THE RELATIONSHIP OF ARM AND WRIST STRENGTH TO THE VELOCITY OF AN OPEN OVERHAND VOLLEYBALL SERVE

by

Janelle Braatz

ABSTRACT

Arm and wrist strength and the open overhand volleyball serve velocity were determined for 44 female Ss in 7 randomly selected high schools in District III of the Wisconsin Interscholastic Athletic Association. A cable tensiometer and cinematography were used to determine the S's strength and serving velocity, respectively. Multiple r was used to analyze the collected data and found the relationship between arm and wrist strength and open overhand volleyball serve velocity was $P > .05$. It was also found that the reliability r coefficient of the arm strength and wrist strength tests were .91 and .90, respectively when comparing the higher to the lower strength test score.

The Relationship of Arm and Wrist Strength to the Velocity of an Open Overhand Volleyball Serve

---

A Thesis Presented

to

The Graduate Faculty

University of Wisconsin - La Crosse

In Partial Fulfillment

of the Requirement for the

Master of Science Degree

---

by

Janelle S. Braatz

May 1977

UNIVERSITY OF WISCONSIN - LA CROSSE
School of Health, Physical Education and Recreation
La Crosse, Wisconsin 54601

Candidate: Janelle S. Braatz

We recommend acceptance of this thesis in partial fulfillment of this candidate's requirements for the degree:

Master of Science

The candidate has completed her oral report.

Dr. E. Kay Flatten — Thesis Committee Member — Date: 4/25/77

John E. Castle — Thesis Committee Member — Date: 4/25/77

N K Butts — Thesis Committee Chairman — Date: 4/25/77

This thesis is approved for the School of Health, Physical Education and Recreation.

Glenn M. Smith — Dean, School of Health, Physical Education and Recreation — Date: 4-29-77

ACKNOWLEDGEMENT

The author would like to express gratitude to her thesis committee members: Dr. Nancy Butts, for her guidance and support as chairman; Dr. Kay Platten, for her aid in filming and film analysis and Dr. John Castek, for his assistance in statistical design and analysis. Special appreciation is extended to my parents for their guidance and aid in furnishing materials. Furthermore a very special thank you is sent to all subjects and their coaches for contributing their practice time and effort to my study.

TABLE OF CONTENTS

CHAPTER I

INTRODUCTION

In recent years great strides have been taken in the number of participants in girls' sports in Wisconsin. Volleyball is one of the sports that has grown extensively, both in number of participants and the advancement of play. In 1973 the Wisconsin Interscholastic Athletic Association had 231 schools enrolled in the girls' volleyball tournament program; by 1976 the number of schools had increased to 402 (W.I.A.A., 1976).

The serve, a fundamental skill in volleyball, is one of the most important aspects of the game. The serve provides a team with the initial offensive weapon necessary for scoring (Odeneal & Wilson, 1962; Sandefur, 1970; Shondell & McManama, 1971).

Serves are divided into three basic categories which are: underhand, sidearm and overhand. In comparing serves, Welch (1960) stated that an overhand serve can be served faster which allows the opponent less time to react and obtain good playing position. Trotter (1965) found the overhand serve required a higher degree of playing proficiency but offered more power or force compared to other serves. Furthermore the overhand serve possesses the aspects of a good serve. It is accurate the majority of the time and the

most difficult to return (Odeneal & Wilson, 1962).

Although there are a number of hand contact positions used in overhand serving, the open palm position was preferred (Laveaga, 1960; Sandefur, 1970; Scates, 1973; Schurman, 1974; Thigpen, 1967; Trotter, 1965). These authors felt the open overhand serve was most desirable and provided the most control over the ball. When executed correctly, the control, power and speed of the open overhand volleyball serve should provide more points than any other serve.

Theoretically the open overhand serve should be the best serve to place the ball into play. The ability of a server to execute an open overhand serve may depend on many factors, including strength. "Strength is basic to performance in activities" (Mathews, 1968, p. 59). The server's strength may greatly determine the striking force imparted to the volleyball and the resulting velocity. If strength affects the velocity, then a coach may emphasize strength training as part of a volleyball conditioning program. If strength does not affect velocity then a coach may place emphasis on other training and strategies.

Statement of the Problem

The existence of a relationship between arm and wrist strength to the velocity of an open overhand serve has not been reported in the literature. It would appear that arm and wrist strength could be components of a server's ability

to perform a fast, open overhand serve. If such a relationship exists then a training program emphasizing arm and wrist strength should be incorporated into a conditioning program. If a relationship does not exist then strength training for the arm and wrist would not be stressed or incorporated in the conditioning program.

Purpose of the Study

The purpose of this study was to determine if a relationship between a server's arm and wrist strength and serve velocity exists in female interscholastic high school volleyball players using the open overhand serve.

Hypothesis

For this study, the hypothesis was stated in the null: there is no significant relationship between arm and wrist strength and the velocity of an open overhand volleyball serve in high school girls.

Assumptions

The following assumptions were made in regard to this study:

1. High speed cinematography provided an accurate method of determining velocity of a volleyball serve.

2. The cable tensiometer provided an accurate method of measuring arm and wrist strength.

Delimitations

The following are delimitations of this study:

1. The subjects were selected from a random sample of seven schools in District III of the Wisconsin Interscholastic Athletic Association (W.I.A.A.) in the 1976-77 school year.

2. A pool of 58 schools were randomly selected from District III of the W.I.A.A. to fill any refusals of participation from the original seven randomly selected schools.

3. Only varsity players of a girls' W.I.A.A. volleyball team who used an open overhand volleyball serve were considered in the sample.

4. All subjects were tested during a volleyball practice session during the last three weeks of the 1976-77 W.I.A.A. volleyball season.

5. A cable tensiometer was used to measure the arm and wrist strength of the servers.

6. Cinematography was used to determine volleyball velocity.

Limitations

The following are limitations of this study:

1. The tests were given at different locations and on different days of the 1976-77 W.I.A.A. volleyball season.

2. Different teaching techniques and training programs were used by each coach.

3. The servers' motivation to do well on the serving

test and strength tests were uncontrollable.

4. The ability of the servers to serve normally with foreign objects such as the cameras and lights, were uncontrollable.

5. The selection of varsity team members, by the respective coaches, differed in each school.

Definition of Terms

Arm strength test. The measurement of the muscular pull of the arm and shoulder when held in an overhand volleyball serve position. A cable tensiometer was used to measure the force exerted.

Cable tensiometer. An instrument used to measure isometric strength through the tension placed on a cable running over a riser on the tensiometer.

Cinematography. A process of motion picture filming and analyzing the developed film. In this study it was used to calculate volleyball velocity.

Interscholastic team. A team that has competition between different schools and in this study a member of the Wisconsin Interscholastic Athletic Association.

Open overhand volleyball serve. A volleyball serve contacted at head level or above with the heel, palm, fingers or any combination of hand parts, as long as the hand remains open on contact.

Strength. The capacity of a muscle or muscle group to exert a force or resist a force.

Varsity volleyball team. A group of interscholastic volleyball players selected as the best volleyball players of that school.

Velocity. The speed of an object in flight, calculated through the basic relationship of distance divided by time. In this study, determined through cinematography.

Wrist Strength test. The measurement of the muscular pull of the wrist when held in an overhand volleyball serve position. A cable tensiometer was used to measure the pull exerted.

CHAPTER II

REVIEW OF RELATED LITERATURE

The review of literature is divided into four major areas: (1) Overhand Serve, (2) Strength, (3) Velocity and (4) Related Topics.

Overhand Serve

"The serve is the most effective scoring weapon in volleyball" (Odeneal & Wilson, 1962, p. 16). Of the three types of serves, underhand, sidearm and overhand, the overhand serve provided the most effective serve (Odeneal & Wilson, 1962; Trotter, 1965; Welch, 1960).

Bunn (1955) stated there are two commonly used serves, the underhand and the overhand, however the overhand serve was considered to be the major offensive serve. In the overhand serve, the ball can be hit with more force than the underhand serve because the arm is swung through a larger arc and gains greater speed of movement.

Overhand serves are generally divided into three types: floater, spin and roundhouse (Scates, 1976). The floater moves in an erratic pattern and is contacted with the heel of the hand. The spin serve makes contact with the heel of the hand which is followed by a quick wrist snap thus the whole hand contacts the ball. The roundhouse serve exhibits

speed and force through a full arm swing with contact by the heel of the hand.

Shondell and McManama (1971a) found the most popular competitive serve was the overhand floater. This serve is contacted with a jab from the heel of the hand through the center of the ball. "The heel of the hand is the most common contacting surface" (p. 28). The contact must be made solid and sharp with a compact striking surface, which eliminates spin. Schurman (1974) suggested the floater is the most effective of the overhand serve deliveries. It is served sharply with a quick wrist snap and brief contact between either the heel or cupped hand position.

Other overhand serves (Scates, 1973) are the spin and roundhouse serve. The spin serve (Scates, 1976; Welch, 1960) is contacted with a quick wrist snap forward followed by the fingers capping the ball on contact. The roundhouse serve (Schurman, 1974) employs the use of the palm and heel of the hand. The cocked back wrist position provided the key to a good roundhouse serve. As the ball is contacted the wrist snaps forward with the palm and fingers rolling over the ball.

In comparing a spin and floater, Welch (1960) stated both serves are very effective and can be used interchangeably. Both serves are contacted with the heel of an open hand but if spin was desired the fingers should cap the ball on contact. This author also felt that the overhand serve was hit very similar to a spike in volleyball.

Although there is an agreement among several authors (Odeneal & Wilson, 1962; Trotter, 1965; Welch, 1960) on the effectiveness of the overhand serve there are several variations in hand contact positions. Scates (1976) emphasizes an open hand method of contact rather than a fist or side of the hand in all three types of overhand serves. McManama and Shondell (1969) indicated there are three common types of overhand service contacts: open hand, cupped and knuckle. All three methods of service contact are a form of an open hand hit. The cupped serve has a similar shape to the open except the thumb and little fingers are turned toward the palm. The knuckle contact results in an open hand hit except the fingers are flexed to a 90 degree angle at the middle and distal joints.

