58 | 2.23 - 4.34 |

*Note*. $p$ = 0.1822. Open and closed refer to body position at the net.

1a. For the center-to-side direction, is there a significant difference between mean movement times with regard to body position (open and closed)?

In question 1a, the direction of movement of center of the court to the sideline ($p$ = .0366) was analyzed. A range of times were recorded for the open position (2.36 to 3.59 seconds) and closed position (2.30 – 3.73 seconds). Statistically significant differences were found when moving from the center of the court to the sideline when comparing the open and closed body positions. The closed body position was faster (2.86 ± .46) when compared with the open body position (3.07 ± .42). Results for question 1a are located in Table 2.

Table 2.

Open Versus Closed Center of the Court to Sideline Moving to the Right

| Position | n | M | SD | Range |
|---|---|---|---|---|
| Open | 10 | 3.07 | .42 | 2.36 - 3.59 |
| Closed | 10 | 2.86 | .46 | 2.30 - 3.73 |

*Note.* $p = 0.0366$. Open and closed refer to body position at the net. Center refers to center of the court and side refers to the sideline.

1b. For the side-to-center direction, is there a significant difference between mean movement times with regard to body position (open and closed)?

In question 1b, the direction of movement of sideline to center ($p = .7967$) was analyzed. A range of times were recorded for the open position (2.41 – 3.90 seconds) and closed (2.23 – 4.34 seconds). Results for question 1b are located in Table 3.

Table 3.

Open Versus Closed Side of the Court to Center Moving to the left

| Position | n | M | SD | Range |
|---|---|---|---|---|
| Open | 10 | 3.00 | .53 | 2.41 - 3.90 |
| Closed | 10 | 2.97 | .71 | 2.23 - 4.34 |

*Note.* $p = 0.7967$. Open and closed refer to body position at the net.

2. Is there a significant difference between mean movement times with regard to direction (center-to-side and side-to-center)?

Questions 2, 2a, and 2b were the basis of the two meter trials. In question 2, a significant difference ($p$ = .8547) was not found between movement time with regard to direction (center-to-side and side-to-center) when not taking into account body position (open and closed). In regard to direction, center-to-side mean time of 2.97 seconds and a range of 2.30 to 3.73 seconds were recorded. In the side-to-center 2.99 seconds was the mean with a range of 2.23 to 4.34 were recorded. The range of times recorded for the side to center was greater than that of the center-side. These results are shown in Table 4.

Table 4.

Mean Movement Times with Regard to Direction

| Position | n | M | SD | Range |
|---|---|---|---|---|
| Center-Side | 20 | 2.97 | .44 | 2.30 – 3.73 |
| Side-Center | 20 | 2.99 | .61 | 2.23 - 4.34 |

*Note.* $p$ = 0.8547. Center refers to center of the court and side refers to the sideline.

2a. For the <u>open</u> body position, is there a significant difference between mean movement times with regard to direction (center-to-side and side-to-center)?

In question 2a, the open body position was analyzed with regard to direction of movement of center-to-side and side-to-center ($p$ = .4928). A range of times were recorded for the open position (2.36 to 3.59 seconds) and closed position (2.41 – 3.90 seconds). This was not a statistically significant finding. Results for question 1a are located in Table 5.

Table 5.

Open Position Mean Movement Times with Regard to Direction

| Position | n | M | SD | Range |
|---|---|---|---|---|
| Center-Side | 10 | 3.07 | .44 | 2.36 – 3.59 |
| Side-Center | 10 | 3.00 | .53 | 2.41 – 3.90 |

*Note*. $p$ = 0.4928. Center refers to center of the court and side refers to the sideline.

2b. For the closed body position, is there a significant difference between mean movement times with regard to direction (center-to-side and side-to-center)?

In question 2b, the closed body position was analyzed with regard to direction of movement of center-to-side and side-to-center ($p$ = .3639). A range of times were recorded for center-to-side (2.39 – 3.73 seconds) and side-to-center (2.24 – 4.34 seconds). This was not a statistically significant finding. Results for question 2b are located in Table 6.

