1996

A biomechanical analysis of three blocking footwork patterns in volleyball players

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A BIOMECHANICAL ANALYSIS OF THREE BLOCKING FOOTWORK PATTERNS IN VOLLEYBALL PLAYERS

A Thesis

Presented to

the Faculty of the Department of

Human Performance

San Jose State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

by

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August 1996

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Abstract

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by Jeff Wanderer

Research concerning blocking footwork patterns in volleyball has not identified which step pattern is associated with either the greatest vertical displacement or the shortest contact time. The purpose of this paper was to determine which of the three most commonly used footwork patterns is associated with the greatest vertical displacement and with the shortest contact time during a volleyball block. Twelve female middle blockers volunteered performing five trials of each footwork pattern to the right. Means for nine kinetic and kinematic variables were collected using a Kistler force platform and the Peak Performance Analysis System. A Kruskal-Wallis analysis of variance was used to test for differences in means between step patterns for contact time and vertical displacement ($\alpha = .05$). Results indicated that there was no statistically significant differences between step patterns for mean contact time or mean vertical displacement. It was concluded that no step pattern was superior to another in terms of either mean contact time or mean vertical displacement. Based on the findings, athletes should be allowed to experiment with and use footwork patterns that are ideal for their abilities and needs.

Acknowledgments

It has been said that a journey of a thousand miles begins with a single step. I would like to now thank all those who helped me learn to walk.

I must first thank my thesis chair, Dr. Gail Evans, for all that she has done for me over the many (far too many) years. Her guidance has been a tremendous help. I would also like to thank Dr. Susan Wilkinson and Dr. Richard Montgomery for all their patience, help, expertise, and the time they afforded me even though they did not have any to spare.

A special thanks goes to Dr. Emily Wughalter for her contributions with the statistical procedures. Steve Mayo deserves mention for all his hard work in an effort to get the force plate operational. George Ebertin deserves mention as well for his ability to keep everything in perspective for me.

Most of all, a loving thanks goes to my parents who believed in me and supported me all along. This work was for them as much as it was for myself. But the people who deserve the biggest thanks are my wife, Debbie (who had to endure the hardships, yet stuck by me), and my daughter, Jordan, who had no idea I was even doing this, but was the purpose for its completion.

Above all else, this work is done in the memory of my grandmother, Hazel.

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CHAPTER I

Introduction

Blocking in volleyball is a very important skill. This is particularly true at the more advanced and competitive levels. Blocking has been associated with a team's winning percentage. Next to spiking, the team with the best blocking will most likely win (Farokhmanesh & Mc Gowen, 1988). A volleyball game is quite often won or lost due to success at the net. Because spiking at advanced levels of play is very explosive, blocking becomes very important. In almost all cases, a spiker will be able to beat a single blocker, so it has become necessary for teams to attempt to put two blockers on one spiker whenever possible.

During the course of a game, there will be three hitters and three blockers at any given time along the net. It is part of team strategy to not let the opponent know which hitter will receive the ball. This places a great burden on the middle blocker who must often wait and react quickly to the direction of the set. Typically, the outside blockers use little or no preparatory footwork when the ball is set to the outside (Scates, 1976). In order for the middle blocker to get to the outside to form a double block with the outside blocker, he or she must make a number of preparatory steps that can be very challenging at times. Because the demands of middle blocking are different from outside blocking, there are certain technique differences (primarily in the footwork) that come into play.

If the set to the outside is high enough, the middle blocker may have sufficient time to get to the outside (using some desired footwork), wait, and then jump. However, with the more complex offenses of today, it is very common for the set to be low or fast to the outside (Coleman & Neville, 1990). In these cases, the middle blocker usually does not have enough time to wait before jumping outside. Quite often, the middle blocker has very little time and must jump immediately upon arrival to the outside position, if not earlier (Selinger & Ackerman-Blount, 1986). Because the middle blocker is attempting to get into position quickly, it is not clear if there may be a loss or gain in jump height due to the choice of footwork employed.

Significance of Study

It is intuitive that the ability to jump high is important for a front row player in volleyball. In order to stop a spiker from hitting a ball into the court, the blocker must be able to jump high and reach into the opponents side of the net. As stated above, the middle blocker usually must make a move to another position before jumping to block. A great deal of the available vertical jump research does not incorporate a horizontal component prior to jumping, and uses a protocol that requires a static squat or countermovement jump (Fukashiro & Komi, 1987; Harman, Rosenstein, Frykman, & Rosenstein, 1990; Hudson, 1986; Jensen & Phillips, 1991; Robertson & Fleming, 1987; Shetty & Etnyre, 1989; Vergroesen, De Boer, & Van Ingen Schenau, 1982; Vint, 1994). There is, however, volleyball research that has investigated the vertical jump that is preceded by an approach (Buekers, 1991; Coutts, 1982; Cox, 1978; Cox, 1980; Cox, Noble, & Johnson, 1982; Farokhmanesh & Mc Gowen, 1988; Khayambashi, 1977; Kwak, Jin, Hwang, & Yoon, 1989; Maxwell, Bratton, & Fisher, 1980). Of this research, there has been limited literature concerning the block (Buekers, 1991; Cox, 1978; Cox, 1980; Cox, et al., 1982; Farokhmanesh & Mc Gowen, 1988; Kwak, et al., 1989). The literature has indicated mixed results concerning the effectiveness of different blocking footwork patterns. Early studies have indicated that the slide step is the fastest (Cox, 1978; Cox, 1980), yet later studies have supported the cross-over step or a form of the cross-over step (Cox, Noble, & Johnson, 1982; Farokhmanesh & Mc Gowen, 1988; Kwak, Jin, Hwang, & Yoon, 1989). It has been only recently that research has identified another effective step technique (Buekers, 1991).

There is a lack of consensus concerning the effectiveness of different footwork patterns in terms of jump height or contact time. Assuming blocking is a critical part of a team's success and an approach may enhance, or detract from, the height of the jump, there is a need to investigate which technique is the most effective.

The Research Problem

A review of the literature has determined that there is conflicting information concerning step technique and jump productivity. While there is research examining the movement time of selected step techniques, and research that examines which technique may yield the most productive vertical jump, the results have been mixed. Knowing which technique is associated with the shortest contact time, and which is associated with the greatest vertical jump, is invaluable to the practitioner as well as the athlete. The problem is two-fold: the research has not conclusively identified which step can be associated with the greatest net jump height, nor has it identified which step is associated with the shortest takeoff times. Because of the lack of available research, there is a need for information regarding the most effective technique (if there is one).

Purpose of Study

The purpose of the present study was to determine which of the three most commonly used step techniques was 1) associated with the greatest displacement in the vertical jump and 2) which was associated with the shortest contact time, when performed by elite female volleyball players aged 16-23 years.

Research Hypothesis

The research results have been mixed on vertical jumping relative to the step technique used (Buekers, 1991; Cox, 1978; Cox, 1980; Cox, et al., 1982; Farokhmanesh & Mc Gowen, 1988; Kwak, et al., 1989). The research has shown no significant difference between step technique and reaction or movement times (Coutts, 1982; Farokhmanesh & Mc Gowen, 1988; Khayambashi, 1977; Kwak, et al., 1989; Maxwell, et al., 1980). Due to the conflict in findings and the lack of significant differences from previous studies, it was expected that the following research would be in agreement with previous findings: no specific step technique is significantly superior to the others in terms of either net jump height or contact time.

Definition of Terms

1. Cross-over step. The cross-over step is illustrated in Figure 1. The first step is the actual cross-over step where the foot opposite to the intended direction crosses over the closer foot. The technique only requires two independent steps (Cox, 1978).

2. Elite athlete. An elite athlete was defined as one who has demonstrated competency enough to be recruited by a Division I collegiate volleyball program.

3. Slide step. As illustrated in Figure 2, the slide step requires three independent steps. The technique is initiated by the foot closest to the