Other authors (Laveaga, 1960; Sandefur, 1970; Thigpen, 1967; Trotter, 1965) refer to the open hand contact position as being most favorable. Laveaga (1960) stressed the overhand serve be hit with a cupped hand through a snapping forward, forceful manner. A serve hit squarely with the heel of the hand was emphasized by Sandefur (1970). Thigpen (1967) felt a serve should be contacted at the exact center of the ball with the heel, palm and fingers of an open hand moving with a forward snapping motion. Trotter (1965) stated the open palm position provided the most control for the overhand volleyball service.

Strength

The importance of strength to an individual has been emphasized since ancient times.

> Observers of sports through the ages have been cognizant of the role of strength, and the topic has intrigued investigators in such diverse fields as physical education, psychology, medicine, child growth and development and gerontology (International Committee for Standardization of Physical Fitness Tests, 1974, p. 350).

Mathews (1968) stressed strength is basic to good performance in athletic skills. Shondell and McManama (1971a) stated a regular volleyball training program should include weight training every other day and on alternate days work on volleyball skills. Schurman (1974) also felt weight training, as well as non-weight exercises should be incorporated into a volleyball program.

Trotter (1965) and Welch (1960) agreed that a volleyball player needs a high standard of physical fitness but also needs specific conditioning for volleyball. "... competition in volleyball calls upon concentrated use of specific muscles namely, fingers, hands, arms, shoulders, back, feet and legs" (Trotter, 1965, p. 211). "... the volleyball player must strengthen his wrists, arms and shoulders, back, feet and calf muscles (Welch, 1960, p. 123).

Odeneal and Wilson (1962) also felt that strength is an important aspect of playing a good volleyball game. In 1974, Schurman stressed the importance of increased strength in the wrist and arms which permits a more forceful spike.

In reference to strength there are two basic types: isotonic and isometric. Isotonic strength refers to the resistance a muscle or muscle group can overcome in one application of force through a full range of motion. Isometric strength refers to the force a muscle group can exert on a fixed resistance (Morehouse & Miller, 1971).

According to de Vries (1974) finding accurate and objective methods to measure strength presents a problem. Isotonic measurements are very time consuming and often become a trial and error situation with fatigue setting in before the maximal strength level is reached. On the other hand isometric measurements are easier, quicker and more precise. The major problem with isometric strength tests are the specificity for that particular angle of pull rather than a full range of movement.

Clarke (1956) conducted a study of isometric muscular strength instruments. The instruments were a cable tensiometer, strain gauge, spring scale and myometer. The results found the cable tensiometer to be the best.

> As reflected by the objectivity coefficients, the cable tensiometer had greatest precision for strength testing. It was the most stable and generally useful of the instruments, and was free of most of the faults of the other devices (p. 272).

Later in a 1970 publication, Clarke and Clarke found the cable tensiometer to be one of the simplest and most widely used strength testing devices. It is small, compact and extremely versatile. Of the isometric strength measuring de-

vices de Vries (1974) found the cable tensiometer as the simplest and most widely used.

In 1970, Anderson compared four strength instruments in measuring flexor muscle strength of the forefinger, wrist and elbow. The four instruments compared were the tensiometer, strain gauge, dynamometer and linear variable differential transformer. Sixty-five men were subjects and were tested three times daily on three different days. The results of this study indicated the tensiometer was the most stable from trial to trial although the strain gauge was best in measuring precision. Furthermore Anderson (1970) stated all four instruments could be used with confidence in their stability and precision. He suggested consideration should be given to the economy and practical application of the four instruments rather than the difference in stability or precision.

Velocity

The overhand serve is a form of the overhand throwing pattern which utilizes the highest speed joint actions of wrist flexion and shoulder medial rotation (Cooper & Glassow, 1972). Broer (1960) agreed that the overhand pattern produced the most speed. This pattern permits the longest backswing and the use of many body parts allowing more speed to develop than the underhand throw.

According to Wells and Luttigens (1976) there are six major factors that determine the speed of a struck ball.

These are the speed, mass and coefficient of restitution of the ball and the speed, mass and coefficient of restitution of the striking implement.

In addition, Broer (1960) suggested that if the purpose of a ball was to travel a set distance in the least amount of time then the angle should be flattened. The amount of flattening depends on the force that can be produced by the person. Wells (1960) stated the efficiency of the imparted force is judged by the speed, distance and direction of the ball after its release. The velocity of the thrown ball is directly related to the amount of force produced in the throwing motion, and the speed at the moment of release.

Piereck (1969) stated there are four basic ways to determine the velocity of a projected object. The four methods are:

1. Measuring the length of the bounce of the ball after contact with the ground.
2. By measuring the height of contact, the horizontal distance the ball travels and the time the ball is in flight and convert this information to a velocity through trigonometric tables.
3. Using ropes that are a prescribed horizontal and vertical distance and measuring the height of contact, the height the ball crosses the ropes and the horizontal distance the ball travels.
4. Motion picture filming.

In reviewing these methods Fiereck (1969) found the bounce method supplies only a rough estimate of ball velocity, since it does not consider spin or angle of rebound. The second method needs large amounts of data to be collected and is time consuming. The third method also takes a great deal of time in setting up ropes and calculating the various measurements. Fiereck (1969) set up a subjective rating method for the velocity of the tennis serve but found errors were made by the raters. Furthermore she identified filming as the best method for determining velocity, although filming requires complicated equipment and time in analyzing the measurements.

Rogers's (1969) study dealt with the velocity and angle of projection of the volleyball spike. In this study three methods of assessing velocity were compared: film analysis, subjective rating and time-distance-height of contact method. This study also found the time-distance-height of contact method was difficult due to obtaining trained raters and took too much time for analysis.

Although film analysis is an accurate method of determining velocity, the equipment is expensive and analysis is time consuming. In comparing the three different velocity tests, Rogers (1969) found variation in correlation coefficients. Correlation coefficients were: film and time-distance was .90; subjective and time distance was .76; and subjective and film was .65. These correlations were based on the

fourth trial of five for the filming (a total of 71) and all five trials for the time-distance and subjective tests (a total of 365).

According to Bunn (1955) filming of sports activities has been used for years. Filming allows accurate analysis of movement in speed, force, distance, angles, etc.

Related Topics

The following references are studies of various articles dealing with strength, velocity, related overhand patterns and volleyball. The articles deal with one or several of these subjects.

Clarke (1960) conducted an experiment on the correlation of strength/mass ratio to arm strength. Forty-eight male students were used to measure the strength and mass of the right arm and the speed of the right arm. Speed was tested through the use of chronoscopes and measured in the horizontal plane. Strength was measured by a spring scale and mass by weighing the arm. The results showed that muscle exertion (strength) is highly specific to a related movement.

In 1961, Smith studied the relationship of maximum speed of movement with the subjects' strength, reaction latency, mass and length of limb. Data was collected on 70 men and included reaction time, speed of movement in the horizontal plane for the preferred arm and vertical plane for the preferred leg. Smith's (1961) conclusions were similar to Clarke (1960) in that speed of limb movement is highly

specific to the limb and direction of movement. Also limb movement was unrelated to measured static strength or the ratio of static strength to limb mass.

In 1974, Myer determined the relationship of baseball throwing velocity and arm strength. The cable tensiometer was used to measure arm strength and velocity was determined by timing the ball over a known distance. Ball release started an electric timing device and the device stopped when the ball hit the target. Fifty-two males were given ten trials. Results revealed there was no significant relationship between arm strength and the velocity of a thrown baseball.

Vogt (1961) studied the effects of grip and wrist strength exercises on tennis playing ability. Eighteen college women comprised two groups, a control and an exercise group. Both groups were pre and post tested on a modified Dyer Backhand Test and cable tensiometer strength tests. After five weeks of wrist and grip strength exercises the exercise group had significantly increased their respective strength. Playing ability was also increased in the exercise group but not significantly.

Another study dealing with grip strength and tennis playing ability was conducted by Stoebe (1976). This study dealt with 75 students ranging from children to adult. The Revised Dyer Backboard Test and Broer-Miller Drive Test were performed for playing ability data. Grip strength was

determined by a hand dynamometer. The correlation between grip strength and tennis ability was found to be nonsignificant except in one group of children.

Soares (1971) conducted a study on the effect of arm rotator and extension strength upon increases in volleyball spiking speed. A control group and two experimental groups were involved in the study. One experimental group used a upper body building weight training program while the second group used a rotator and extensor arm strength weight training program. Strength was measured by a cable tensiometer and speed was measured through a velocity box. The data revealed that the increase in spiking speed was due to factors other than strength of the arm such as experience and coordination of spiking ability.

Using wall volley tests, Williams (1968) compared the function of grip and wrist strength in volleyball, tennis and badminton. Thirty female subjects were split into an experimental and a control group through matching of wrist strength tests. The first week initial measurements were taken on wall tests and cable tensiometer strength tests. Later the experimental group was given isometric exercises and then both groups were retested. Conclusions of the study indicated that increased strength compliments skill performance on wall volley tests in tennis, badminton and volleyball. Since wall volley tests are designed to evaluate game skill he concluded that strength increases will improve

overall skill in tennis, badminton and volleyball. Furthermore Williams (1968) stated that the volleyball skills test seemed to be the most highly related to grip and wrist strength of the three sports.

Atwater (1970) conducted a study dealing with the analysis of the overarm throw. Three groups of subjects consisting of skilled men, skilled women and average women were used. All 15 right handed subjects were given three trials for establishing maximum throwing velocities. Data were collected by using cameras in a side, rear and overhand method. Ball velocities were 100-125 feet per second for skilled men, 70-80 feet per second for skilled women, and 40-50 feet per second for average women. It was found that the ball velocity at 400 milli-seconds before release, was directly related to the initial ball velocity after release. Furthermore the joint action acceleration from the trunk to the throwing arm was identical to the acceleration in the initial ball velocity (Atwater, 1970).