Table 6.

Closed Position Mean Movement Times with Regard to Direction

| Position | n | M | SD | Range |
|---|---|---|---|---|
| Center-Side | 10 | 2.86 | .46 | 2.30 – 3.73 |
| Side-Center | 10 | 2.97 | .71 | 2.24 – 4.34 |

*Note*. $p$ = 0.3639. Center refers to center of the court and side refers to the sideline.

3. Is there a significant difference between mean movement times with regard to hand position (anterior, lateral, and posterior)?

Questions 3, 3a, and 3b were the basis of the six meter trials. In question 3, a significant difference ($p$ = .7326) was not found between movement time with regard to hand position (anterior, lateral, and posterior). In regard to hand positions the recorded times were anterior at 4.17, lateral at 4.15, and posterior at 4.24 seconds. The ranges of at times each hand position were 2.56 – 5.47 seconds for anterior, 2.79 – 5.76 seconds for lateral and 2.47 – 6.00 seconds for posterior. The largest range of times recorded for the six meter trials was for posterior. The results are shown in Table 7.

Table 7.

Mean Movement Times with Regard to Hand Position

| Position | n | M | SD | Range |
|---|---|---|---|---|
| Anterior | 22 | 4.17 | .63 | 2.56 – 5.47 |
| Lateral | 22 | 4.15 | .74 | 2.79 – 5.76 |
| Posterior | 22 | 4.24 | .82 | 2.47 – 6.00 |

*Note.* $p$ = 0.7326. Anterior was defined as in front of the hips. Lateral to the side of the hips. Posterior behind the hips.

3a. For the forward direction, is there a significant difference between mean movement times with regard to hand position (anterior, lateral, and posterior)?

In question 3a, forward movement was analyzed with regard to hand position ($p$ = .2418). The mean forward movement times for the hand positions were 4.28, 4.13, and

4.37 seconds for anterior, lateral, and posterior. A range of times were recorded for the anterior (3.43 – 5.47 seconds), lateral (3.32 – 5.76 seconds) and posterior (3.46 – 6.00 seconds) hand positions. This was not a statistically significant finding. Results for question 3a are located in Table 8.

Table 8.

Mean Forward Movement Times with Regard to Hand Position

| Position | n | M | SD | Range |
|---|---|---|---|---|
| Anterior | 11 | 4.28 | .55 | 3.43 – 5.47 |
| Lateral | 11 | 4.13 | .68 | 3.32 – 5.76 |
| Posterior | 11 | 4.37 | .82 | 3.46 – 6.00 |

*Note.* $p = 0.2418$.

3b. For the <u>backward</u> direction, is there a significant difference between mean movement times with regard to hand position (anterior, lateral, and posterior)?

In question 3b, backward movement was analyzed with regard to hand position ($p = .2418$). The mean forward movement times for the hand positions were 4.28, 4.13, and 4.37 seconds for anterior, lateral, and posterior. A range of times were recorded for the anterior (3.43 – 5.47 seconds), lateral (3.32 – 5.76 seconds) and posterior (3.46 – 6.00 seconds) hand positions. This was not a statistically significant finding. Results for question 3b are located in Table 9.

Table 9.

Mean Backward Movement Times with Regard to Hand Position

| Position | n | M | SD | Range |
|---|---|---|---|---|
| Anterior | 11 | 4.07 | .72 | 2.56 – 5.22 |
| Lateral | 11 | 4.17 | .82 | 2.79 – 5.76 |
| Posterior | 11 | 4.10 | .84 | 2.47 – 5.78 |

*Note. p* = 0.7799.