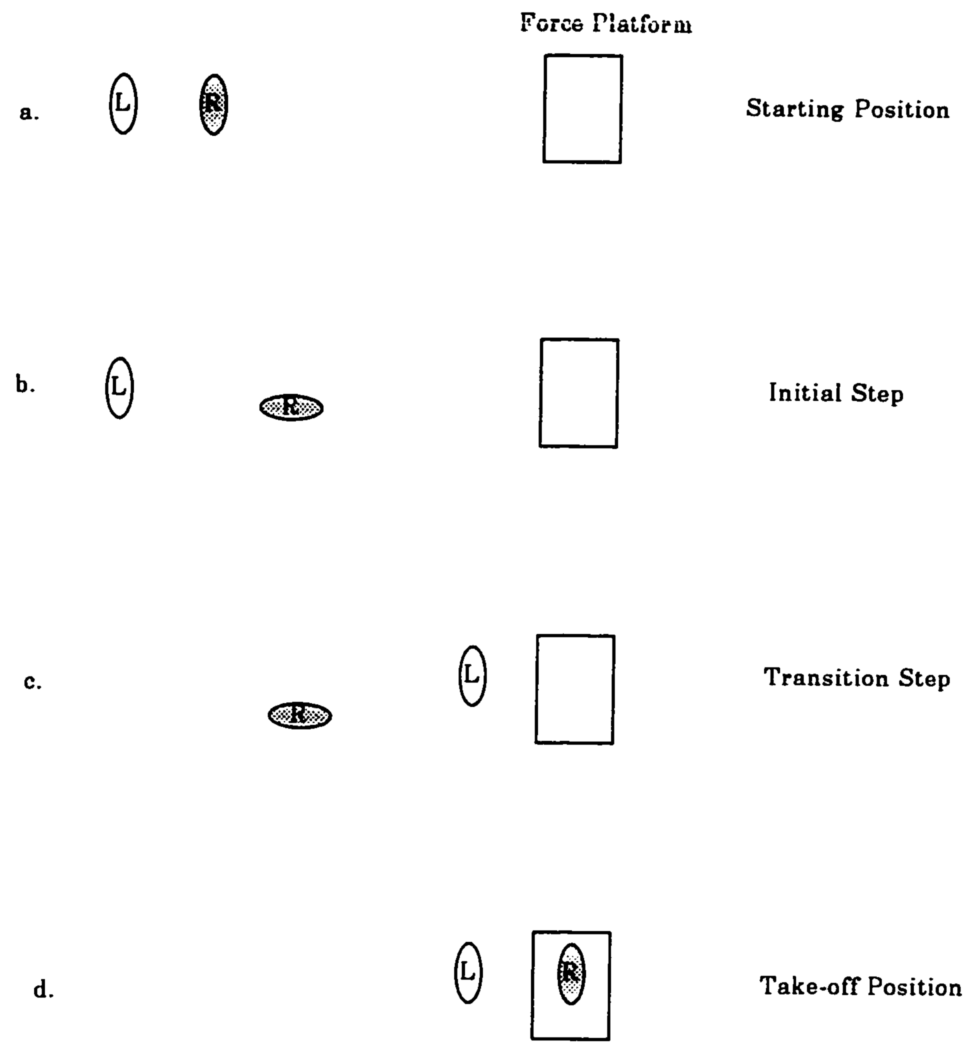
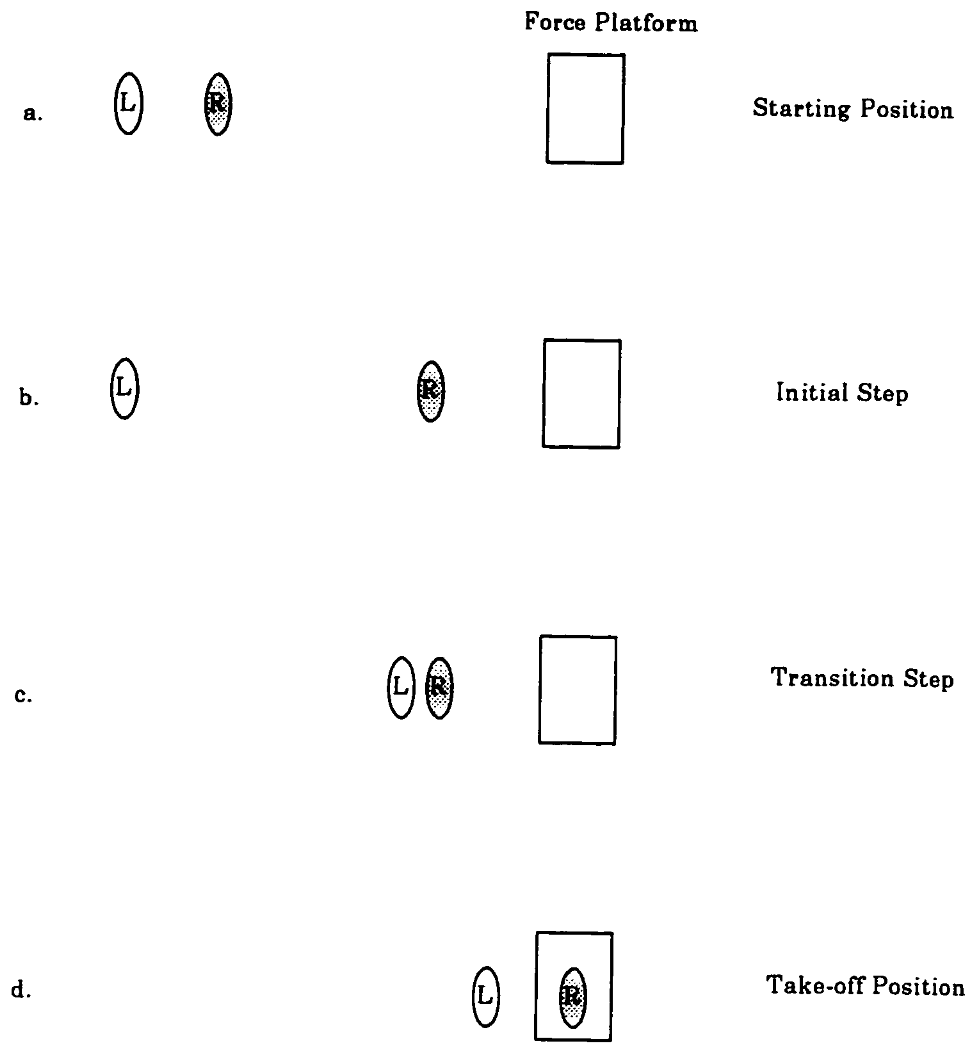


Figure 1. Footwork patterns and sequences for the cross-over step to the right.



<u>Figure 2.</u> **Footwork patterns and sequences of the shuffle step to the right.**

intended final position. At no time do the feet cross (Cox, 1987). The slide step shall also be known as the shuffle step.

4. Turn-and-run step. The turn-and-run technique requires only as many steps as needed to arrive at the final position. Figure 3 illustrates the turn-and-run technique using five steps. The technique is very similar to the cross-over, however the cross-over technique is initiated by the cross-over step and the turn-and-run is not. The final two steps for the cross-over and the turn-and-run are very similar, however (Buekers, 1991).

Assumptions for Study

It was assumed that the subjects would perform each test accurately and with the intent to perform their best. However, an assumption was also made that the results would not completely reflect those that may be found in a competitive setting. It was also assumed that each subject would have a preferred step technique that may influence the results.

Delimitations

This study was delimited to the following:

1. Elite college and club female volleyball players (aged 16-23 years) in Santa Clara County;
2. subjects who have experience with all three steps; and
3. performance occurring in a laboratory setting.

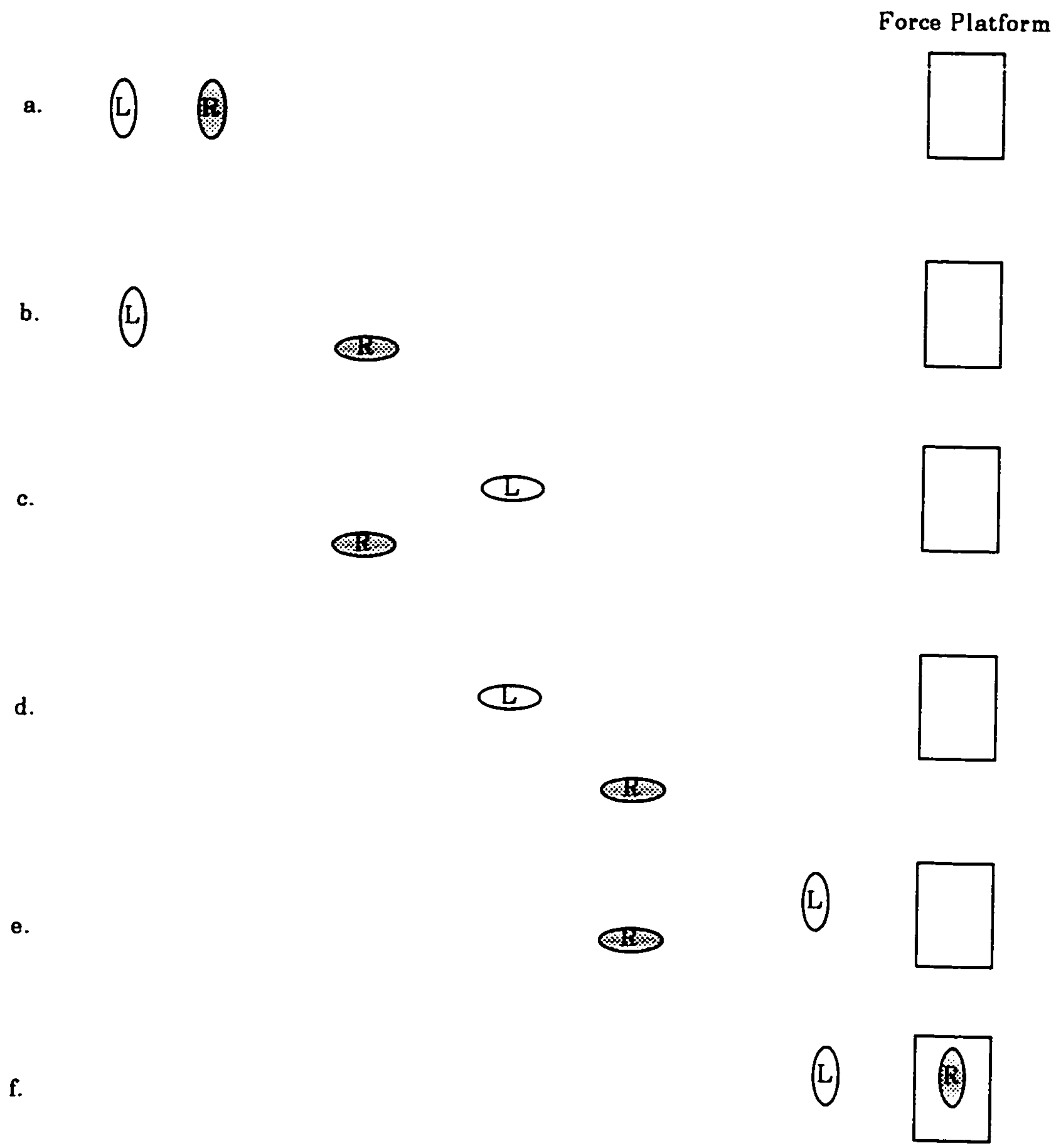


Figure 3. Footwork patterns and sequences for the turn-and-run step to the right.

Limitations

The results of this study are limited by the following:

1. the specific sample tested;
2. the lack of a competitive, game-like situation;
3. the clarity and resolution of the TV monitor and the Peak System during digitizing;
4. the subject's effort during testing;
5. the clarity and resolution of the video camera at 60 images per second;
6. direction of footwork patterns only being to the right;
7. subjects who were not randomly selected;
8. the reliability and validity of the digitizing equipment and the digitizer; and
9. knowledge about how to use each step.

Summary

Blocking is perhaps the second most important skill in volleyball, yet it is to date, one of the least studied aspects of volleyball. The height of the jump will partially dictate the success of a blocker. A blocker with a poor jump will typically not be successful. It is therefore critical for a blocker to maximize the jump when attempting to block. The middle blocker must usually wait to see the direction of each set prior to moving to block. The blocker must get to the blocking point and jump quickly without sacrificing vertical jump height.

The purpose of the present study was to compare and determine which, if any, of the selected footwork techniques is associated with the fastest takeoff time and the greatest net vertical jump height.

CHAPTER II

Review of Related Literature

This chapter reviews the literature related to the parameters of jumping associated with volleyball. There has been a limited amount of research devoted to jumping in volleyball. However, there have been numerous studies dedicated to vertical jumping in general. This chapter will be divided into four sections as follows: (1) the introduction, (2) an examination of the literature and research associated with the biomechanics of vertical jumping, (3) a review of the literature related to jumping and blocking technique in volleyball, and (4) the chapter summary.