In a cinematographical study of the badminton backhand stroke Barth (1961) determined linear velocity of the racket and three body levers in four highly skilled female subjects. Racket velocities ranging from 46.700 feet per second to 32.085 feet per second were found in this study. The film analysis revealed the hand-racket lever contributed the greatest to racket velocity, forearm lever second and the arm third. Furthermore the summation of all three lever

velocities totaled only about 50 percent of the total racket velocity.

Through cinematographical analysis Campbell (1976) determined the contact point of an overhand clear in badminton. Initial velocities were determined on four highly skilled players during a French Clear Test. The average velocity was 121.67 feet per second and ranged from 79.52 to 162.69 feet per second. The majority of the clears were contacted in front of the shoulder joint but behind the elbow and wrist. Contact was above the head with the racket arm extended upward.

McCloy (1948) (cited in Nelson, 1964) studies the velocity of a volleyball spike for highly skilled players through cinematography. Although the study lacks details on the methodology, the mean velocity was 91 feet per second and the maximal velocity was 162 feet per second. Nelson (1964) did a follow up study on McCloy's 1948 study. Nelson felt that volleyball had progressed markedly since 1948 and spike velocity should have increased. Nelson (1964) found out of eight highly skilled players the highest velocity was 99.3 feet per second. He concluded that the 1964 study may have lower velocities due to sampling error. In spite of possible sampling error the differences in results were too great, suggesting further research should be conducted to establish methods for determining volleyball spike velocity.

Summary

The preceding review of literature dealt with the various aspects of this study: the open overhand serve, strength and velocity.

The overhand serve was considered to be the fastest possible volleyball serve. Furthermore the majority of the literature (Laveaga, 1960; Sandefur, 1970; Shondell & McManama, 1971; Thigpen, 1967; Trotter, 1965) favored an open contact hit for the overhand volleyball serve.

Generally strength training was considered to be an important part of a volleyball conditioning program (Shondell & McManama, 1971; Schurman, 1974; Trotter, 1965; Welch, 1960). In addition the literature suggested the cable tensiometer is one of the simplest and most versatile strength testing instruments.

Various methods of determing velocity were reviewed. Generally the literature (Bunn, 1955; Piereck, 1969; Roger, 1969) supported cinematography as the most accurate method of determining velocity of an object.

Although many studies (Myer, 1974; Soares, 1971; Smith, 1961) involving strength and velocity indicated these two factors are not significantly related, other studies (Vogt, 1961; Williams, 1968) suggested a relationship between strength and playing ability.

CHAPTER III

METHODS

The procedures used in this study are presented in the following sections: (1) Subject Selection, (2) Development of Strength Tests, (3) Filming Procedures, (4) Testing Procedures and (5) Analysis Procedures.

Subject Selection

The subjects selected for this study were female high school varsity volleyball players in the 1976 District III of the Wisconsin Interscholastic Athletic Association (W.I.A.A.). A letter (see Appendix A) was sent to the W.I.A.A. to obtain a current list of schools in District III. A return letter (see Appendix A) was received indicating 58 schools had girls' volleyball teams in District III of the W.I.A.A.

Each of the 58 schools were listed alphabetically and numerically assigned numbers (see Appendix B). Out of these 58 schools, seven were randomly selected through a table of random numbers. An additional pool of numbers was selected to fill any refusals of participation from the original seven randomly selected schools (see Appendix B).

After the seven schools were selected an informational letter and a permission form were sent to each head volleyball coach (see Appendix C). Upon return of the permission form the coaches were contacted by telephone to obtain the

number of subjects on their respective volleyball teams and arrange a testing date. Also written or verbal permission was received from the high school principal. If permission to test was denied, the next school in the pool was sent the informational letter and form. If the permission form was not received a follow up was done by telephone. During the telephone call the coach was asked if the informational letter was received. If the letter was not received or was lost a second copy was sent. If the letter was received but not returned, the coach was asked if permission was granted or denied and previously stated procedures were followed.

Subjects had to be a member of their high school's girls' varsity volleyball team. Membership to the varsity team was determined by their respective coach. In addition the subject had to serve in an open overhand method. A total of 44 high school girls met the criteria and participated in the study.

Strength Test

The strength testing instrument used for this study was a cable tensiometer, model T5-6007-114-00, using a one-sixteenth inch cable and manufactured by the Pacific Scientific Company, Anaheim, California (see Appendix D).

The cable tensiometer was calibrated by attaching known weights in five pounds increments to the end of a cable and recording the force exerted on the cable tensiometer. The recorded tension was compared to the manufacturer's tension

to Pounds Conversion Table. A conversion graph (see Appendix E) was constructed since the manufacturer's conversion table was not in a linear relationship. This conversion graph was then used to determine cable tensiometer readings in pounds.

The cable tensiometer measured the force exerted on the cable by each subject. In this study the cable tensiometer was attached to a cable and strap apparatus (see Appendix D). The strap was used to exert the force on the cable by placement of the subject's wrist or arm through the nylon strap loop. The nonstrap end was attached to an eye hook on a base designed and constructed by the researcher.

The base constructed by the researcher had to be portable in order to test at the different schools and sturdy enough to withstand the force exerted by the subjects. For specific base construction details and assembly see Appendix D.

The bottom of the base consisted of a wood platform with a metal angle iron brace and a metal pipe welded to sheet metal. Attached to the pipe welded to the sheet metal was another pipe held at the bottom with a bolt and wing nut. About one foot from the bottom of the second pipe was a U-Clamp that fastened the pipe to the brace.

A back rest with restraining straps was slid over the second pipe. The restraining straps were used to keep the subject's shoulder blades in contact with the plywood back

rest. Set screws held the back rest to the second pipe.

An adjustable height attachment was secured through a bolt and wing nut. At the upper end of the height attachment were the eye hooks which attached the cable and strap to the base.

To prevent possible movement of the structure a chain was placed at the center of the second pipe. This chain was secured to a stationary structure in the school gymnasium as a volleyball standard, bleacher or door bar.

A pilot study was conducted to determine the test-retest reliability of the strength measures. Subjects in this pilot test were fourteen female high school volleyball players in District II of the W.I.A.A. Data (see Appendix F) was collected for the best of two trials on arm strength and on wrist strength. An interval of six days elapsed between the test and retest. Identical subject order was used in the test and retest except for one subject who was absent during the retest. Test-retest correlation coefficients on the thirteen subjects were .89 for arm strength and .82 for wrist strength.

Filming Procedures

A pilot study was conducted to determine the best frame rate to film an open overhand serve. The subject of the pilot study was a member of the University of Wisconsin-La Crosse Women's Volleyball Team. The subject served a fast open hand roundhouse serve. The study was conducted in the

wrestling room, Mitchell Hall, University of Wisconsin-La Crosse.

A Cine-8mm camera was placed 15 feet from the subject and five feet from the floor to the middle of the lens. The camera was set at 1.9 F-stop and loaded with Kodak 4X film. Three, 1000 watt Lowell Lights were used as artificial light. An one hundredth second clock was set 18 feet in front and to the right of the camera to check the frame speed of the camera. Film rate varied from 150-225 frames per second with two or three trials at each film rate. After analysis of the film, 150 frames per second was the chosen rate and frame speed was found to be accurate. This rate was fast enough to allow the ball to be easily identified in each frame.

The filming of the actual study was also done with a Cine-8mm, model SP-1V, high speed motion picture camera mounted on a tripod. The shutter factor was 160 degrees and the center of the lens was five feet from the floor. The film frame rate was 150 frames per second with Kodak 4X reversal film 7277, in a super 8 cartridge.

Since all serves were not to be filmed a Bell and Howell Auto Load Filmsound 8mm camera mounted on a tripod was set up without film to serve as a dummy camera. The sounds of the two cameras were similar thus the subjects did not know when they were actually being filmed.

Both cameras were placed 15 feet from the subject. The filming camera was perpendicular to the subject's serving

line and the dummy camera slightly to the side of the filming camera. Three, 1000 watt Lowell Lights were used and focused toward the serving line. A subject identification number card was placed 25 feet from the camera. A Sekonic Studio Deluxe, Model-28c2, light meter was used to determine the F-stop. Figure 1 illustrates the set up for the actual filming.

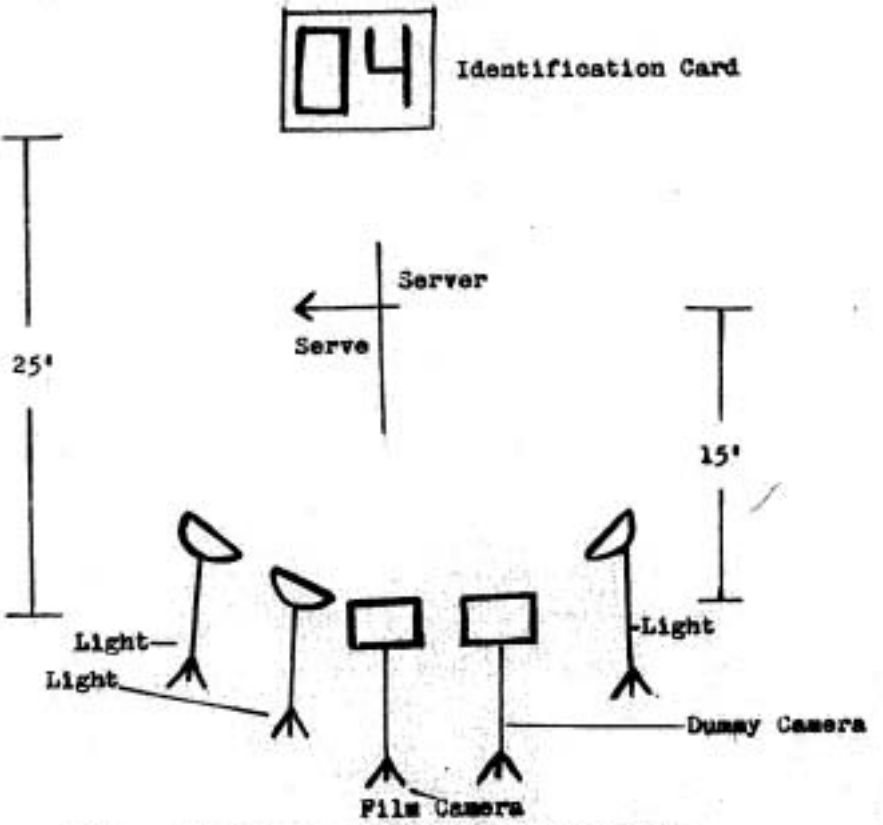


Figure 1. Diagram of Filming Arrangement

Two official size and weight volleyballs, Nike - Number Five, were used for serving. Both balls contained eight pounds of pressure and had a circumference of 26 inches. Two strips of three quarter inch black electrical tape were wrapped around each volleyball in perpendicular planes to provide good ball contrast in filming. Ball pressure and circumference were measured before each scheduled testing.