4. Is there a significant difference between mean movement times with regard to direction (forward and backward)?

Questions 4, 4a, and 4b were the basis of the six meter trials. In question 4, a significant difference (*p* = .2437) was not found between movement time with regard to direction (forward and backward) when not controlling for hand position. In regard to direction the mean times were forward at 4.26 and backward at 4.12. The ranges of at times each direction were 3.32 – 6.00 seconds for forward and 2.47 – 5.78 seconds for backward. The largest range of times recorded for the six meter trials in regard for direction was for backward. The results are shown in Table 10.

Table 10.

Mean Backward Movement Times with Regard to Direction

| Position | n | M | SD | Range |
|---|---|---|---|---|
| Forward | 33 | 4.26 | .68 | 3.32 – 6.00 |
| Backward | 33 | 4.12 | .82 | 2.47 – 5.78 |

*Note*. $p$ = 0.2437.

4a. For the anterior hand position, is there a significant difference between mean movement times with regard to direction (forward and backward)?

In question 4a, forward and backward movement with anterior hand placement was analyzed ($p$ = .2057). The mean forward movement times with anterior hand position was 4.28 seconds for forward movement and 4.07 seconds backward movement. The ranges of times were recorded for the anterior hand placement moving forward was 3.43 – 5.47 seconds and 2.56 – 5.22 seconds for backward movement. This was not a statistically significant finding. Results for question 4a are located in Table 11.

Table 11.

Mean Movement Times with Regard to Direction and Anterior Hand Placement

| Position | n | M | SD | Range |
|---|---|---|---|---|
| Forward | 11 | 4.28 | .55 | 3.43 – 5.47 |
| Backward | 11 | 4.07 | .72 | 2.56 – 5.22 |

*Note*. $p$ = 0.2057.

4b. For the <u>lateral</u> hand position, is there a significant difference between mean movement times with regard to direction (forward and backward)?

In question 4b, forward and backward movement with lateral hand placement was analyzed ($p$ = .8244). The mean forward movement times with lateral hand position was 4.13 seconds for forward movement and 4.17 seconds backward movement. The ranges of times were recorded for the lateral hand placement moving forward was 3.32 – 5.76 seconds and 2.79 – 5.76 seconds for backward movement. This was not a statistically significant finding. Results for question 4b are located in Table 12.

Table 12.

Mean Movement Times with Regard to Direction and Lateral Hand Placement

| Position | n | M | SD | Range |
|---|---|---|---|---|
| Forward | 11 | 4.13 | .68 | 3.32 – 5.76 |
| Backward | 11 | 4.17 | .82 | 2.79 – 5.76 |

*Note*. $p$ = 0.8244.

4c. For the <u>posterior</u> hand position, is there a significant difference between mean movement times with regard to direction (forward and backward)?

In question 4c, forward and backward movement with anterior hand placement was analyzed ($p$ = .2057). The mean forward movement times with posterior hand position was 4.37 seconds for forward movement and 4.10 seconds for backward movement. The ranges of times were recorded for the posterior hand placement moving forward was 3.46 – 6.00 seconds and 2.47 – 5.78 seconds for backward movement. This was not a statistically significant finding. Results for question 4c are located in Table 13.

Table 13.

Mean Movement Times with Regard to Direction and Posterior Hand Placement

| Position | n | M | SD | Range |
|---|---|---|---|---|
| Forward | 11 | 4.37 | .82 | 3.46 – 6.00 |
| Backward | 11 | 4.10 | .84 | 2.47 – 5.78 |

*Note*. $p$ = 0.1097.

There was no significant difference ($p$ = 0.7326) between the mean movement times of individuals who used an anterior (4.17 seconds), lateral (4.15 seconds), or posterior (4.24 seconds) hand position. The lowest mean movement time for all hand positions was the anterior hand position when moving backward (4.07 seconds). Figure 1 displays the mean times for hand positions when moving forward and backward. The intersection of the lines indicates that the means within a given direction for the lateral hand placement as being the best (4.13 seconds) and the worst (4.17 seconds) times.