Introduction

Much of the attention concerning jumping in volleyball has been devoted to spiking (Alexander & Seaborn, 1980; Borgeaud, 1989; Chung, Shin, Choi, Shin, 1990; Cisar & Corbelli, 1989; Coutts, 1978; Coutts, 1980, Coutts, 1982; Dusault, 1986, Gong & Huang, 1992; Huliba, 1982; Kan, 1982; Khayambashi, 1977; Liu, 1989; Maxwell, 1982; Maxwell, et al., 1980; Topishev, 1977). Very little research has been provided in the area of blocking (Buekers, 1991; Cox, 1978; Cox, 1980, Cox, et al., 1982; Farokhmanesh & Mc Gowen, 1988; Kwak, et al., 1989) The block jump and the spike jump essentially share the same goal (with specific adaptations for specific demands): to perform a maximal vertical jump. An understanding of the biomechanics of vertical jumping is a prerequisite for the understanding of block jumping. To date, there has been a great amount of research dedicated to the vertical jump (Coutts, 1982; Fukashiro & Komi, 1987; Harman, et al., 1990; Hudson, 1986; Jensen & Phillips, 1991; Khayambashi, 1977; Lamb, 1976; Maxwell, et al., 1980; Robertson & Fleming, 1987; Shetty & Etnyre, 1989; Van Ingen Schenau, Bobbert, Huijing, & Woittiez, 1985; Van Soest, Roebroeck, Bobbert, Huijing, & Van Ingen Schenau, 1985; Vergroesen, et al., 1982; Vint, 1994).

Biomechanics of Vertical Jumping

It has been well documented that jumping ability is improved with the use of the stretch-shorten cycle of the involved muscles. The use of stored elastic energy has been associated with higher concentric forces (Aura & Viitasalo, 1989).

During a vertical jump, the biceps femoris is contracting eccentrically during the early part of the push-off phase and concentrically at the end of the push-off phase (Visser, Hoogkamer, Bobbert, & Huijing, 1990). Visser, et al. (1990) stated that the biceps femoris can begin the concentric contraction at a higher rate following an eccentric contraction. Visser, et al. (1990) also stated that changing the hip angle lengthened the biceps femoris muscle. However, changing the knee angle had no effect on the biceps femoris length.

In 1985, Van Ingen Schenau, Bobbert, Huijing, & Woittiez examined instantaneous torque-angular velocity of the ankle in plantar flexion during jumping. Subjects performed maximal jumps from a semi-squat position. The results were compared to those found using isokinetic plantar flexion. They found that the semi-squat jumps had six times the maximal power output to that of isokinetic plantar flexion. The authors suggested that the transfer of stored elastic energy from the knee to the ankle was a major contributor to increases in maximal power output.

Bi-articular muscles have been shown to generate more force than mono-articular muscles (Jaric, Ristanovic, & Corcos, 1989; Van Leeuwen & Spoor, 1992). Force, force-time, and force-velocity parameters of bi-articular muscles have been significantly related to kinematic variables in complex movements as in jumping and in jumping height (Jaric, et al., 1989). Because these muscles cross two joints, energy is transferred from one joint to the other.

Power is thought to be transmitted distally from the hip to the distal joints (Bobbert & Van Ingen Schenau, 1988; Vergroesen, et al., 1982). Also, the proximal joints are at, or near, maximum extension velocity upon maximal plantar flexion output (Van Ingen Schenau, et al., 1985). Knee muscles contribute significantly to the performance of a vertical jump, however the muscle groups surrounding the hip and ankle were found to generate the most energy (Robertson & Fleming, 1987). Robertson and Fleming's (1987) findings were consistent with that of previous work (Cappozzo, Figura, & Marchetti, 1976; Robertson & Winter, 1980; Vergroesen, et al., 1982; Visser, et al., 1990). Cappozzo et al. (1976) and Robertson and Winter (1980) found that muscles crossing the hip and ankle produce energy while muscles crossing the knee absorbed energy, and contributions of the hip, knee, and ankle were found to be 40.0%, 24,2% and 35.8%, respectively. These findings are in conflict with those of Hubley and Wells (1983) who found contributions of the hip, knee, and ankle muscles to be approximately 28%, 49%, and 23%, respectively.

Comparison Of One-Legged And Two-Legged Countermovement Jumps

During a squat jump, the jumper uses both legs fairly equally. However in a volleyball game setting, a true squat jump is seldom performed. Van Soest, Roebroeck, Bobbert, Huijing, and Van Ingen Schenau (1985) compared one-legged countermovement jumps with two-legged countermovement jumps. The authors found that a single leg jump was more than 50% that of two-legged jumps. The subjects were not able to enter into a full squat prior to jumping with the single leg protocol, but were able to attain heights greater than half that of the two-legged heights.

In a single leg countermovement jump, the body cannot go into full flexion, yet is still able to produce more than half that of a two leg countermovement jump (Van Soest, et al., 1985). No difference was found in the mean torque of the knee despite lower angular velocities, although it was found that net torque at the ankle was high throughout the push-off phase. It was also found that one-legged jumps produced greater power than two-legged jumps.

Countermovement Jumps

It is commonly understood that a muscle can perform with greater power if it is slightly stretched prior to execution. Countermovement jumps have been associated with greater heights in vertical jumps compared with static squat jumps (Fukashiro & Komi, 1987; Sanders & Wilson, 1992). Fukashiro and Komi (1987) found that countermovement jumps yield higher peak values for moments than for squat jumps. Countermovement jumps have been considered to employ the stretch-reflex response. However, it was suggested by Fukashiro and Komi in 1987 that "the performance differences between squat jumps and countermovement jumps might result from the difference in work by the hip extensors rather than from the effect of stored elastic energy" (p. 15). Vergroesen, et al. (1982) concluded that there may be other mechanical factors at work that support the high positive work output in countermovement jumps.

Contribution of the Arms

During a vertical jump, the arms can contribute to the takeoff velocity and to the total jump height (Harman, et al., 1990; Sanders & Wilson, 1992; Shetty & Etnyre, 1989). The contribution of the arms to maximal force and power has been found to be 6% and 15%, respectively (Shetty & Etnyre, 1989). Jumps with an arm swing have been shown to be more effective than jumps with no arm swing with respect to jump height (Harman, et al., 1990).

It has been found that skilled subjects show a greater contribution of the arms when compared with unskilled subjects (Shetty & Etnyre, 1989). The effective use of the arms may be developed and learned with increases in skill. Because the arms can be used for balance when in a dynamic situation prior to the vertical jump, there may be a reduction in unwanted horizontal forces which will improve the vertical jump (Shetty & Etnyre, 1989).

Coordination of the Vertical Jump

The coordination of the vertical jump has been suggested to be largely controlled by simultaneous segmental movements (Kreighbaum & Barthels, 1996). Hudson (1986) suggests that when velocity is important, the movement pattern is more likely to be simultaneous.

Robertson and Fleming (1987) found that all three extensor moments (ankle, knee, and hip) acted simultaneously during the extension phase of the vertical jump. They also found that the sequence of contractions was not proximal to distal as was expected. It was expected that the muscle contraction scheme would follow that of the continuity of joint forces principle (Broer & Zernicke, 1979; Dyson, 1962; Jensen & Schultz, 1977; Luttgens & Wells, 1982; Morehouse & Cooper, 1950; Northrip, Logan, & Mc Kinney, 1974; and Simonian, 1981; all as cited in Robertson and Fleming, 1987), and the summation of forces principle as described by Broer and Zernicke (1979), Dyson (1962), Gowitzke and Milner (1980), and Plagenhoef (1971) as cited in Robertson and Fleming (1987).

Jensen and Phillips (1991) looked to see if there was variation in the sequence, or timing, in joint reversals during the extension phase of jumping if the jumping task was altered. Previous work has indicated that the maximum extension velocities of the hip, knee, and ankle occur temporally close to each other and the time of takeoff (Gregoire, Veeger, Huijing, & Van Ingen Schenau, 1984; Hudson, 1986; Van Soest, et al., 1985). Jensen and Phillips (1991) found that between changes in jumping tasks, there was "neither an invariant sequence nor invariant temporal structure in joint reversal" (p. 71). The authors also concluded that despite variability in the kinematics of the involved joints, the propulsive properties remained similar. Their findings agreed with Hudson (1986) who suggested that even when the jumping system is performed out of sequence, it is still capable of recovery.

Hudson (1986) did also find that for skilled jumpers, the timing was more important than the sequencing of segments.

Volleyball Specific Jumping

Approach Prior to Takeoff

It has been found that subjects who precede a jump with a number of steps have increases in vertical jump height (Khayambashi, 1977; Maxwell, et al., 1980; Scates, 1976) Khayambashi (1977) observed that for females, there was less benefit for a longer approach. The maximum height attained for the female group was observed using the three-step approach. It is possible that there is an optimal speed (through an appropriate number of steps) that will allow a player to show the greatest gain in jump height.

Coutts (1982) examined the kinetics of two volleyball jumping techniques using 24 male and 62 female players. Ground reaction forces were measured for two commonly used spike approach techniques: the hop jump approach and the step-close approach. Both the hop jump and the step-close techniques showed a high velocity at the end of the approach that resulted in a fast and large impulse absorption phase. A fast positive impulse with a high average force, peak force, and acceleration is consistent with the storage and utilization of elastic energy in muscles. Eleven of the fifteen variables for the hop style were significantly different from the step-close style at the .01 level. However, it was observed that the two styles appeared to be equal in terms of takeoff velocity. The time and force during the un-weighting phase were similar as well.

Footwork Patterns for Blocking

Current volleyball techniques for blocking footwork include three types: slide step, cross-over step, and the turn-and-run step. The slide and cross-over steps have been commonly used for some time. The turn-and-run has become more popular in recent years (C. Choate, personal communication, January 26, 1995).

Relatively little research has been done on the effectiveness of blocking footwork and techniques. Up until 1978, most experts in volleyball agreed that a form of the cross-over step was quickest in moving a player laterally along the net (Keller, 1970; Scates, 1976; Stanley, 1977). However, there is little or no research confirming or contradicting this belief.

Cox (1978) investigated the relationship between choice response and three initial step techniques (slide, cross-over, and jab cross-over). Forty-five male volunteers were selected for study. Each subject was right-footed and untrained in competitive volleyball. Each subject was randomly assigned to one of three treatment groups. Subjects, facing a choice display board, were instructed to straddle a line marked directly between two contact mats. Subjects were instructed to focus on the center of the display board. From a ready position (knees slightly bent, feet shoulder width, and hands held at shoulder height), subjects were to perform the appropriate footwork in the direction of the light stimulus. Time was measured with the beginning of the light stimulus and ending upon contact with the contact switch mat. It was concluded that a relationship exists between choice response time and initial step technique in a lateral movement. The slide step was faster than the cross-over and the jab cross-over. However, it was noted that the difference between the slide and the cross-over steps was only 45 milliseconds.