Testing Procedures

A testing site in the respective gymnasium was chosen in which electrical outlets on different circuits were available and the testing equipment was out of the way of the practicing team. The strength test equipment and film equipment were set up as indicated in Appendix D and Figure 1, respectively.

The following directions were given before the serve test, arm strength test and wrist strength test, respectively. Refer to Figure 2 for arm strength test and Figure 3 for the wrist strength test.

> "Perform your normal open overhand volleyball serve staying behind the restraining line. There will be two practice serves. After the practice serves, you will perform five serves which will be filmed. If you have a bad toss or miss contact with the ball the serve will be repeated. Are there any questions?"

Figure 2. Arm Strength Test

"Stand on the base with your back against the back rest. Keep your feet flat on the stand and back in contact with the back rest. A restraining strap will be placed across your trunk. Place your serving arm in the position you serve an overhand serve. The nylon strap will be placed around your wrist. Pull forward on the strap with one continuous pull. Do not jerk or take your shoulder or back off the back rest. You will receive two trials with a rest between. If directions are not followed the test will be repeated. Are there any questions?"

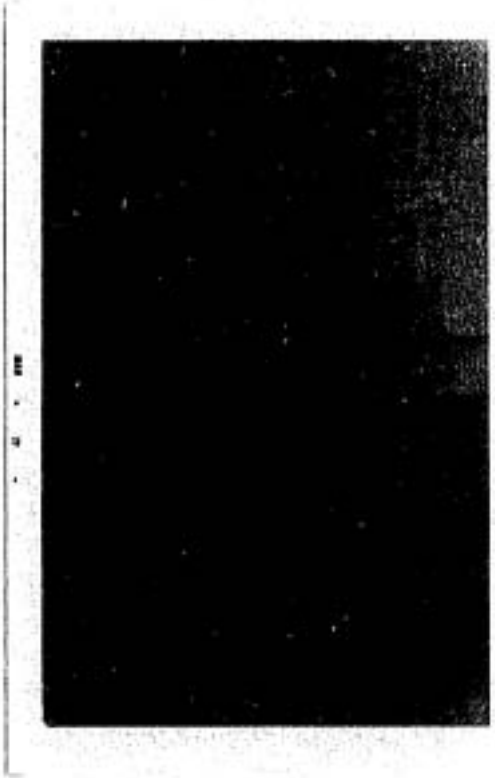


Figure 3. Wrist Strength Test

"Stand in the same manner as the arm strength test with the restraining strap. Place your serving arm above your head. Your elbow will be kept straight and be held to prevent any bending. Pull the strap forward in one continuous movement. Do not jerk the strap or bend your elbow. You will receive two trials with a rest between. If directions are not followed the test will be repeated. Are there any questions?"

After the directions and answering of any questions, subjects were given a consent form (see Appendix G). When permission was granted by the subject testing started. The subjects were given two practice trials on each of the two strength tests to familiarize them with the apparatus and techniques. Two practice serving trials were given and then five test trials. Trial numbers three and four were actually filmed while trials one, two and five were filmed by the dummy camera.

Following the filming the two trials of the arm strength test were given. After the completion of the arm strength test, the two trials of the wrist strength test were given. On both strength tests the subjects were strapped to the back rest, given the first trial, a short rest and then given the second trial.

Each subject was chronologically assigned an identification number through a flip card in filming. The same identification number was used by the subject in the strength tests. A data sheet (see Appendix H) was used to record film information, identification number, strength test scores and a brief subject description.

Analysis Procedures

Tensiometer readings for the strength tests were converted to pounds through the use of a conversion graph (see Appendix E). The higher score in arm strength and the higher

score in wrist strength were used for statistical analysis.

A Kodak Extragraphic Film Projector was used to analyze the film by projecting the film on to five squares to the centimeter graph paper. The projector was placed perpendicular and three feet from the graph paper.

The first frame after the server's hand was no longer in contact with the volleyball was drawn on the graph paper. This drawing consisted of the volleyball and identification card which was the reference point. The film was then advanced five frames, the reference point was matched and the second volleyball drawn. The distance between the center of the two drawn volleyballs represents the distance the volleyball traveled.

A conversion factor was determined to convert graph units to feet. To determine the distance the ball traveled in feet the diameter of the volleyball needed to be computed with the following formula:

$$\text{Volleyball Diameter} = \frac{\text{Volleyball Circumference}}{\pi}$$

The relationship of circumference of the ball equals the diameter times π was used to convert graph units to feet. The circumference of the volleyball was measured to be 2.167 feet divided by π, 3.142, equals the diameter of the volleyball which is .6870 feet. The diameter of the ball in graph units was determined by counting the graph units on a line drawn through the center of the ball and parallel to the horizontal

graph units. Dividing the diameter of the actual volleyball of .6870 feet by the number of graph units equaled the conversion factor in feet per graph unit.

$$\text{Conversion Factor} = \frac{\text{Volleyball Diameter}}{\text{Diameter of Ball in Graph Units}}$$

An X and Y axis were set up to determine the distance the ball traveled both horizontally and vertically. Coordination points were determined for the center of each volleyball. The X coordinate of one volleyball was subtracted from the X coordinate of the second volleyball. The Y coordinates were done identically. The resulting difference was multiplied times the conversion factor of feet per graph unit. The X difference was the horizontal distance and the Y difference the vertical distance.

The determination of time was achieved through film rate. The film was shot at 150 frame intervals per second which equals one frame interval per .0067 seconds. The five frames between volleyball drawings equals four time intervals. The total time elapsed between volleyball drawings was four multiplied times .0067 second per frame interval or .0268 seconds.

The time, horizontal and vertical distance data were entered into a computer program to determine the initial velocity of the volleyball. The velocity was determined by the Initial Angle and Initial Velocity of a Projectile program

(see Appendix I).

After determination of the initial velocity and the higher arm and wrist strength scores the data was treated by Multiple Correlation. The data was subjected to a .05 significance level for rejecting or accepting the hypothesis.

CHAPTER IV

RESULTS AND DISCUSSION

The results and discussion of this study are divided into three major areas: (1) Subjects, (2) Results and (3) Discussion.

Subjects

A total of seven W.I.A.A., District III, schools were randomly selected to participate in this study. The initial seven Wisconsin schools were: Bangor High School, Bangor; Blair High School, Blair; Kickapoo High School, Viola; Loyal High School, Loyal; Necedah High School, Necedah; Onalaska High School, Onalaska and West Salem High School, West Salem. Due to the lack of any open overhand servers, Bangor, Blair and Onalaska High Schools did not participate. The next three schools, Alma High School, Alma; Chippewa Falls High School, Chippewa Falls and Mondovi High School, Mondovi were selected from the pool of schools and these three schools granted permission to test.

A total of 44 subjects were tested from the seven schools. Of the 44 subjects, complete data was obtained on 36 and were used in the statistical analysis (see Appendix J). The film analysis that determined volleyball velocity could not be analyzed in both trials for subject numbers one, two, three and 42. In subjects number 43 and 44, one of the two

serves was not analyzable. Mechanical camera difficulties were responsible for these unusable serving trials and were not used in the statistical analysis. Also, subjects number 29 and 30 had one serve trial each that did not have open hand contact and were omitted from statistical treatment.

All strength test measurements produced useable results. All incomplete data subjects had strength test measurements within the range of total subjects with complete data except subject number one in arm strength (see Appendix J).

Results

Data collected were from the two actual filmed serves and the two trials of each strength test. Table 1 represents the range, mean and standard deviation of all complete data collected. The trial labeled higher refers to the subjects' best score while the lower trial is the subjects' worst or lower score of the two trials.

Table 1. Mean, Standard Deviation, and Range for Serve Velocity, Arm and Wrist Strength.

Test	Mean	S. D.	Range
Arm Strength (lbs)			
Higher	27.6389	6.4169	17.50-58.25
Lower	25.0833	5.8508	15.00-54.00
Wrist Strength (lbs)			
Higher	19.6458	3.4483	13.25-31.25
Lower	18.1528	3.2968	10.00-28.25
Velocity (ft/sec)			
Higher	60.6408	8.0737	39.1410-79.7648
Lower	55.0402	7.9781	32.4143-70.1023

Multiple correlation (Table 2) was utilized in the statistical analysis of data to determine if a relationship exists between arm and wrist strength and volleyball serve velocity. The obtained correlation coefficients were compared to a table (Fisher, 1954, p. 209) to determine if the correlation coefficients were significant at the .05 level.

Table 2. Multiple Correlation Coefficients of All Trials.

	Higher Arm	Higher Wrist	Higher Velocity	Lower Arm	Lower Wrist	Lower Velocity
Higher Arm Strength	1.0000					
Higher Wrist Strength	.6889*	1.0000				
Higher Velocity	-.0548	.1085	1.0000			
Lower Arm Strength	.9099*	.6882*	.0242	1.0000		
Lower Wrist Strength	.6092*	.9018*	.0464	.6458*	1.0000	
Lower Velocity	-.1228	-.0163	.7940*	-.0925	-.0786	1.0000

*$p < .05$

A correlation coefficient of -.0548 was obtained in comparing arm strength and volleyball serve velocity. A correlation coefficient of .1085 was obtained in comparing wrist strength and volleyball serve velocity. A table (Fisher, 1954, p. 209) was consulted to determine if the correlation coefficient was significant at the .05 level with 35 degrees of freedom. In order to be significant at the .05 level a value of .3246 or above had to be obtained. The results revealed the correlations for strength and velocity were not significant at the .05 level.