There was no significant difference ($p$ = 0.8547) between the mean movement times of individuals who moved with an open (3.04 seconds) or closed (2.92 seconds) body position at the net. However, when moving from center-to-side, there was a significant difference ($p$ = 0.0366) between the mean movement times for open (3.07 seconds) and closed (2.86 seconds) body position. Figure 2 displays the mean times for body position when moving from center-to-side and from side-to-center. The closed body position had faster times than the open position for both directions.

The lack of statistical significance does not fully explain what was found by the study. A lack of adequate subjects has left the researchers with a statistical finding that does not reflect the true reality of the research topic.

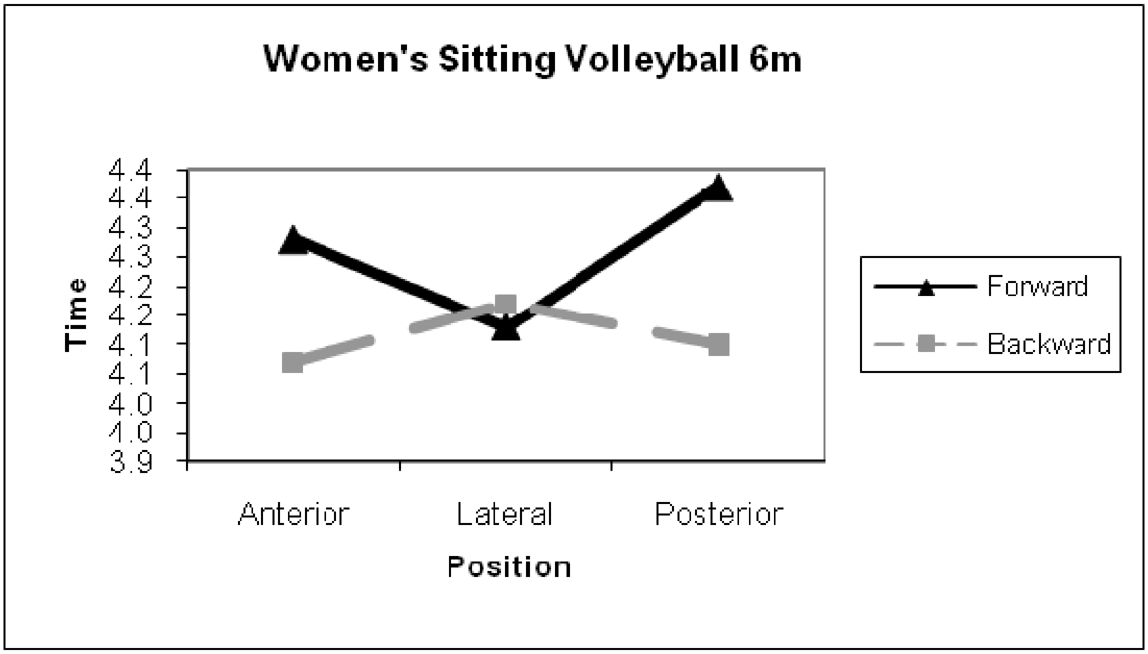


Figure 1. Line graph of women's sitting volleyball movement times at 6 m

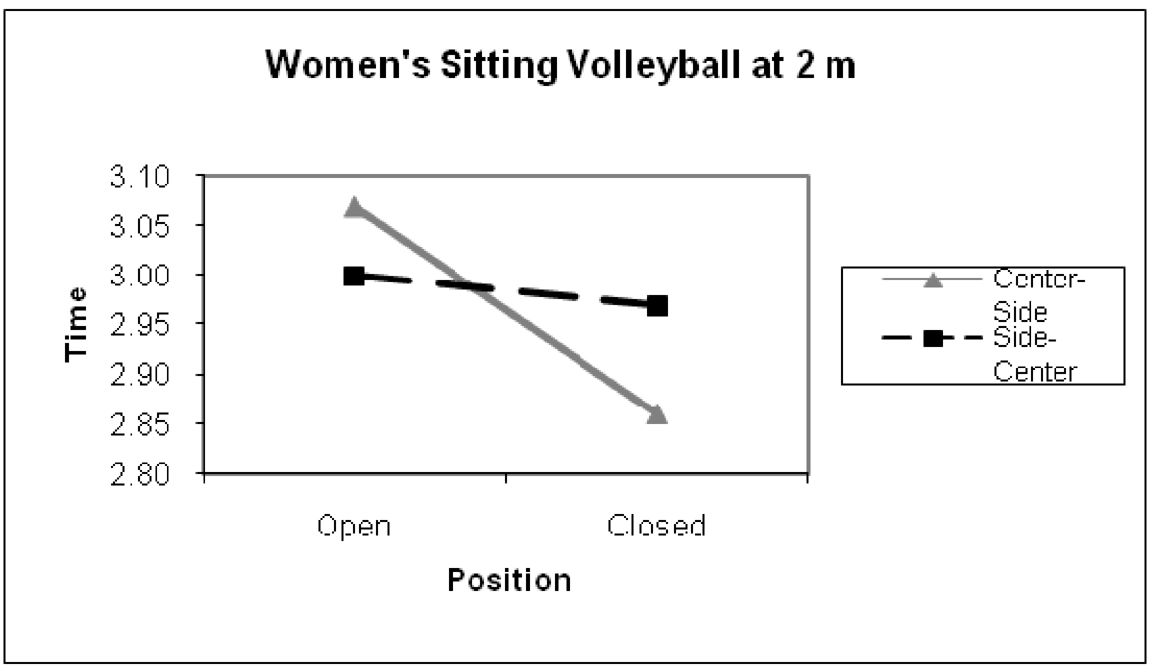


Figure 2. Line graph of women's sitting volleyball movement times at 2 meters.

# CHAPTER FIVE

## Discussion

### *Introduction*

One research question resulted in a statistically significant finding. This finding was in the two meter trials with the player moving from the center of the net to the sideline to their right. The closed position mean time was .21 seconds faster that the open position. Image 1 shows the difference in movement distance for a given time for a single subject moving in an open and closed position, respectively. The player is moving to the right. This is further explained by Image 2. This center of the court movement in the closed position was statistically significantly faster than the open position. A difference of .26 seconds exists from the time the figure on the left is in the block position to the figure on the right. Little argument can be made that there is meaningful difference in the two figures ability to block the ball from their positions in the photo.

The open position can be seen as less effective in allowing the player to arrive prepared to play the ball. The researchers hypothesize that the lack of significant in movement to the left in the open and closed positions may be related to the level of amputation and its location in each subject. Individual adaptations to movement make it difficult to precisely state the direct reason for the difference or lack of difference in movement times.