In a 1980 study, Cox investigated the response times for skilled volleyball players versus unskilled subjects from his earlier study. Thirty male and twelve female skilled volleyball players volunteered as subjects. Thirty-six of the subjects were right footed, two were ambidextrous, and four were left footed. The procedure was the same as in Cox's 1978 study except that the step techniques investigated were the slide and cross-over steps only. The results indicated a relationship existed between choice response time and step technique. His findings were in agreement with his earlier work (Cox, 1978) that the slide step technique was faster than the cross-over step technique in lateral movement. Despite the faster movement times for the slide step, no evidence was found that suggested this technique provided the athlete with more leg power. Cox did note that the cross-over step may be more favorable in the development of power, but additional research would be needed.

Cox, Noble, and Johnson later (1982) followed up Cox's 1980 study by examining three step techniques (slide, cross-over, and jab cross-over) and the time involved in the jump and block. Three male and three female skilled volleyball players volunteered as subjects. All subjects claimed to be right handed and footed. All subjects were well practiced in the three steps. Landmarks were marked with paint for easy identification during film analysis. All trials were filmed using two 16 mm Locam cameras at 100 fps. The results indicated a relationship between step method and the selected time variables. The results of ANOVA indicated that the jab cross-over step was superior to the other step techniques. No explanation was given why. It was observed, however, that the slide step required a long duration during the gathering and portioned impulse phases of the vertical jump. The authors suggested that the jab cross-over was superior because of the increased use of leg power. Gathering time was lower in the jab cross-over step because gathering for the vertical jump began with the second step and was nearing the portioned impulse time phase of the jump when the outside foot contacted the ground. It was concluded that the step method characterized by the smallest gathering and portioned impulse times would produce the greatest vertical jumps. There is evidence that shorter takeoff times are related to increases in jumps (Aura & Viitasalo, 1989; Coutts, 1982; Hay, 1993). Despite earlier findings (Cox, 1978, 1980), the cross-over step was observed to be preferable in getting the athlete into the desired blocking position quickly. The cross-over step was superior to the slide step for every variable examined.

In 1991, Buekers also examined the time structure of the block through a comparison of three different step techniques (slide, cross-over, and running steps, as described by Beal and Crab in 1987). Their research hypothesis questioned whether the running steps technique was superior in terms of lateral movement speed and total movement time. Subjects were ten experienced volleyball players who volunteered for the study. Two floor mats over pressure sensors were placed on the floor along the net. A photoelectric cell and reflector were placed above the net that transmitted a signal to a computer. For each contact with the pressure mat, a time was recorded. The total movement time was divided into two phases: the duration of the lateral displacement (from mat A to mat B) and the time spent on mat A after the first block. The slide step technique showed the longest movement times and the running step technique showed the shortest movement times. No significant differences were found for the cross-over and running steps techniques. These findings were in direct conflict with those of Cox, Noble, and Johnson (1982), but were in agreement with current experts (Beal & Crab, 1987).

In 1988, Farokhmanesh and Mc Gowen compared the slide, cross-over, and the jab cross-over steps. A beginning volleyball class was used as subjects. The subjects had to travel nine or fifteen feet to the blocking position. Vertical jump and movement time were measured. It was observed that the jab cross-over was faster, on average, than the cross-over and the slide step by three and fourteen milliseconds, respectively. The jab cross-over was also associated with greater average jump heights (0.6 inches) when compared with the slide and cross-over steps. The authors questioned the preference of any such technique based upon the small differences in results.

Kwak, Jin, Hwang, Yoon (1989) examined the slide and the cross-oversteps. Ten male and fourteen female highly skilled athletes were used as subjects. Subjects were filmed using a 16 mm high speed camera, and ground reaction forces were recorded using an AMTI force platform. Horizontal velocities of the two step techniques were compared. The horizontal velocities for the cross-over step were greater than those of the slide step for both males and females. Analysis of variance results indicated a significant interaction effect between gender and step. The authors admitted that training biases may have been present because the males were trained using the cross-over step and the females were trained using the slide step. For the females, there was no significant difference in reaction time between the cross-over and slide steps. The authors suggested that shorter reaction times of the cross-over step might be due to the body position upon arrival to the platform (blocking position). This body position requires little countermovement, whereas the slide step requires greater countermovement.

Summary of Related Literature

The bi-articular muscles crossing the hip, knee, and ankle have all been shown to contribute to the vertical jump (Jaric, Ristanovic, & Corcos, 1989). It is well understood that muscles can perform more work through the utilization of stored elastic energy as in countermovement jumps. This increased energy level is said to be transmitted distally from the hip to the distal joints (Vergroesen, et al., 1982). However, there have been many contradictory findings as to whether the joints act simultaneously or sequentially during the vertical jump. There has also been conflict concerning the contribution of the knee in the vertical jump (Robertson & Fleming, 1987). Nonetheless, a pre-stretch of the bi-articular muscles crossing the hip can be associated with improvements in the vertical jump. This is relevant when considering jumps that utilize a countermovement.

Countermovement jumps using a single leg have been shown to be more than half as powerful as two-legged countermovement jumps (Van Soest, et al., 1985). Each step technique described may utilize each leg differently. While one leg may act as a brake during the on-weighting phase, the other may be productive in the push off phase. Thus, one leg will contribute differently than the other.

The takeoff velocity of a vertical jump may be optimized with a properly timed arm swing (Shetty & Etnyre, 1989). The contribution by the arm swing to the takeoff velocity of skilled jumpers has been shown to be greater than for unskilled subjects. This is important when comparing research concerning jumping in volleyball.

Jump heights can be improved with a short run-up of some sort. The most common footwork patterns preceding a volleyball block include: slide step, cross-over, and turn-and-run. The slide step has been shown to get a player from one place to another the fastest (Cox, 1978). Cox et al. (1982) later found that the jab cross-over step actually got the player into the air the fastest. More recently, the turn-and-run technique was shown to get the player into an airborne blocking position the fastest (Buekers, 1991).

All the techniques mentioned employ a countermovement jump following a number of preparatory steps. The pre-stretch of the musculature crossing the ankle, knee, and hip act to improve the vertical jump. However, increases in jump height are more closely related to portioned impulse time and a short on-weighting phase (Aura & Viitasalo, 1989; Coutts, 1982; Hay, 1993).

The kinetic differences of two jumping techniques were compared (Coutts, 1982). One technique examined was the step-close technique used when spiking. Despite their differences in applications, the cross-over step for blocking and the step-close for spiking are very similar in execution.

A review of the literature has indicated that the turn-and-run technique will get a player into the a blocking position fastest. However, the research has not indicated if there is any significant difference in step techniques. There appears to be minimal differences in terms of speed and jump height between techniques.

CHAPTER III

Methods

This chapter describes the procedures that were used to collect and analyze the kinetic and kinematic data for the volleyball block jump. The chapter has been divided into the following sub-topics: (1) general procedures, (2) videography techniques, (3) video analysis, (4) ground reaction analysis, (5) kinetic and kinematic analysis, (6) statistical procedures and (7) the treatment of data.

General Procedures

Selection of Subjects

Due to the descriptive nature of the study and the lack of experienced subjects available, twelve female middle blockers were used as subjects for this study. The subjects were volunteers drawn from the following teams: eight from San Jose State University and four from Team Mizuno (an elite junior volleyball program). All but one of the subjects were right handed. Approval by the Human Subjects Institutional Review Board at San Jose State University was sought prior to data collection (Appendix A). Informed written consent was obtained prior to data collection as well (Appendix B). A subject information survey was also collected prior to testing (Appendix C).

Warm-up Procedures

Subjects warmed up prior to joint landmark marking and videotaping. Warm-up protocol consisted of jogging in place for 1-minute followed by five high knee jumps in place. Subjects performed light stretching (15 seconds) of the quadriceps and hamstrings muscles.

Trial Procedures

Subjects were videotaped in the Fall of 1995 in the San Jose State University Biomechanics Laboratory. Prior to the videotaping of trials, subjects were videotaped standing at full height. Subjects performed five trials of each footwork pattern to the right. Each subject began at approximately the middle of the net (no less than 4 meters and no more than 6 meters from the platform). An additional person was placed opposite the net and slightly to the left of the subject. This person represented an opponent setter and caught (in the overhead position) a volleyball tossed by an assistant out of view of the camera. Upon contact with the ball by the catcher, the subject moved to the outside blocking position (with only one foot contacting the force platform) before initiating a vertical jump. During the performance of each trial, another person was positioned just to the right of the force platform to simulate an outside blocker. Additional trials were given when a subject did not feel comfortable with the performance of a trial.

Subject Markings

To facilitate landmark digitizing from video, the subjects were videotaped wearing jog bras and lycra shorts. Joint landmarks were marked after warm-up using cloth athletic tape. Left and right (when appropriate) landmarks were marked as follows: (1) proximal phalanx (toe); (2) calcaneous (heel); (3) medial malleolus (ankle); (4) patella (knee); (5) greater trochantor of the femur (hip); (6) umbilicus; (7) lateral and anterior aspect of the greater tubercle of the humerus (shoulder); (8) approximate seventh cervical vertebrae, (9) medial aspect of the humeral epicondyle (elbow); (10) the carpals (wrist); (11) the proximal phalanx; and (12) the distal tip of the nose.

Ordering and Selection of Trials for Analysis

Prior to each subject's performance, a die was cast to determine which footwork pattern would be performed first. A roll of 1 or 2 indicated a shuffle step pattern, a roll of 3 or 4 indicated a cross-over step, and a roll of 5 or 6 indicated a turn-and-run step pattern. For the second step pattern, the die was cast in the same manner disregarding a roll for an identical step pattern. The third step pattern was the last remaining step pattern not previously performed. Five trials in succession, of each step pattern per subject, were recorded. The average (mean) of the five trials for each step pattern was used for analysis.

Videography Techniques

Videotaping Equipment

All trials for all subjects were videotaped using one Panasonic AG-HT5 video camcorder (Model 450) and tripod. This camera was selected in conjunction with the Peak Performance 3-D Motion Analysis System.