Reliability coefficients were determined for the higher trial compared to the lower trial in arm strength, wrist strength and serving velocity. The reliability correlation coefficients were .91 for arm strength, .90 for wrist strength and .79 for volleyball serve velocity.

Discussion

The results of this study revealed there is no significant relationship between arm and wrist strength and the velocity of an open overhand volleyball serve in female high school students. This implies that arm and wrist strength alone are not significant components in serving a fast open overhand serve. Since arm and wrist strength are not significant components involved in the velocity of the open overhand serve, then a coach does not need to emphasize arm and wrist strength training in a serve conditioning program.

Although the strength conditioning of an athlete was stressed by several authors (Odencal & Wilson, 1962; Trotter, 1965; Welch, 1960) this study does not seem to establish a need for arm and wrist strength training for increasing serve velocity. Schurman (1974) stressed the importance of increased strength in the arm and wrist which should produce a more forceful spike. Spiking and serving are both overhand patterns thus if increased arm and wrist strength can improve the spike, the overhand serve should also be improved with increased strength however this was not found in the present study.

Smith (1961) referred to speed as strength in action. Velocity is very closely related to speed. Since velocity and speed are similar, velocity may be an outcome of strength. Furthermore Bunn (1955) and Wells (1960) refer to the speed of a ball being dependent on the force imparted to the ball. If force has a dependent relationship on the speed of the ball, then it may be possible that strength may affect the speed of a ball. However, in this study arm and wrist strength and ball velocity had no significant relationship.

Although the subjects were told to perform the arm strength test in the same arm position as serving a volleyball this exact position may not have been reached. Similarly the wrist strength test may not have been performed in the exact serving position of the subject. If either of these situations existed then the strength of the muscles at serve contact were not measured but at what ever angle the subject held her arm or wrist in strength testing. Furthermore, the arm and wrist strength involved in a volleyball serve is basically isotonic while the measurement taken by the cable tensiometer was isometric. However the reliability of the two strength tests from higher trial to lower trial were high.

Secondly the serves that were analyzed may not have been the subjects' best serves. Subject number 25 had 28.1561 feet per second difference in the velocities of her two filmed serves. Although subject number 25 was the extreme this vast difference showed the possibility of other subjects

not performing or obtaining their best or normal speed serve. A lower reliability correlation coefficient was found compared to the strength test.

Finally the success of an overhand serve may depend on many factors as the timing of contact, the point of contact, the speed of the arm, strength of the arm, the initial angle, the length of the arm and so forth which were not measured in this study. Since the serve has so many components a single aspect as arm and wrist strength may not be shown to have a significant relationship in volleyball serve velocity. Coordinating all the various components or factors into the proper sequence may be the actual secret to obtaining a successful fast serve. Although each of these components may contribute to the final serve velocity a single factor may not be significant.

CHAPTER V

CONCLUSIONS

The conclusions of the study are divided into three areas: (1) Summary, (2) Conclusions and (3) Recommendations.

Summary

The purpose of this study was to determine if a relationship between a server's arm and wrist strength and the velocity of an open overhand volleyball serve existed in female high school students on an interscholastic team. Forty-four subjects were tested from seven randomly selected schools in District III of the W.I.A.A. High Speed cinematography was used to determine velocity. Arm and wrist strengths were determined isometrically with a cable tensiometer while in a standing position.

A multiple correlation was utilized in the statistical analysis of data. Reliability correlation coefficients were determined for the two strength tests and the velocity by comparing the higher trial to the lower trial.

Conclusions

In this study the hypothesis was stated in the null: there is no significant relationship between arm and wrist strength of a server and the velocity of an open overhand volleyball serve for girls. This hypothesis was accepted.

Furthermore the high reliability correlation coefficient of the two strength tests seem to show the designed base as an appropriate apparatus to test arm and wrist strength in the serving position.

Recommendations

The following are recommendations for further studies in this area.

1. Conduct a similar study filming more trials of the open overhand serve for analysis.

2. Conduct a similar study measuring serve contact, arm and wrist position and utilize these measurements for strength testing.

3. Conduct a similar study to compare a fist overhand serve, sidearm serve and/or underhand serve with an open overhand serve and server's strength.

4. Conduct a study to compare the height of contact and/or length of arm lever to the velocity of the serve and server's strength.

5. Conduct a cinematographic study to determine the relationship between the speed of the hand at contact, the initial ball velocity and the server's strength.

6. Conduct a similar study in other districts of the W.I.A.A. and compare results.

7. Conduct a similar study using advanced or professional players as subjects.

8. Utilize more artifical lights to obtain better film quality.

9. Utilize a film analyzer to determine ball velocity.

10. Conduct further studies on the designed base for strength testing.

REFERENCES CITED

Anderson, L. Comparison of the characteristics of four strength testing instruments. Unpublished master thesis, Pennsylvania State University, 1970.

Atwater, A. E. Movement characteristics of the overarm throw: a kinematic analysis of men and women performers. Unpublished doctoral dissertation, University of Wisconsin-Madison, 1970.

Barth, D. A. A cinematographic analysis of the badminton backhand stroke. Unpublished master thesis, University of Illinois-Urbana, 1961.

Broer, M. Efficiency of human movement. Philadelphia: W. B. Saunders Company, 1960.

Bunn, J. W. Scientific principles of coaching. Englewood Cliffs: Prentice-Hall, Inc., 1955.

Campbell, K. A. A cinematographic study of the point of contact in the badminton overhand clear. Unpublished master thesis, University of Wisconsin-La Crosse, 1976.

Clarke, D. H. Correlation between the strength/mass ratio and the speed of an arm movement. Research Quarterly, 1960, 31, 570-574.

Clarke, D. H. & H. H. Clarke. Research processes in physical education, recreation and health. Englewood Cliffs: Prentice-Hall, Inc., 1970.

Clarke, H. H. Recent advances in measurement and understanding of volitional muscular strength. Research Quarterly, 1956, 27, 263-275.

Cooper, J. M. & B. B. Glassow. Kinesiology (3rd ed.). Saint Louis: The C. V. Mosby Company, 1972.

de Vries, H. Physiology of exercise for physical education and athletes. Dubuque: Wm. C. Brown Company Publishers, 1974.

Fiereck, L. M. Assessment of velocity for the tennis serve of college women. Unpublished master thesis, Southern Illinois University, 1969.

Fisher, R. A. Statistical methods for research workers. New York: Hafner Publishing Company, Inc., 1954.

International Committee for Standardization of Physical Fitness Tests. L. A. Larson (Ed.). Fitness, health and work capacity: international standards for assessment. New York: MacMillan Company, Inc., 1974.

Laveaga, R. E. Volleyball (2nd ed.). New York: The Ronald Press Company, 1960.

McManama, J. & D. Shondell. Teaching Volleyball Fundamentals. Athletic Journal, 1969, 40(3), 43-50.

Mathews, D. K. Measurement in physical education (3rd ed.). Philadelphia: W. B. Saunders Company, 1968.

Morehouse, L. E. & A. T. Miller, Jr. Physiology of exercise (6th ed.). Saint Louis: The C. V. Mosby Company, 1971.

Myer, R. W. Jr. The relationship between arm strength and baseball throwing velocity. Unpublished master thesis, University of Texas-Austin, 1974.

Nelson, R. C. Follow-up investigation of the velocity of the volleyball spike. Research Quarterly, 1964, 35, 83-84.

Odeneal, W. T. & H. E. Wilson. Beginning volleyball. Belmont, California: Wadsworth Publishing Company, Inc., 1962.

Rand Corporation. A million random digits with 100,000 normal deviates. T. H. Harshbarger. Introductory statistics: a decision map. New York: The MacMillan Company, 1971.

Rogers, V. A. Three methods of assessing the velocity and angle of projection of the volleyball spike. Unpublished master thesis, Frostberg State College, Southern Illinois University, 1969.

Sandefur, B. Volleyball. Pacific Palisades, California: Goodyear Publishing Company, Inc., 1970.

Scates, A. E. Winning volleyball (2nd ed.). Boston: Allyn and Bacon, Inc., 1976.

Scates, A. E. Power volleyball. Journal of Health, Physical Education and Recreation, 1973, 44(8), 32-39.

Schurman, D. Volleyball. New York: Atheneum, 1974.

Shondell, D. S. & J. L. McManama. Volleyball. Englewood Cliffs: Prentice-Hall, Inc., 1971a.

Shondell, D. S. & J. L. McManama. Volleyball fundamentals and techniques. Athletic Journal, 1971, 52, 32-42.

Smith, L. E. Individual differences on strength, reaction latency, mass and length of limbs and their relation to maximal speed of movement. Research Quarterly, 1961, 32, 208-220.

Soares, J. The effect on arm rotator strength and arm extension strength upon increase of the volleyball spiking speed. Unpublished master thesis, Brigham Young University, Provo, Utah, 1971.

Stoebe, H. E. The relationship of grip strength and tennis ability. Unpublished seminar paper, University of Wisconsin-La Crosse, 1976.

Thigpen, J. Power volleyball for girls and women. Dubuque: Wm. C. Brown Company Publishers, 1967.

Trotter, B. J. Volleyball for girls and women. New York: The Ronald Press Company, 1965.

Vogt, M. A. The effect of grip and wrist strengthening exercises on tennis playing ability. Unpublished master thesis, The Women's College, University of North Carolina-Greensboro, 1961.

Welch, J. (Ed.). How to play and teach volleyball. New York: Associated Press, 1960.

Wells, K. F. Kinesiology. Philadelphia: W. B. Saunders Company, 1960.