A lack of statistical significance does not truly represent the result of the study. There are several instances that need to be discussed and explored further that are relevant and meaningful to the sport of sitting-volleyball. Images taken from the digital film illustrate the importance of not only the data that obtained, but other key areas of future research. The importance of balance, muscular endurance, energy system efficiency, core strength, and training techniques are all related to the findings of this study. These areas of importance of each of these areas are not independent of each other.

Image 1. Open compared to closed body position with same subject.

Open Position →  ← Closed Position

Image 2. Open compared to closed body position with same subject.

Open Position →  ← Closed Position

There are no studies from which to answer the proposed research questions. The greater issue of understanding sitting-volleyball is the impact this understanding will have on Paralympians, disabled children, and young adults who are future Paralympic hopefuls. The purpose of the study was to assess the lateral, forward, and backward movement of sitting-volleyball players over two given distances, two and six meters. As was previously discussed, the very muscles that move the body are the same as those that execute game skills. Movement and skill performance forms a unique paradigm that has not been explored.

Future funding will need to increase as the awareness of sitting-volleyball increases. Funding increases would allow for greater travel for players and the ability to coordinate more player participation in future studies. More examination needs to take place on training methods to help isolate the habits that are beneficial to performance of game skills and conditioning. Amputation level is another area that should be addressed in future studies. This is one of many issues facing the athlete. A prominent limitation of this study was its low subject number. Providing answers to performance questions from athletes and coaches has been an area that is lacking. Answers are not quickly found, but attempts are being made to enhance the body of knowledge concerning the sport.