Camera Settings, Locations, and Operation

The Panasonic camera operated at 60 images per second with an indoor setting and the gain in the up position. The camera was focused using the manual focus fixed at the point of takeoff. The camera was also zoomed as wide as possible. The camera was located perpendicular to the net such that filming captured the subject's frontal plane. The height of the camera was approximately 1.1 meters above the floor. The distance of the camera from the subject was 6 meters. It was established, based on observation, that the field of view would be sufficient to capture the vertical heights attained by the subjects.

General Laboratory Set Up

Subjects were videotaped performing in the Biomechanics Laboratory at San Jose State University. Figure 4 illustrates the laboratory set up for data collection. To aid with lighting and to avoid shadowing during taping, subjects performed the step techniques to the right facing the windows on the north wall of the laboratory. A portable outdoor net was positioned such that

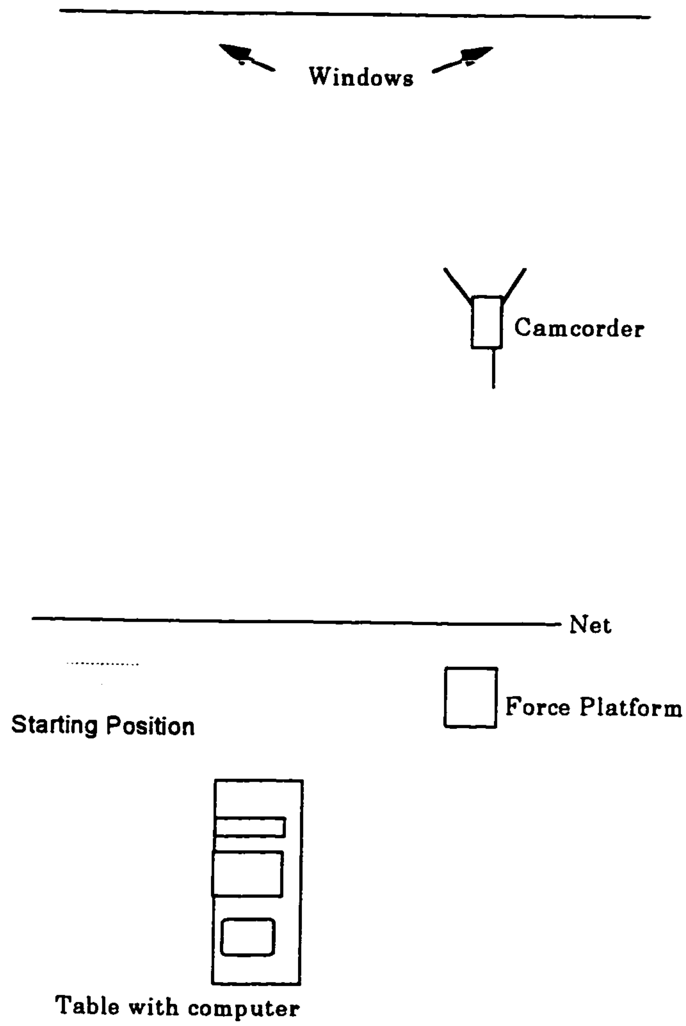


Figure 4. General laboratory set up showing the arrangement of the camera, net, computer, and force platform.

the force platform was situated to the right side of the net. A table supporting the computer and analysis hardware was placed opposite and behind the subject and the force platform.

Video Analysis

Analytic Equipment

The Peak Performance 3-D Motion Analysis System is an integrated computer-video work station. The Peak Performance System consists of an HIQ personal computer (Model #25275-56DMEV4MC420A0-A), an event synchronization unit, and an analog to digital (A/D) interface unit. The video system consists of a Panasonic video cassette recorder (Model AG 6300) and a Panasonic color monitor (Model CT1400MG). A Peak5 software package and appropriate hardware control the video cassette recorder during digitizing, and for data smoothing, uses a direct linear translation (DLT) method.

Digitizing the Performance

Prior to the performance of each subject, a meter stick was held horizontally and videotaped. The meter stick was later digitized for scaling. Twenty-one body landmarks were digitized throughout the execution of a performance. The digitizing process began just prior to contact of the right foot upon the force platform and ended just after the subject reached peak of flight. Each landmark was digitized for all frames including takeoff and touchdown. The points digitized included:

1. Approximate left distal phalanx
2. Approximate left medial calcaneous
3. Left medial and anterior malleolus
4. Left patella
5. Left greater trochantor
6. Umbilicus
7. Approximate right distal phalanx
8. Approximate right medial calcaneous
9. Right medial and anterior malleolus
10. Right patella
11. Right greater trochantor
12. Seventh cervical vertebrae
13. Left anterior and posterior aspects of the greater tubercle of the humerus
14. Left medial humeral epicondyle
15. Left anterior carpals
16. Left distal second phalanx
17. Right anterior and posterior aspects of the greater tubercle of the humerus
18. Right medial humeral epicondyle
19. Right anterior carpals
20. Right distal second phalanx

21. Distal end of the nose

Measurement of Vertical Jump

The digitized data point for the umbilicus was used to approximate the center of mass (COM) for each subject. The net displacement of the center of mass was used to determine the vertical jump for each trial. The net displacement of the COM was calculated by subtracting the height of the COM at takeoff from the height of the COM at peak of flight.

Ground Reaction Analysis

Takeoff and kinetic characteristics were evaluated using a computer-integrated force platform. A Kistler Multi-Component Platform for Biomechanics and Industry (Type 9281B) interfaced with the Peak System and mounted flush with the hardwood floor was used to obtain ground reaction force data. Sampling at 500 Hz was initiated through a remote hand-held switch by the experimenter just prior to contact with the platform surface. Total sampling time for the force platform was one second.

Kinematic and Kinetic Analysis

Kinematic and kinetic data were computed from video and force platform data. To investigate the interactions among the segments in the takeoff phase, the following kinetic and kinematic parameters (as used by Coutts, 1982) were used:

1. Horizontal velocity of the COM at takeoff

2. Contact time
3. Impact phase time
4. Change in impulse
5. Impact force
6. Vertical thrust
7. Vertical velocity of the COM at takeoff
8. Peak force

Statistical Procedures

Subjects

Descriptive information on each subject was obtained. Means and standard deviations were collected on subjects' height, weight, and age. The level of competition and the years of experience were also collected.

Main Problem

Means and standard deviations for the vertical displacement of the COM following takeoff and the total contact time for each step were recorded. Because the number of subjects was low and parametric assumptions could not be met, statistically significant differences across step techniques were examined through a Kruskal-Wallis analysis of variance. Because the study was neither replicating another study, nor exploratory in nature, results between step styles were examined at an experiment-wise alpha of .05 (B. Shifflett, personal communication, November 9, 1994).

Related Problem

Means and standard deviations for each of the kinetic and kinematic variables were recorded. To examine similarities and/or differences with respect to interaction between step and competition level or years of experience, a 95% confidence interval was used.

Treatment of Data

Subject demographic and trial data were kept confidential by the experimenter. Data for each subject were coded so that subjects could not be identified. In addition, all data were stored in a locking file cabinet in the office of the San Jose State University Women's Volleyball Team. Only the investigator had access to research data. Following the collection period, data were destroyed.

Summary

Twelve female middle blockers were used for the study. Subjects warmed up and were videotaped performing five trials of each footwork pattern to the right. Subjects were videotaped using one video camcorder in conjunction with the Peak Performance 3-D Motion Analysis System. A net was placed in the laboratory such that the subjects performed the trials facing a window (to aid with lighting) and the force platform was on the right side. Twenty-one body landmarks were digitized and ground reaction data were collected using a Kistler Multi-Component Platform for Biomechanics and Industry. Eight kinematic and kinetic parameters were collected. Statistical procedures included a Kruskal-Wallis analysis of variance to test the main hypothesis, and a 95% confidence interval to test the related questions.

CHAPTER IV

Results and Analysis

The purpose of the present study was to 1) determine which of the three most commonly used step techniques is associated with the greatest displacement in vertical jump and 2) which is associated with the shortest contact time using elite female volleyball players aged 16-23 years. Using the procedures outlined in the methods chapter, kinetic and kinematic data were collected for each trial and each subject. The mean values from the five trials of each step pattern were analyzed. This chapter has been divided into five major headings as follows: (1) scoring of data, (2) reliability of data, (3) findings, (4) statistical analysis of the data, and the (5) chapter summary.

Scoring of Data

Contact time was derived directly from force plate analysis printouts provided by the Peak Performance 3-D Motion Analysis System. Mean contact times for the shuffle, cross-over, and turn-and-run steps were calculated by hand for each subject (Appendix D).

Digitized points were conditioned and converted into coordinate data points via the Peak Performance Analysis System. Because the Peak Performance software program used in this study could not calculate displacement between frames, coordinate data points (expressed in meters) were used to determine vertical displacement. In so doing, the vertical coordinate for the COM at takeoff (given by computer printout) was subtracted by hand from the vertical coordinate at the peak of flight (also, given by computer printout). All calculations were double checked for accuracy. This was repeated for each trial for each subject's three different step patterns and the mean displacements were calculated (Appendix E).

Reliability of Data

Prior to the testing of any subjects, the force platform was calibrated using a known weight, the video camera was focused on the takeoff point, and the computer system was tested to ensure proper operation. Mean landing forces were found to be very similar to those found by Allyn (1995) when subjects of similar stature were used.

The goals of the study were not explained to the subjects prior to testing to minimize the effect of knowing the demand characteristics (B. Shifflett, personal communication, October 25, 1994). To minimize the Hawthorne Effect (Thomas & Nelson, 1990), only the necessary and required instructions were provided to subjects. No instruction or performance feedback was provided to the subjects.

The step pattern order for each subject was randomized to avoid any possible effects of practice or fatigue that the step order may have had on the results. In addition, it was found that all possible combinations of step order were represented and that no step order was repeated more than three times.

To avoid possible differences caused by camera angles, the camera was placed at a right angle to the net. The camera was placed on a tripod with all moveable parts tightly locked and placed in a fixed position marked on the floor. The camera was also placed such that the takeoff position was in a straight line with the focal axis of the camera. To avoid possible differences due to videotape quality, clarity and speed that may have interfered with the digitizing process, the same brand and speed (T-120) videotape was used to record all trials. All tapes were new and previously unused for recording.

Investigator reliability for digitizing was established prior to testing. Reliability was determined through a coefficient alpha using the odd-even method followed by a Spearman-Brown Prophesy Formula (r = .98) upon a series of 46 repeated measures. Measures were taken of an object videotaped in the lab.