Wells, K. F. & K. Luttgens. Kinesiology scientific basis of human motion (6th ed.). Philadelphia: W. B. Saunders Company, 1976.

Williams, C. M. Wall volley test performance as a function of grip and wrist strength. Unpublished master thesis, North Texas State University-Denton, 1968.

Wisconsin Interscholastic Athletic Association, 41 Park Ridge Drive, Stevens Point, Wisconsin 54481. Correspondence. December, 1976.

APPENDIX A

413 Royal Street
Onalaska, Wisconsin 54650
August 31, 1976

Miss Karen Kuhn
W.I.A.A.
41 Park Ridge Drive
P.O. Box 267
Stevens Point, Wisconsin 54481

Dear Miss Kuhn:

I am a graduate student at the University of Wisconsin-La Crosse and previously a teacher at Marathon High School. I am presently working on my Master Thesis in Physical Education. My thesis deals with the relationship of arm strength and the velocity of an open overhand volleyball serve.

For my thesis, I need an up to date list of schools in District III of the W.I.A.A., that have girls' volleyball programs. I realize the deadline for this information is September 1st, but hope I can receive the information as soon as possible. Could you please send this information by September 9th?

Enclosed is a self-addressed stamped envelope. If the above information can not be provided, please indicate so by September 9th.

Thank you for your time and consideration.

Sincerely,

Janelle Braatz

September 2, 1976

Ms. Janelle Braatz
413 Royal Street
Onalaska, Wisconsin 54650

Reference: Volleyball Schools - District III

Dear Ms. Braatz:

As you requested, listed below are the boys and girls volleyball schools of District III.

Girls Schools

Adams-Friendship	Fall Creek	Onalaska
Alma	Gale-Ettrick-Tremp.	Osseo-Fairchild
Altoona	Gilman	Pepin
Arcadia	Greenwood	Plum City
Arkansaw	Hillsboro	Prescott
Augusta	Holmen	Reedsburg
Bangor	Independence	River Falls
Baraboo	Kickapoo (Viola)	Royall (Elroy)
Black River Falls	La Crosse Central	Sparta
Blair	La Crosse Logan	Spring Valley
Chippewa Falls	LaFarge	Taylor
Cochrane-Fountain	Lincoln (Alma Center)	Tomah
DeSoto	Loyal	Viroqua
Durand	Mauston	Westby
Eau Claire Mem.	Melrose-Mindoro	Weston
Eau Claire North	Menomonie	West Salem
Eleva-Strum	Mondovi	Whitehall
Elk Mound	Necedah	Wisconsin Dells
Ellsworth	Neillsville	
Elmwood	New Lisbon	

Boys Schools

Adams-Friendship	Cashton	Sparta
Baraboo	Portage	Wisconsin Dells
Brookwood	Reedsburg	

Sincerely,

Karen Kuhn, Assistant to the Director

KK: dd

APPENDIX B

DISTRICT III SCHOOLS NUMBER ASSIGNMENT

1. Adams-Friendship
2. Alma
3. Altoona
4. Arcadia
5. Arkansaw
6. Augusta
7. Bangor
8. Baraboo
9. Black River Falls
10. Blair
11. Chippewa Falls
12. Cochrane-Fountain
13. DeSoto
14. Durand
15. Eau Claire Mem.
16. Eau Claire North
17. Eleva-Strum
18. Elk Mound
19. Ellsworth
20. Elmwood
21. Fall Creek
22. Gale-Ettrick-Tremp.
23. Gilman
24. Greenwood
25. Hillsboro
26. Holmen
27. Independence
28. Kickapoo (Viola)
29. La Crosse Central
30. La Crosse Logan
31. LaFarge
32. Lincoln (Alma Center)
33. Loyal
34. Mauston
35. Melrose-Mindoro
36. Menomonie
37. Mondovi
38. Necedah
39. Neillsville
40. New Lisbon
41. Onalaska
42. Osseo-Fairchild
43. Pepin
44. Plum City
45. Prescott
46. Reedsburg
47. River Falls
48. Royall (Elroy)
49. Sparta
50. Spring Valley
51. Taylor
52. Tomah
53. Viroqua
54. Westby
55. Weston
56. West Salem
57. Whitehall
58. Wisconsin Dells

LIST OF RANDOM NUMBERS AND POOL OF NUMBERS

41	29	39
33	42	9
10	49	24
56	23	55
7	5	27
38	3	50
28	35	15
11	48	22
2	34	25
37	31	57
40	53	18
6	20	12
32	47	8
26	51	43
30	52	44
36	45	21
54	19	58
17	1	4
13	16	
46	14	

(Rand Corporation, 1971, p. 504 & 505)

APPENDIX C

Coaches Name
Girls' Volleyball Coach
High School
City, Wisconsin 00000

Dear Coach:

Every volleyball coach understands the importance of a good serve. During my past three (3) years of coaching volleyball, I have often questioned the importance of arm strength in regard to the serve.

I am interested in determining the relationship of a server's arm strength to the speed of an overhand serve. This information may benefit your team in determining where training emphasis should be placed. If strength plays an important role in serving then strength training could be stressed.

Due to the impossibility of testing all the schools in Wisconsin, seven (7) schools have been randomly selected from District III of the W.I.A.A. Your school is one of the seven (7) schools selected to participate in this study. Your willingness to participate, will help to determine the relationship between arm strength and serve speed.

The test for strength will be a basic arm and wrist strength test. The speed of the volleyball serve will be done through motion picture film. Accuracy will not be measured and all equipment will be supplied. Your regular practice session may be conducted on another court, while I am testing varsity players that use an open overhand serve.

In order to keep randomization of this study, I need to obtain permission from you to test. Enclosed is a permission form along with a self-addressed, stamped envelope. Whether permission to test is granted or denied, please return the permission form by Thursday, September 30th. If further information is desired please send any questions in the self-addressed envelope. (Remember, only a small portion of your practice time will be needed to test the open overhand servers and all equipment will be supplied.)

If permission is granted, I will contact you to obtain pertinent testing information.

Thank you for your time and consideration.

Sincerely,

Janelle Braatz

PERMISSION FORM

Please return by: September 30, 1976

Girls' Volleyball Coach

I hereby give permission for Janelle Braatz to test the girls varsity volleyball team at _____ High School, in the cable tensiometer strength test and filming of the players serving. I realize only open overhand servers will be used in the test and all individual results will be kept confidential.

_____ _____
Date Coach

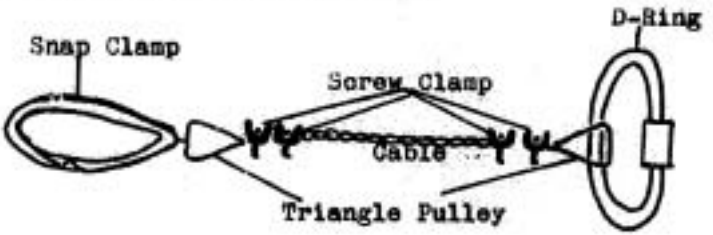
_____ _____
Best Time to Contact Phone Number

I deny permission to test the girls' volleyball team at _____ High School.

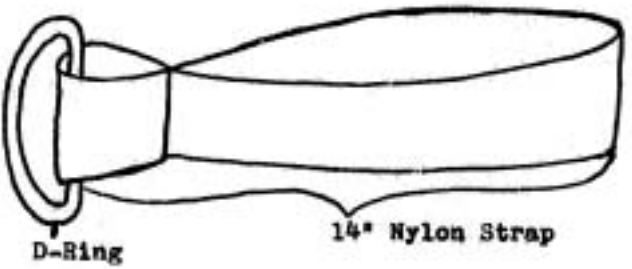
_____ _____
Date Coach

APPENDIX D

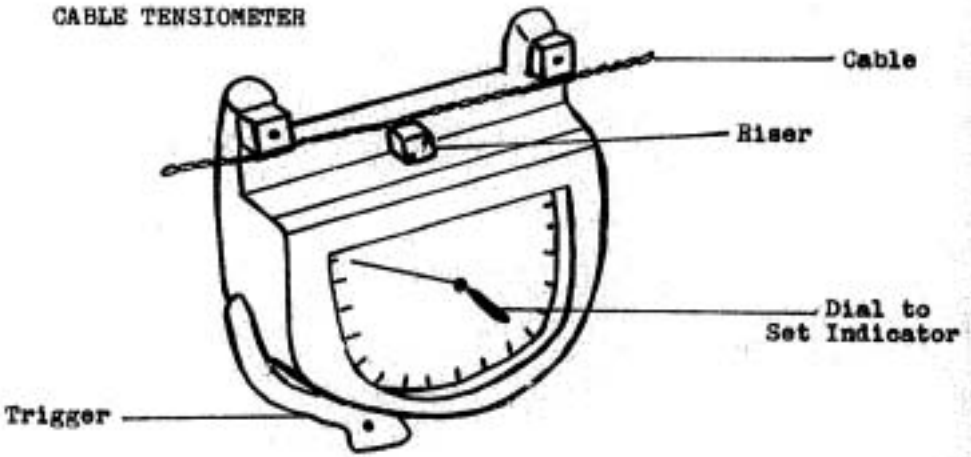
CABLE ATTACHMENT (**NOT TO SCALE**)