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Table 1.

Open Versus Closed

| Position | n | M | SD | Range |
|---|---|---|---|---|
| Open | 20 | 3.04 | .47 | 2.36 - 3.90 |
| Closed | 20 | 2.29 | .58 | 2.23 - 4.34 |

*Note*. $p$ = 0.1822. Open and closed refer to body position at the net.

Table 2.

Open Versus Closed Center of the Court to Sideline Moving to the Right

| Position | n | M | SD | Range |
|---|---|---|---|---|
| Open | 10 | 3.07 | .42 | 2.36 - 3.59 |
| Closed | 10 | 2.86 | .46 | 2.30 - 3.73 |

*Note*. $p$ = 0.0366. Open and closed refer to body position at the net. Center refers to center of the court and side refers to the sideline.

Table 3.

Open Versus Closed Side of the Court to Center Moving to the left

| Position | n | M | SD | Range |
|---|---|---|---|---|
| Open | 10 | 3.00 | .53 | 2.41 - 3.90 |
| Closed | 10 | 2.97 | .71 | 2.23 - 4.34 |

*Note*. $p$ = 0.7967. Open and closed refer to body position at the net.

Table 4.

Mean Movement Times with Regard to Direction

| Position | n | M | SD | Range |
|---|---|---|---|---|
| Center-Side | 20 | 2.97 | .44 | 2.30 – 3.73 |
| Side-Center | 20 | 2.99 | .61 | 2.23 - 4.34 |

*Note*. $p$ = 0.8547. Center refers to center of the court and side refers to the sideline.

Table 5.

Open Position Mean Movement Times with Regard to Direction

| Position | n | M | SD | Range |
|---|---|---|---|---|
| Center-Side | 10 | 3.07 | .44 | 2.36 – 3.59 |
| Side-Center | 10 | 3.00 | .53 | 2.41 – 3.90 |

*Note*. $p$ = 0.4928. Center refers to center of the court and side refers to the sideline.

Table 6.

Closed Position Mean Movement Times with Regard to Direction

| Position | n | M | SD | Range |
|---|---|---|---|---|
| Center-Side | 10 | 2.86 | .46 | 2.30 – 3.73 |
| Side-Center | 10 | 2.97 | .71 | 2.24 – 4.34 |

*Note*. $p$ = 0.3639. Center refers to center of the court and side refers to the sideline.

Table 7.

Mean Movement Times with Regard to Hand Position

| Position | n | M | SD | Range |
|---|---|---|---|---|
| Anterior | 22 | 4.17 | .63 | 2.56 – 5.47 |
| Lateral | 22 | 4.15 | .74 | 2.79 – 5.76 |
| Posterior | 22 | 4.24 | .82 | 2.47 – 6.00 |

*Note*. $p$ = 0.7326. Anterior was defined as in front of the hips. Lateral to the side of the hips. Posterior behind the hips.

Table 8.

Mean Forward Movement Times with Regard to Hand Position

| Position | N | M | SD | R |
|---|---|---|---|---|
| Anterior | 11 | 4.28 | .55 | 3.43 – 5.47 |
| Lateral | 11 | 4.13 | .68 | 3.32 – 5.76 |
| Posterior | 11 | 4.37 | .82 | 3.46 – 6.00 |

*Note*. $p$ = 0.2418.

Table 9.

Mean Backward Movement Times with Regard to Hand Position

| Position | N | M | SD | R |
|---|---|---|---|---|
| Anterior | 11 | 4.07 | .72 | 2.56 – 5.22 |
| Lateral | 11 | 4.17 | .82 | 2.79 – 5.76 |
| Posterior | 11 | 4.10 | .84 | 2.47 – 5.78 |

*Note*. $p$ = 0.7799.