Results

Descriptive Information

Twelve subjects volunteered for this study. Eight were Division I college athletes and four were elite-level club athletes. One subject had competed in the 1994 competitive season. All other subjects were currently participating in their competitive season. Information concerning age, height, weight, present level of competition, and the number of years experience was collected prior to data collection. Means and standard deviations for years of experience, age, height, and weight are presented in Table 1.

Table 1

Subject Demographic Information Including Means and Standard Deviations.

Level	N	Experience (yrs)	Age (yrs)	Height (cm)	Weight (kg)
College	8	6.88 +/- 1.96	20.25 +/- 1.49	182.68 +/- 4.66	72.60 +/- 5.78
Club	4	5.50 +/- 1.73	16.75 +/- 0.50	186.58 +/- 4.71	68.63 +/- 5.21
All	12	6.42 +/- 1.93	19.08 +/- 2.11	183.98 +/- 4.85	71.28 +/- 5.70

Due to the disproportionate number of college subjects versus club subjects, it was considered important to view the data with regard to the subject's demographics. Years of experience ranged from 4 to 10 years, while the age of the subjects ranged from 16 to 23 years. Height and weight ranged from 174.6 to 190.2 cm and 64.4 to 82.1 kg, respectively.

Contact Time

Mean contact time was calculated through the Peak Performance Analysis System across all subjects and is presented in Table 2. Mean

Table 2

Mean Contact Time (in Seconds) And Standard Deviations (Given in Parentheses) For Each Step Pattern For All Subjects By Level of Competition and Years of Experience.

	College			Club			All
Step	<7 yrs	≥7 yrs	All	<7 yrs	≥7 yrs	All	
Shuffle	0.333	0.326	0.329	0.277	0.361	0.319	0.325
	(.048)	(.049)	(.045)	(.002)	(.105)	(.078)	(.055)
Turn-and-run	0.316	0.306	0.310	0.280	0.296	0.288	0.303
	(.057)	(.051)	(.049)	(.007)	(.076)	(.045)	(.047)
Cross-over	0.300	0.318	0.311	0.307	0.366	0.336	0.311
	(.016)	(.081)	(.062)	(.112)	(.039)	(.048)	(.062)

contact times were calculated for the following subgroups: college level subjects, club level subjects, subjects with less than seven years experience, and subjects with seven or more years experience. In addition, mean contact times were calculated for college level subjects with less than seven years experience and seven or more years experience, and for club subjects with less than seven years experience and seven or more years experience.

Subjects with less than seven years experience. Mean contact time for all subjects with less than seven years experience using the shuffle step was observed to be 0.336 (SD = .061) seconds. Mean contact time for all subjects with less than seven years experience using the turn-and-run step was observed to be 0.303 (SD = .052) seconds. Mean contact time for all subjects with less than seven years experience using the cross-over step was observed to be 0.316 (SD = .080) seconds.

Subjects with seven or more years experience. Mean contact time for all subjects with seven or more years experience using the shuffle step was observed to be 0.311 (SD = .046) seconds. Mean contact time for all subjects with seven or more years experience using the turn-and-run step was observed to be 0.302 (SD = .045) seconds. Mean contact time for all subjects with seven or more years experience using the cross-over step was observed to be 0.303 (SD = .025) seconds.

Vertical Displacement

Mean vertical displacements were calculated across all subjects and are presented in Table 3. Mean vertical displacements were calculated for the following subgroups: college level subjects, club level subjects, subjects with less than seven years experience, and subjects with seven or more years

Table 3

Mean Vertical Displacements (in Meters) And Standard Deviations (Given in Parentheses) For Each Step Pattern For All Subjects By Level of Competition and Years of Experience.

	College			Club			All
Step	<7 yrs	≥7 yrs	All	<7 yrs	≥7 yrs	All	
Shuffle	0.276	0.332	0.311	0.298	0.286	0.292	0.307
	(.012)	(.096)	(.079)	(.116)	(.003)	(.067)	(.072)
Turn-and-run	0.250	0.316	0.291	0.284	0.324	0.304	0.295
	(.021)	(.066)	(.062)	(.056)	(.041)	(.046)	(.055)
Cross-over	0.295	0.307	0.303	0.294	0.346	0.320	0.308
	(.037)	(.076)	(.061)	(.110)	(.036)	(.073)	(.063)

experience. In addition, vertical displacements were calculated for college level subjects with less than seven years experience and seven or more years experience, and for club subjects with less than seven years experience and with seven or more years experience.

Subjects with less than seven years experience. Mean vertical displacements for all subjects with less than seven years experience using the shuffle step was found to be 0.285 (SD = .060) meters. Mean vertical displacements for all subjects with less than seven years experience using the turn-and-run step was found to be 0.263 (SD = .037) meters. Mean vertical displacements for all subjects with less than seven years experience using the cross-over step was found to be 0.294 (SD = .061) meters.

Subjects with seven or more years experience. Mean vertical displacements for all subjects with seven or more years experience using the shuffle step was found to be 0.319 (SD = .082) meters. Mean vertical displacements for all subjects with seven or more years experience using the turn-and-run step was found to be 0.318 (SD = .057) meters. Mean vertical displacements for all subjects with seven or more years experience using the cross-over step was found to be 0.318 (SD = .067) meters.

Related Kinetic and Kinematic Parameters

Seven kinetic and kinematic variables were measured in addition to contact time and vertical displacement. Means for each variable by step pattern are reported in Table 4. Means for each subject by step pattern are also presented in Appendix F.

Table 4

Means and Standard Deviations (Given in Parentheses) for Seven Kinetic and Kinematic Variables For All Subjects by Step Pattern.

	Step Pattern					
	Shuffle		Turn-and-run		Cross-over	
Variable	Mean	SD	Mean	SD	Mean	SD
Impact force (N)	1671	(443)	1668	(582)	1491	(576)
Impact phase time (sec)	0.062	(.042)	0.035	(.024)	0.061	(.052)
Vertical thrust (N)	1803	(185)	1996	(291)	1707	(226)
Impulse change (Ns)	152.6	(24.1)	159.6	(25.5)	135.7	(42.7)
Peak force (N)	1812	(186)	2004	(294)	1723	(214)
Horizontal takeoff velocity (m/s)	0.150	(.087)	0.286	(.196)	0.206	(.186)
Vertical takeoff velocity (m/s)	2.622	(.375)	2.467	(.240)	2.452	(.365)

Analysis of Data

Contact Time

In order to test the main hypothesis related to contact time, mean contact time for each step pattern was tested for differences through a Kruskal-Wallis ANOVA (performed through Statistics With Finesse on an IBM compatible computer). Results indicated no significant difference was found between step patterns with respect to contact time ($p = .7560$).

Contact time and competitive level. Mean contact times for each step pattern were compared for possible differences due to level of competition (college or club). A 95% confidence interval was used to test for differences in means for contact times between college and club subjects for the three step patterns. In addition, a 95% confidence interval was used to test for differences in mean contact times between step patterns for college subjects. A 95% confidence interval was also used to test for differences in mean contact time between step patterns for club subjects. For all three step patterns, no statistical difference was discovered between college and club subjects. In addition, no significant difference was observed between step patterns within each subgroup (college or club).

Contact time and years of experience. To test for possible differences in contact time due to years of experience, a 95% confidence interval was used. Mean contact time for each step pattern was compared between subjects with seven or more years experience and subjects with less than seven years experience. In addition, a 95% confidence interval was used to test for differences in mean contact times between step patterns for subjects with seven or more years experience. A 95% confidence interval was also used to test for differences in mean contact time between step patterns for subjects with less than seven years experience. Results indicated no significant difference in step patterns when considering years of experience. In addition, no significant difference between step patterns was observed within each subgroup (subjects with less than seven years experience and subjects with seven or more years experience).

Vertical Displacement

To test the main hypothesis concerning vertical displacement, mean vertical displacements for each step pattern were tested using a Kruskal-Wallis ANOVA. Results indicated that no statistical difference was observed between step patterns with respect to vertical displacement ($p = .8728$).

Vertical displacement and competitive level. Mean vertical displacements for each step pattern were compared for possible differences due to the level of competition. A 95% confidence interval was used to determine differences in means between college and club subjects for each step pattern. In addition, a 95% confidence interval was used to test for differences in mean vertical displacements between step patterns for college subjects. A 95% confidence interval was also used to test for differences in mean vertical displacements between step patterns for club subjects. Mean vertical displacement for each step pattern was not significant with respect to the level of competition or within each subgroup (college or club).

Vertical displacement and years of experience. To test for possible differences in vertical displacement due to years of experience, a 95% confidence interval was used. Mean vertical displacement for each step pattern was compared between subjects with seven or more years experience and subjects with less than seven years experience. In addition, a 95% confidence interval was used to test for differences in mean vertical displacements between step patterns for subjects with seven or more years experience. A 95% confidence interval was also used to test for differences in mean vertical displacements between step patterns for subjects with less than seven years experience. Results indicated no significant difference in step patterns when considering years of experience. In addition, no significant difference between step patterns was observed within each subgroup (subjects with less than seven years experience and subjects with seven or more years experience).

Summary

Mean kinetic and kinematic data were collected for each step pattern for each subject. Mean contact times were calculated for the following subgroups: college level subjects, club level subjects, subjects with less than seven years experience, and subjects with seven or more years experience. In addition, mean contact times were calculated for college level subjects with less than seven years experience and seven or more years experience, and for club subjects with less than seven years experience and seven or more years experience. Differences between means for contact time for each step pattern for all subjects was not significant. In addition, there were no statistically significant findings for contact time and years of experience or level of competition.

Mean vertical displacements were calculated for the following subgroups: college level subjects, club level subjects, subjects with less than seven years experience, and subjects with seven or more years experience. In addition, vertical displacement times were calculated for college level subjects with less than seven years and seven or more years experience, and for club subjects with less than seven years experience and seven or more years experience. The differences between means for vertical displacement for each step pattern for all subjects was not significant. In addition, there were no statistically significant findings for vertical displacement and years of experience or level of competition.

CHAPTER V

Discussion, Conclusions, and Recommendations

This chapter has been divided into the following major headings: (1) discussion of findings, (2) conclusions, (3) weaknesses of study, (4) recommendations for future research, and (5) chapter summary.

Discussion of Findings

The purposes of this study were to examine which step pattern was associated with the greatest vertical displacement and which step pattern was associated with the shortest contact time. The null hypothesis was taken as the research hypothesis. That is, no specific step technique would be superior to the others in terms of either jump height or takeoff times.