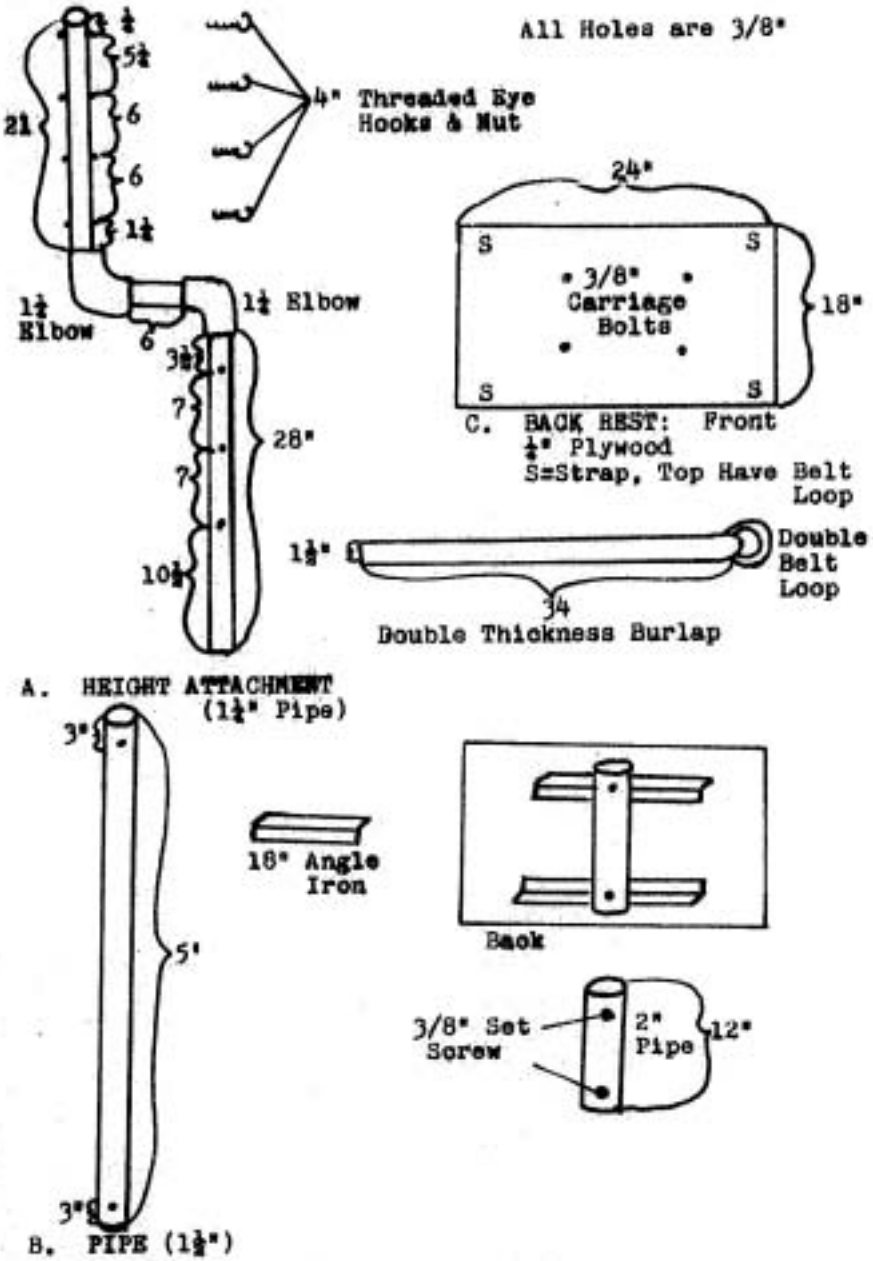


HAND & WRIST STRAP

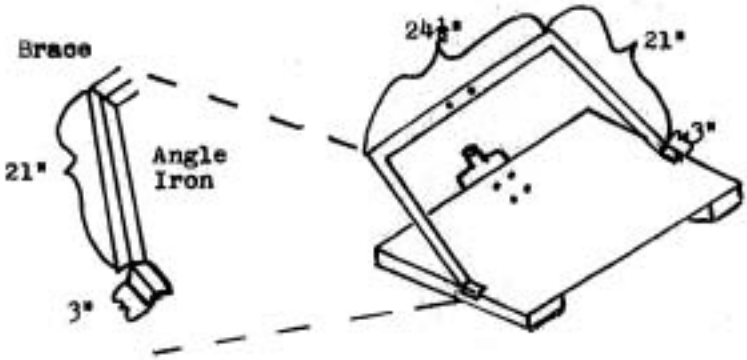


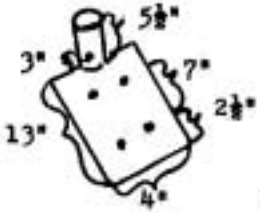
CABLE TENSIOMETER



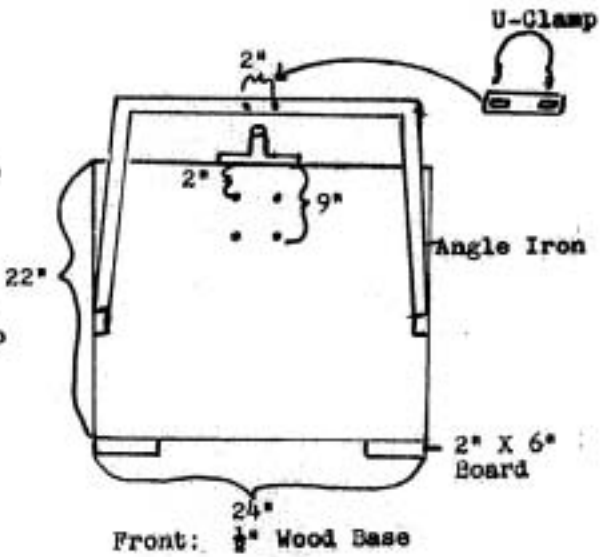

All Holes are 3/8"
4" Threaded Eye Hooks & Nut
21
5½
6
6
1½
1½ Elbow
1½ Elbow
6
3½
7
7
10½
28"
24"
S
S
3/8" Carriage Bolts
S
S
18"
C. BACK REST: Front ¼" Plywood
S=Strap, Top Have Belt Loop
1½"
Double Belt Loop
34
Double Thickness Burlap
A. HEIGHT ATTACHMENT (1½" Pipe)
3"
5'
3"
B. PIPE (1½")
18" Angle Iron
Back
3/8" Set Screw
2" Pipe
12"