Table 10.

Mean Backward Movement Times with Regard to Direction

| Position | N | M | SD | R |
|---|---|---|---|---|
| Forward | 33 | 4.26 | .68 | 3.32 – 6.00 |
| Backward | 33 | 4.12 | .82 | 2.47 – 5.78 |

*Note*. $p$ = 0.2437.

Table 11.

Mean Movement Times with Regard to Direction and Anterior Hand Placement

| Position | N | M | SD | R |
|---|---|---|---|---|
| Forward | 11 | 4.28 | .55 | 3.43 – 5.47 |
| Backward | 11 | 4.07 | .72 | 2.56 – 5.22 |

*Note*. $p$ = 0.2057.

Table 12.

Mean Movement Times with Regard to Direction and Lateral Hand Placement

| Position | N | M | SD | R |
|---|---|---|---|---|
| Forward | 11 | 4.13 | .68 | 3.32 – 5.76 |
| Backward | 11 | 4.17 | .82 | 2.79 – 5.76 |

*Note*. $p$ = 0.8244.

Table 13.

Mean Movement Times with Regard to Direction and Posterior Hand Placement

| Position | N | M | SD | R |
|---|---|---|---|---|
| Forward | 11 | 4.37 | .82 | 3.46 – 6.00 |
| Backward | 11 | 4.10 | .84 | 2.47 – 5.78 |

*Note*. $p$ = 0.1097.