Vertical Displacement And Contact Time

The findings of the present research have supported the null hypothesis. That is, there were no statistically significant differences between jump height and contact times for any of the three step techniques. It was determined in previous work (Khayambashi, 1977; Maxwell, et al., 1980; Scates, 1976) that subjects who precede a vertical jump with a number of preparatory steps have demonstrated higher vertical jumps than without an approach. Kayambashi (1977) found that the maximum height attained for a female group was observed using a three step approach.

It was noted by this author that the cross-over step was very similar in execution to the three-step approach used by spikers. With this in mind, one may be led to believe that the cross-over step would have been more effective in getting higher vertical displacements than the other two steps investigated. The findings of the present research have partially supported the findings of earlier work (Cox, Noble, and Johnson, 1982). Mean vertical displacement was the greatest using the cross-over step, although it was not significantly different than the turn-and-run and shuffle steps.

For all college players, the shuffle step had the longest mean contact time of all step patterns which is in agreement with Cox, Noble, & Johnson (1982) and Buekers (1991). This can be explained by the lengthy gathering (impact phase) time (see Table 4) required for the countermovement before jumping (Kwak, et al., 1989). With the exception of college and club players with the least experience, the turn-and-run step had the shortest mean contact time which was consistent with the work by Kwak et al. (1989).

Interaction of Results

Cox, Noble, and Johnson (1982) have claimed that shorter gathering times are related to greater vertical jumps. However, results from the present study do not support their work. The turn-and-run step had the shortest mean gathering time (impact phase time), yet had the lowest mean vertical displacement for the group. Shorter takeoff times have been related to increases in jumps (Aura & Viitasalo, 1989; Coutts, 1982; Hay, 1993). In the present study, however, the step with the shortest mean contact time (turn-and-run) was related to the lowest mean vertical displacement. The step with the longest total contact time (shuffle) was not related to either the highest or the lowest vertical displacement. Since the longest mean contact time was observed with the shuffle step, these results support the previous work of Kwak, et al. (1989).

The turn-and-run step had the shortest mean gathering and contact time. In addition, it had the highest mean vertical thrust and mean peak force, yet still had the lowest mean vertical displacement. It may be interesting to note that the cross-over step had the lowest mean value for five of the nine variables measured. Despite this fact, the cross-over step had the highest mean vertical displacement. Even though the cross-over step did not rank well in terms of kinetic and kinematic variables, it may be speculated that the cross-over is a more natural movement for volleyball players.

The shuffle step had the lowest mean horizontal and the highest mean vertical velocities at takeoff, which may indicate a higher vertical displacement. However, mean vertical displacement for the shuffle step was second behind the cross-over step. The cross-over step had the lowest mean vertical velocity, yet maintained the highest mean vertical displacement. The high horizontal velocity at takeoff for the turn-and-run step may have been due to the short total contact time. The high vertical velocity at takeoff would influence the vertical velocity at takeoff which could have caused the vertical displacement to be as low as it was.

Another perplexing condition was observed with regard to vertical thrust and vertical displacement. The step pattern with the highest vertical thrust (the turn-and-run) was associated with the lowest vertical displacement. This might be partially explained in that the high horizontal velocity from the approach may have positively influenced the vertical thrust, but because horizontal velocity was high, the COM may not have achieved a maximal vertical displacement. It may be interesting to note that the turn-and-run step ranked most favorably for five of seven kinetic and kinematic variables, yet was associated with lowest vertical displacement.

On the other hand, the cross-over step was found to have the lowest mean vertical thrust, yet had the highest mean vertical displacement. It might be reasonable to hypothesize that subjects were able to jump higher due to the similarities in footwork between the cross-over and the step-close used when spiking.

Despite the cross-over step being associated with the highest mean vertical displacement, the turn-and run step had a mean vertical displacement that was only 0.013 meters less than the cross-over step. While the turn-and run step had a mean contact time of 0.303 seconds, the shuffle step had a mean contact time that was only 0.022 seconds longer. Essentially, the mean values obtained from the three step patterns did not clearly identify a step pattern that was more advantageous than another in terms of contact time or vertical displacement.

Conclusions

The purposes of this study were to examine which step pattern was associated with the greatest vertical displacement and which was associated with the shortest contact time. The research hypothesis stated that no step pattern would be significantly different from another in terms of vertical displacement or contact time. Results have indicated that this hypothesis can be accepted. In this study, there were no statistically significant differences between step patterns with respect to contact time or vertical displacement for the sample tested. Previous literature has been inconclusive in identifying a step pattern that is significantly superior in terms of vertical displacement or contact time. The results of this study have been in line with previous research (Farokmanesh & Mc Gowen, 1988).

Temporal examination of the three step patterns has determined there is no significant difference between step patterns in general, based upon years of experience, or level of competition for the sample tested. The middle blocker must often jump immediately upon arriving at the takeoff position. Therefore, it is desirable for the blocker to get into the air as quickly as possible. Despite the lack of statistical difference between step patterns, the turn and run was, on average, 0.022 seconds faster than the shuffle step. This was found not to be statistically, or ecologically significant.

In light of the results, one must consider several factors including: the demands of blocking, the speed of the set ball, and the flow of the game. A good blocker will attempt to not only reach high, but also penetrate the opponent's side of the net (Scates, 1976). Timing for a blocker is critical to a blocker's success, to avoid blocking errors, and to block a ball at the peak of the jump (C. Choate, personal communication, January 26, 1995). Since a ball that has been spiked travels at a very high velocity, it is important for the blocker to be in the air quickly. However, the mean difference (0.022 seconds) between the turn-and-run step and the shuffle step in this study is an amount of time that rivals human reaction time (Magill, 1989; Shea, Shebilske, & Worchel, 1993).

From the sample tested, the preference of one step pattern over another cannot be substantiated on the basis of contact time. Despite a longer gathering time seen with the shuffle step, there was no statistical difference between the three patterns that would suggest one step is more favorable.

Generally when blocking, no advantage is served by an increase as little as one inch for example. Vertical displacements for all three step patterns were not statistically significant in general, based upon years of experience, or level of competition for the sample tested. When blocking, a jump that is one inch, for example, higher than another has very little ecological significance. In this study, the largest mean difference in vertical displacement was between the cross-over step and the turn-and-run step (0.013 meters), which was neither statistically, nor ecologically, significant.

A step pattern that can produce a vertical jump that is, on average, 1.3 centimeters better than other step patterns has little ecological significance. Previous research has questioned the preference of a 0.6 inch increase in jump height (Farokhmanesh & Mc Gowen, 1988). A blocker with perfect timing on a block will not be aided by an additional 1.3 centimeters.

Implications

This study has shown that there is no statistical significance between the three step patterns used for blocking. Implications from this study must be viewed in light of the situations that arise during a volleyball game. This study used subjects that traveled between 4 and 6 meters. During the course of a volleyball game, a middle blocker may have to travel more or less depending on the defensive situation faced by the player.

Situations may partially dictate which footwork to use. Athletes and practitioners must consider which footwork will get the athlete to the blocking position the fastest depending on the specific game situation. If the distance to cover is very short, the turn-and-run may not be suitable.

Likewise, if the distance to be covered is great, the shuffle step may be too slow compared to the turn-and-run step. It may be wise to consider using the turn-and-run step when the distance to be covered is great. Also, if the distance is very short, the shuffle step may be appropriate.

Since there is no statistical difference between step patterns with respect to contact time or vertical displacement, it may be more beneficial for athletes to experiment with all step patterns. Attempting to limit a blocker to one or two footwork patterns may be counterproductive. Certain situations may dictate different footwork patterns. When defending against a complicated or fast offense, the middle blocker faces a greater number of blocking options. Some middle blockers may have longer stride lengths than others that may call for a preference of one step pattern over another. Some athletes may be able to perform a specific step pattern better due to training, physical ability, personal preference, or task demand characteristics.

Practitioners should consider the results of this study with caution. The results have indicated that there is no statistically significant differences between the step patterns examined. That is not to say that the step patterns examined are all equally effective, but rather, in terms of the research hypothesis, there were no differences observed. It may be that researchers are asking the wrong questions. Instead of trying to find the most effective step technique, perhaps researchers ought to consider other factors which may influence the effectiveness of blocking. If the previous research has been inconclusive in determining the most effective step pattern, then perhaps the research has examined the wrong questions.

From the sample tested, the results indicated that the turn-and-run step had the fastest mean contact time, and the cross-over step had the greatest mean vertical displacement for the three steps examined. However, due to the lack of statistical significance between means, it would be unwise to attempt to limit the teaching of blocking footwork patterns to the cross-over and turn-and-run step.

Weaknesses of Study

The lack of diversity in the subject pool may be considered a weakness. The subjects examined were not yet collegiate athletes or were college level athletes which competed on the same team. Furthermore, the subjects who were competing on the same team may have had similar training which may have influenced the results.

No investigation of a preferred step pattern was made. It may be reasonable to expect each subject to have a preference of step pattern. Subjects from the same college program may have had a preferred step pattern based upon previous training practices. Likewise, the club subjects each may have had a preference for a specific step pattern. In addition, no information was collected concerning the amount of experience using the step patterns.

The lack of a game-like atmosphere may have contributed to less than valid data. The test protocol had no intrinsic value for the blocker to jump high or takeoff quickly, whereas during a game, blockers typically focus on working hard to stop a spiker. In addition, during a game, the middle blocker is visually observing several cues and does not know where the ball will be set which may affect the preparation to block. In the present study, the subjects were all informed that they would be moving to the right.

The present study failed to examine the braking force for each step pattern. Braking force is closely tied to contact time and the conversion of horizontal to vertical velocity. Braking force is critical for a middle blocker when forming a double block. If the middle blocker does not brake enough when moving laterally, the blocker will probably drift into the outside blocker during free flight decreasing the potential to maximize the vertical jump and risking injury.

Recommendations for Future Study

The results of this study have determined that none of the step patterns examined was better than another in terms of either contact time or vertical displacement at a statistically significant level. Future investigators may wish to address the weaknesses discussed in the preceding section. Two key potential sources of error need to be addressed in a future study: the lack of a game-like environment and subject motivation to perform with maximal effort.

It would be desirable to include more subjects from different universities, rather than from the same program, but limit subjects to top college athletes. For example, it may be preferable to draw subjects from college programs that are ranked in the top twenty in the country, or subjects that compete internationally or for the national team. It may also be interesting to examine subjects that hold National Collegiate Athletic Association solo blocking records.