D. BASE

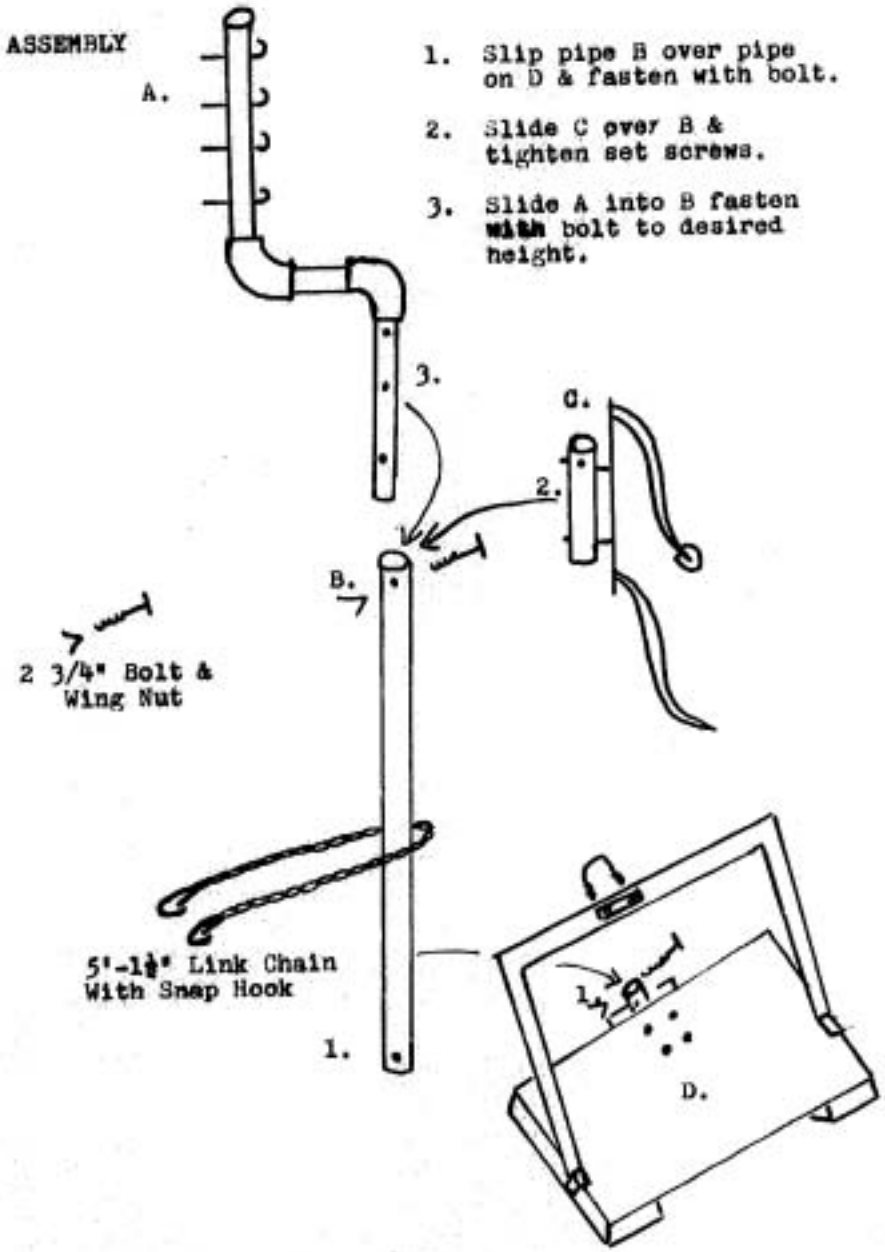




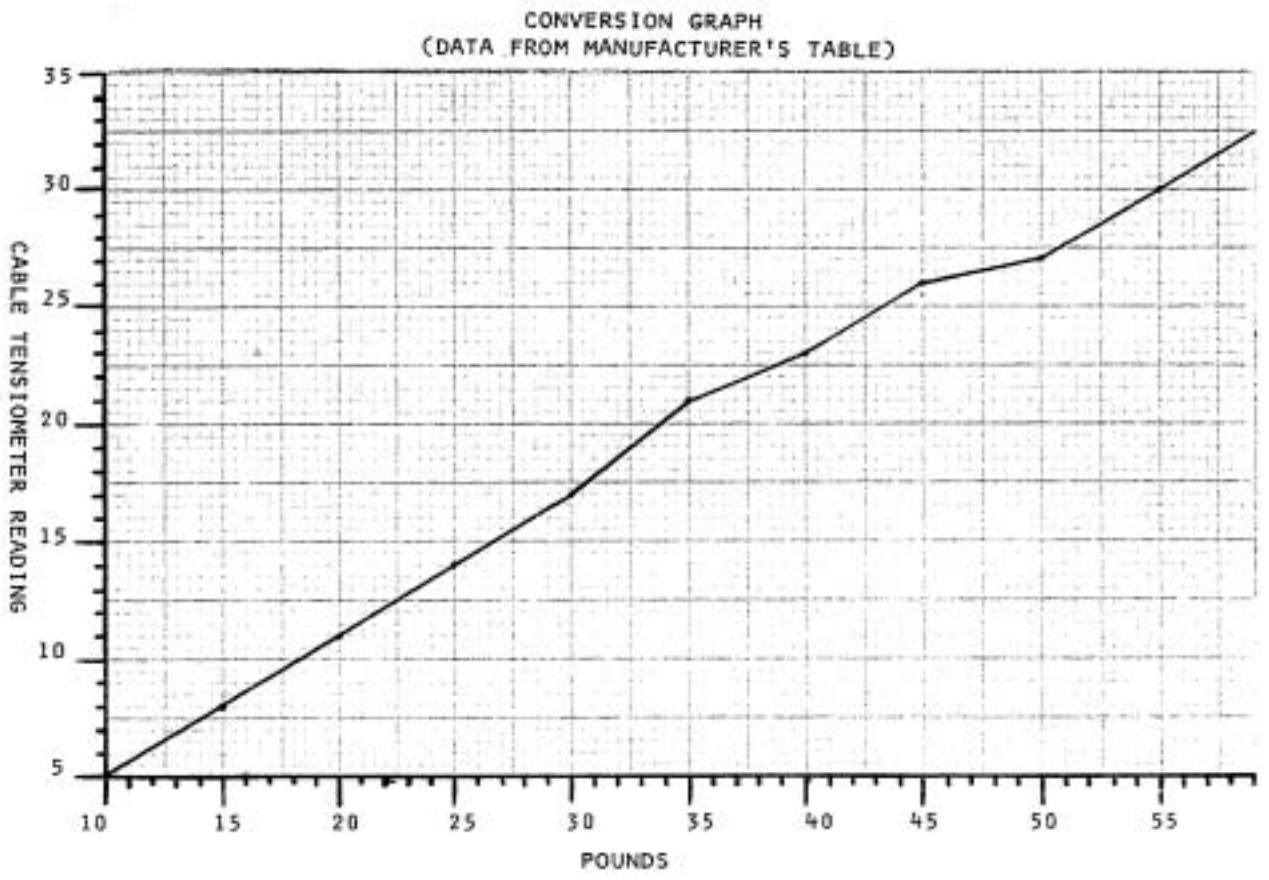
1/8" Flat Metal Base Attached to Bottom of Wood Base.



Front: ½" Wood Base


ASSEMBLY
A.
1. Slip pipe B over pipe on D & fasten with bolt.
2. Slide C over B & tighten set screws.
3. Slide A into B fasten with bolt to desired height.
3.
C.
2.
B.
2 3/4" Bolt & Wing Nut
5'-1½" Link Chain With Snap Hook
1.
D.

APPENDIX E


CONVERSION GRAPH
(DATA FROM MANUFACTURER'S TABLE)
CABLE TENSIOMETER READING
35
30
25
20
15
10
5
10
15
20
25
30
35
40
45
50
55
POUNDS

APPENDIX F

PILOT STUDY STRENGTH TEST DATA

Subject Number	Arm Strength*		Wrist Strength*	
	Test	Retest	Test	Retest
1	17	**	12	**
2	15	16	9.5	9.0
3	15	16	11	10.5
4	11	12	12	10
5	13	13	11	10
6	20	18.5	14	12
7	18	17.5	15	15
8	18	18.5	12	12
9	20	21.5	15	14
10	15	15.5	14	12
11	15	15.5	12	10.5
12	18	20.5	12	12
13	19	19	13	15.5
14	15	12	10	8.5

*Scores represent the best of two trials and are cable tensiometer readings.

**Subject absent on retest.

Arm strength correlation for test-retest = .89

Wrist strength correlation for test-retest = .82

APPENDIX G

CONSENT FORM

I hereby consent to be a subject in the study being conducted by Janelle Braatz.

I understand the arm and wrist strength test. I give permission to be filmed on an open overhand volleyball serve and tested for arm and wrist strength through the use of a cable tensiometer.

It is understood that my identity will in no way be used as a part of the results or publication of the study.

_____

Subject Signature

APPENDIX H

DATA SHEET

Filming Data: Camera _____

Film _____

Camera Speed _____

F/Stop _____

Shutter Factor _____

Distances: Subject to Camera _____

Ht. of Lens _____

Reference Measure _____

Filming: Location and Time _____

Lighting: Natural _____

Artificial: Type _____
No. _____
Placement _____

Diagram: Filming set up shown on back.

Subjects:

No.	Arm Strength Trial I	Arm Strength Trial II	Wrist Strength Trial I	Wrist Strength Trial II	Description of Subject
___	_____	_____	_____	_____	_____
___	_____	_____	_____	_____	_____
___	_____	_____	_____	_____	_____
___	_____	_____	_____	_____	_____
___	_____	_____	_____	_____	_____
___	_____	_____	_____	_____	_____
___	_____	_____	_____	_____	_____
___	_____	_____	_____	_____	_____

APPENDIX I

COMPUTER PROGRAM FOR
INITIAL ANGLE AND INITIAL VELOCITY OF A PROJECTILE

```
GET-*IAV
Run
IAV

INITIAL ANGLE AND INITIAL VELOCITY OF A PROJECTILE

WHAT IS THE DISTANCE OF THE TARGET IN FEET?  X
WHAT IS THE CONTACT HEIGHT OF TARGET ABOVE OR
     BELOW RELEASE IN FEET?  Y
WHAT IS THE TIME TO THE TARGET IN SECONDS?  TIME OF CAMERA


DISTANCE            X             FEET
HEIGHT              Y             FEET
TIME                CAMERA TIME   SECONDS
INITIAL ANGLE       00000         DEGREES
INITIAL VELOCITY    00000         FEET/SECOND
```

APPENDIX J

CALCULATED STRENGTH AND VELOCITY DATA
(Based on Higher and Lower Scores)

Subject Number	Higher Arm (lbs.)	Higher Wrist (lbs.)	Higher Velocity (ft./sec.)	Lower Arm (lbs.)	Lower Wrist (lbs.)	Lower Velocity (ft./sec.)
1	14.00	13.25	*	14.00	13.25	*
2	20.00	16.50	*	19.00	16.50	*
3	25.75	17.50	*	23.25	16.50	*
4	30.00	24.00	67.7083	29.25	21.50	59.4534
5	19.00	15.75	58.9337	17.50	15.00	58.3296
6	25.75	19.00	62.4816	23.25	15.75	58.0414
7	23.25	15.00	61.3519	23.25	13.25	56.1167
8	23.25	18.25	55.6233	18.25	17.50	54.7363
9	23.25	11.50	61.9658	19.00	10.00	56.3696
10	28.25	21.50	53.5610	25.00	19.00	53.1994
11	30.00	21.50	60.1294	21.50	19.00	57.9838
12	26.75	21.50	55.6879	25.75	20.00	49.9709
13	20.75	19.00	61.1596	16.50	15.00	52.8010
14	33.00	22.50	68.0878	30.50	16.50	65.7496
15	37.50	21.50	66.1803	26.75	21.50	65.8707
16	43.25	20.00	48.4976	36.25	18.25	42.1323
17	23.25	18.25	61.6975	21.50	17.50	54.6608
18	28.25	23.25	58.7005	27.50	21.50	56.6998
19	34.25	23.25	56.7080	33.00	21.50	56.3553
20	22.50	16.50	58.5602	21.50	15.00	58.2487
21	18.25	15.75	70.9478	17.50	15.00	62.2504

Continued

Subject Number	Higher Arm (lbs.)	Higher Wrist (lbs.)	Higher Velocity (ft./sec.)	Lower Arm (lbs.)	Lower Wrist (lbs.)	Lower Velocity (ft./sec.)
22	30.00	23.25	79.7648	30.00	20.00	70.1023
23	17.50	13.25	64.7797	16.50	11.50	57.6368
24	25.00	19.00	64.5075	25.00	19.00	63.5275
25	30.00	21.50	69.9569	28.25	20.75	41.8008
26	28.25	20.00	53.5491	23.25	19.00	45.1753
27	30.00	19.00	72.8688	29.00	18.25	62.1733
28	38.75	26.75	52.5093	35.00	18.25	62.1733
29	31.75	16.50	40.8830	30.00	15.00	*
30	58.25	31.25	75.5102	54.00	28.25	*
31	26.75	18.25	39.1410	26.75	18.25	32.4143
32	35.00	21.50	64.6149	28.25	16.50	58.9983
33	37.50	25.00	74.8922	37.50	25.00	64.1317
34	17.50	16.50	54.9786	15.00	16.50	50.8293
35	33.75	15.00	50.7042	31.75	15.00	50.3783
36	17.50	15.00	62.6439	16.50	15.00	58.0628
37	31.25	23.25	50.036	25.00	21.50	44.3897
38	25.00	19.00	55.9105	25.00	18.25	49.5229
39	22.50	20.00	64.8533	21.50	20.00	58.9367
40	28.25	21.50	55.6600	28.25	21.50	55.2713
41	30.00	21.50	64.6148	26.75	21.50	58.5852
42	21.50	13.25	*	21.50	11.50	*
43	41.50	21.50	59.9829	41.50	18.25	*
44	31.25	15.75	54.0751	28.25	15.00	*

*No Data Available