*Appendix B*

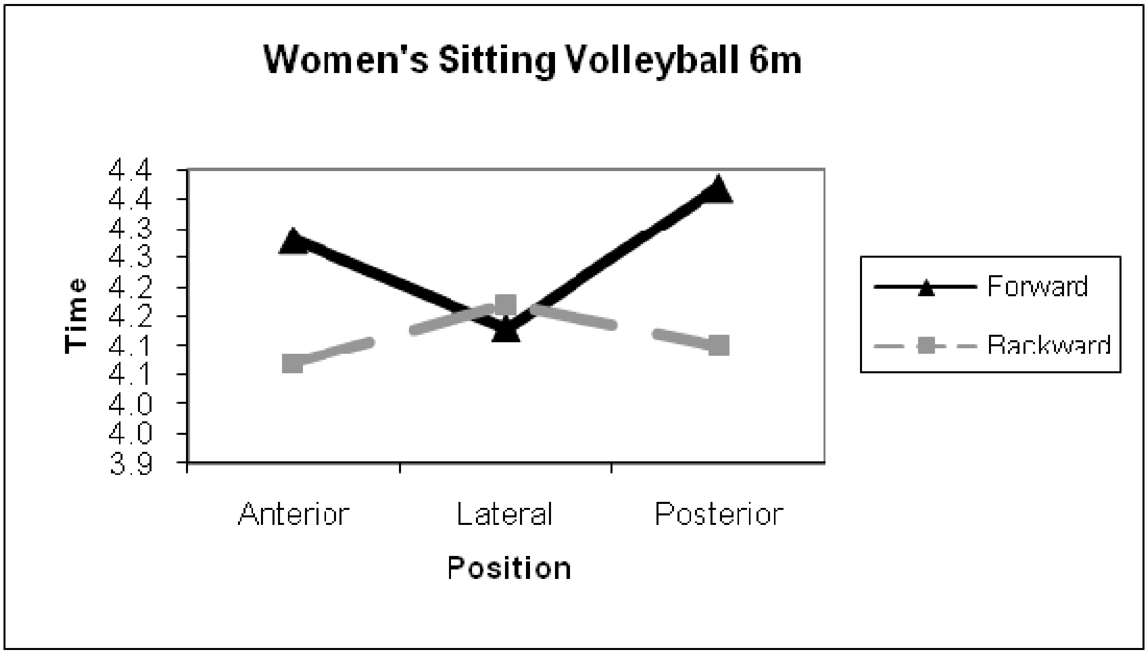



Figure 1. Line graph of women's sitting volleyball movement times at 6 m

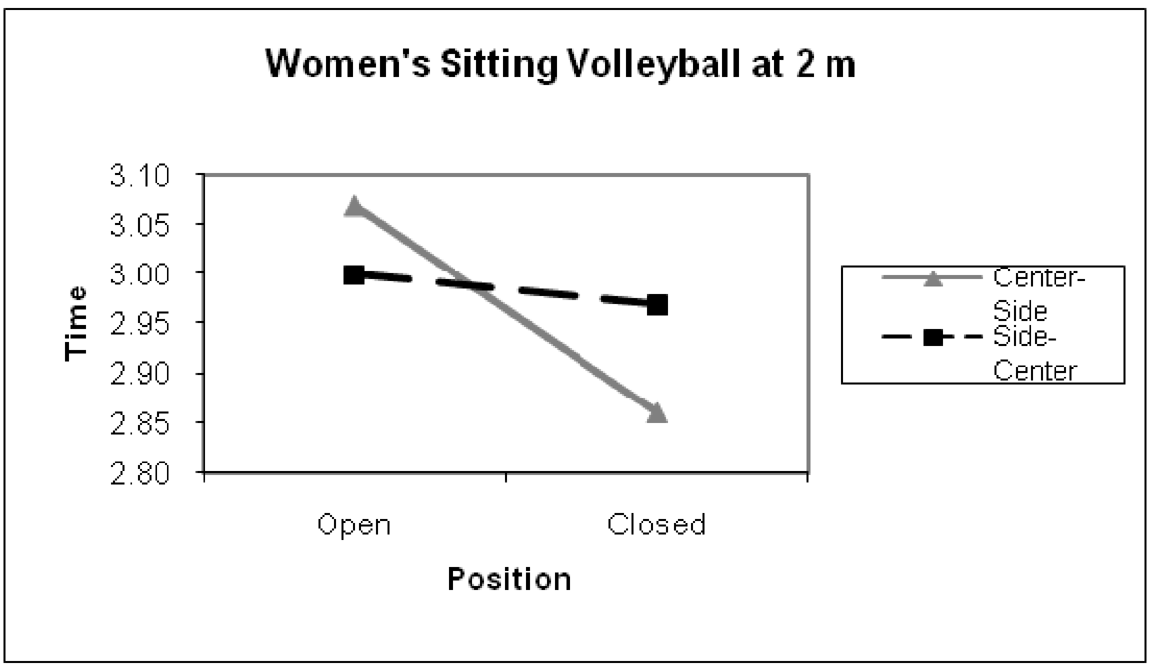
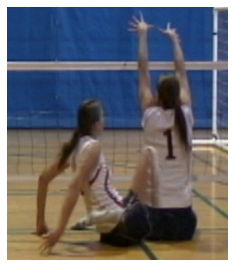



Figure 2. Line graph of women's sitting volleyball movement times at 2 m

*Appendix C*

Image 1. Open compared to closed body position with same subject.

Image 2. Open compared to closed body position with same subject.



*Appendix D*

3 December 2007

Ms. Maggie M. Zerger
Dr. Michelle Gray
Campus Box 189
College of Education and Professional Studies
Department of Kinesiology & Health Studies
University of Central Oklahoma
Edmond, OK 73034

Dear Ms. Zerger and Dr. Gray:

Thank you for submitting your IRB application (UCO IRB# 07231) entitled, "Thesis: a study of movement in sitting-volleyball," for review by the UCO Institutional Review Board (IRB). The Jackson College of Graduate Studies & Research is pleased to inform you of the approval of your application.

On behalf of the JCGS&R and UCO IRB, I wish you the best of luck with your research project. If the JCGS&R can be of any further assistance in your pursuit of research, creative & scholarly activities, please do not hesitate to contact us.

Cordially,

Dr. Gregory M. Wilson
Interim Associate Dean
Chair, UCO Institutional Review Board

GMW/

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