The lack of a game-like environment may be the largest source of error. The results from a study under game-like circumstances may be more applicable to practitioners. The absence of a competitive environment diminishes the ability to apply this study in the field. The results found in the lab may not match those found under a competitive situation. Essentially, placing subjects under competitive conditions, subjects may respond with maximal effort. It is recommended that future investigators attempt to use a portable force platform that can be placed on a volleyball court during a game-like or actual competition situation.

To study kinetic variables under game like conditions, future investigators may need to use a force plate that is portable or can be placed in a position that will allow the collection of data during a volleyball game. It may also be interesting to investigate differences between moving to the left versus moving to the right.

Summary

While step patterns could be identified as having the greatest mean vertical displacement or the fastest mean takeoff time, there were no statistically significant differences between the step patterns that would suggest one step pattern was more favorable than another. The largest difference between means for contact time was observed at 0.022 seconds, which was found not to be statistically significant. Mean vertical displacements for each footwork pattern showed a mean difference of 1.3 centimeters which was also found to not be statistically significant.

It was concluded that athletes and practitioners should consider footwork patterns that may be appropriate for different situations, and that blockers should be allowed to experiment with all step patterns so that they may be able to use the footwork pattern that best suits their physical ability or task demands.

It was also concluded that more subjects from a larger cross section of top college programs, or subjects of who compete at the national team level, would have been desirable, and that the collection of data would be more valid and worthwhile if collected under game-like situations.

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Appendix A

Human Subjects Institutional Review Board Approval.

SJSU SAN JOSE STATE UNIVERSITY

A campus of The California State University

Office of the Academic Vice President • Associate Academic Vice President • Graduate Studies and Research
One Washington Square • San José, California 95192-0025 • 408/924-2480

TO: Jeffrey Michael Wanderer
5948 Bridgeport Lake Way
San Jose, CA 95123-2438

FROM: Serena W. Stanford
AAVP, Graduate Studies & Research

DATE: May 17, 1995

The Human Subjects-Institutional Review Board has approved your request to use human subjects in the study entitled:

"A Biomechanical Analysis of Selected Blocking Footwork Patterns for Contact Time and Jump Height in Elite Female Volleyball Players"

This approval is contingent upon the subjects participating in your research project being appropriately protected from risk. This includes the protection of the anonymity of the subjects' identity when they participate in your research project, and with regard to any and all data that may be collected from the subjects. The Board's approval includes continued monitoring of your research by the Board to assure that the subjects are being adequately and properly protected from such risks. If at any time a subject becomes injured or complains of injury, you must notify Serena Stanford, Ph.D., immediately. Injury includes but is not limited to bodily harm, psychological trauma and release of potentially damaging personal information.

Please also be advised that each subject needs to be fully informed and aware that their participation in your research project is voluntary, and that he or she may withdraw from the project at any time. Further, a subject's participation, refusal to participate, or withdrawal will not affect any services the subject is receiving or will receive at the institution in which the research is being conducted.

If you have any questions, please contact me at (408) 924-2480.

Appendix B

Informed Written Consent Form.

SJSU SAN JOSE STATE UNIVERSITY

A campus of The California State University

Division of Intercollegiate Athletics • One Washington Square • San José, California 95192-0062 • 408/924-1200

Agreement to Participate in Research

Responsible Investigator: Jeff Wanderer

Title of Protocol: A biomechanical analysis of selected blocking footwork patterns for contact time and jump height in elite female volleyball players

Subject: ______

I have been asked to participate in a research study investigating the kinetic and kinematic variables associated with blocking footwork patterns used by middle blockers in volleyball. I will be asked to wear lycra type shorts and have specified joints marked with athletic cloth tape and be video taped while performing three different footwork patterns. No forseeable risks or discomforts are anticipated. I understand that no direct benefits to myself are expected, although the video tapes and resultant data are available to me at any time. I understand that the results of this sudy may be published but no information that could identify me will be included unless I so authorize. However, the researcher may keep the video tapes for his own purposes. Questions about this study may be addressed to the principle investigator, Jeff Wanderer (408-924-1444). Complaints about this study may be presented to the Human Performance Chair (James Bryant, 408-924-3010). Questions or complaints about research, subjects' rights, or research related injury may be presented to Serena Stanford, Ph.D., Associate Vice President of Graduate Studies and Research, at (408) 924-2480. I understand that if I choose not to participate in this study no services of any kind, to which I am otherwise entitled, will be lost or jeopardized. My consent to participate in this study is given voluntarily. I may refuse to participate in the study or in any part of the study, and if I decide to participate in this study, I am free to withdraw at any time without prejudice to my relations with San Jose State University or any participating institutions. I acknowledge that I have received a signed and dated copy of the consent form.

***The signature of a subject on this document indicates agreement to participate in the study.**
****The signature of a parent or gaurdian on this document indicates approval the child or ward to participate in the study and that the child or ward is freely willing.**
*****The signature of a researcher on this document indicates agreement to include the above named subject in the research and attestation that the subject has been finally informed of his or her rights.**

Subject's Signature	Date	Name of Subject (print)
Parent/Gaurdian Signature	Date	Relation to Child or Ward

Investigator's Signature   Date   Phone

Appendix C

Subject Information Survey.

SJSU SAN JOSE STATE UNIVERSITY

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Division of Intercollegiate Athletics • One Washington Square • San José, California 95192-0062 • 408/924-1200

SUBJECT ID ____________________ DATE__________

Competitive information

TEAM__________________ LEVEL (circle) DI college DI club

OF YEARS EXPERIENCE________________

Demographic information

AGE_________

HEIGHT_________

WEIGHT_________

Appendix D

Mean Contact Time for the Shuffle Step, Cross-over Step, and the Turn-and-run Step by Subject.

Subject	Competitve Level	Years of Experience	Step Pattern Shuffle	Turn and Run	Cross-over
1	College	7	0.302	0.282	0.401
2	College	10	0.332	0.270	0.278
3	College	4	0.327	0.342	0.282
4	College	9	0.261	0.287	0.203
5	College	7	0.341	0.296	0.323
6	College	6	0.384	0.355	0.304
7	College	5	0.289	0.251	0.314
8	College	7	0.394	0.395	0.383
9	Club	7	0.435	0.350	0.393
10	Club	4	0.275	0.275	0.276
11	Club	7	0.287	0.242	0.234
12	Club	4	0.278	0.285	0.338

All values expressed in seconds.

Mean Contact Time by Subject and Step Pattern.

Appendix E

Mean Vertical Displacement for the Shuffle Step, Cross-over Step, and Turn-and-run Step by Subject.

Subject	Competitive Level	Years of Experience	Step Pattern: Shuffle	Turn and Run	Cross-over
1	College	7	0.281	0.288	0.238
2	College	10	0.464	0.428	0.422
3	College	4	0.281	0.252	0.331
4	College	9	0.396	0.323	0.319
5	College	7	0.224	0.264	0.236
6	College	6	0.263	0.269	0.295
7	College	5	0.285	0.228	0.258
8	College	7	0.297	0.277	0.321
9	Club	7	0.284	0.353	0.371
10	Club	4	0.216	0.244	0.216
11	Club	7	0.288	0.295	0.320
12	Club	4	0.380	0.323	0.371

All values expressed in seconds.

Mean Vertical Displacement by Subject and Step Pattern.

Appendix F

Mean Values for Seven Related Kinetic and Kinematic Variables for the Shuffle Step, Cross-over Step, and Turn-and-run Step by Subject.

Subject	Trial	impact force (N)	impact time (Sec)	vert. thrust (N)	change impulse (Ns)	peak force (N)	horiz. takeoff velocity (m/s)	vertical takeoff velocity (m/s)
		Variable						
	Shuffle	1552	0.075	1561	156.1	1561	0.129	2.592
1	Turn and Run	1972	0.038	1966	168.6	1972	0.129	2.484
	Cross-over	1587	0.067	1444	215.7	1587	0.129	2.373
	Shuffle	1893	0.028	1882	194.6	1893	0.144	3.288
2	Turn and Run	1674	0.017	1903	132.5	1903	0.513	3.129
	Cross-over	315	0.022	1249	60.3	1249	0.040	2.730
	Shuffle	1717	0.073	1881	175.6	1881	0.000	2.913
3	Turn and Run	1951	0.050	1948	145.0	1951	0.000	2.370
	Cross-over	316	0.008	1866	143.4	1866	0.171	2.082
	Shuffle	2017	0.115	2016	151.4	2017	0.192	2.625
4	Turn and Run	2403	0.075	2390	199.6	2403	0.033	2.799
	Cross-over	1921	0.082	1920	116.0	1921	0.129	2.754
	Shuffle	1695	0.032	1658	107.3	1695	0.144	2.004
5	Turn and Run	448	0.010	2520	194.7	2520	0.501	2.319
	Cross-over	1798	0.045	1808	153.2	1808	0.078	2.157
	Shuffle	2006	0.055	1992	154.1	2006	0.036	3.006
6	Turn and Run	1144	0.012	1484	129.2	1484	0.486	2.340
	Cross-over	2121	0.067	2120	142.6	2121	0.183	1.728
	Shuffle	1514	0.155	1897	129.3	1897	0.168	2.610
7	Turn and Run	1879	0.060	1870	140.0	1879	0.279	1.860
	Cross-over	1805	0.028	1795	136.0	1805	0.180	2.751
	Shuffle	1791	0.048	1764	140.8	1791	0.342	2.718
8	Turn and Run	2139	0.028	2106	162.3	2139	0.456	2.424
	Cross-over	1713	0.045	1695	140.0	1713	0.213	2.661
	Shuffle	1592	0.085	1586	178.3	1592	0.234	2.139
9	Turn and Run	1776	0.068	1759	171.9	1776	0.453	2.640
	Cross-over	1690	0.198	1717	183.9	1717	0.501	3.000
	Shuffle	369	0.005	1512	141.1	1512	0.129	2.157
10	Turn and Run	1379	0.007	1740	161.1	1740	0.054	2.214
	Cross-over	1591	0.013	1591	99.4	1591	0.000	2.154
	Shuffle	1836	0.025	1828	134.1	1836	0.150	2.625
11	Turn and Run	961	0.022	1983	125.2	1983	0.286	2.477
	Cross-over	1385	0.105	1654	80.6	1654	0.206	2.452
	Shuffle	2065	0.052	2053	168.0	2065	0.129	2.784
12	Turn and Run	2295	0.035	2277	185.4	2295	0.246	2.544
	Cross-over	1646	0.048	1625	157.7	1646	0.645	2.586

Mean Values for Related Kinetic and Kinematic Variables by Subject and Step Pattern.