1976

A kinematic analysis of the softball batting form of high and low average female batters

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A KINEMATIC ANALYSIS OF THE SOFTBALL BATTING FORM OF HIGH AND LOW AVERAGE FEMALE BATTERS

by

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An Abstract

of a thesis submitted in partial fulfillment

of the requirements for the degree of

Master of Science in the School

of Health, Physical Education

and Recreation at

Ithaca College

August, 1976

Thesis Advisor: Dr. H. H. Merrifield

ABSTRACT

The purpose of this study was to conduct a kinematic analysis of selected phases in the softball batting form of eight high school female softball players.

Female subjects (N=8) were randomly selected from squad lists submitted by the coaches of selected high school varsity softball teams. Subjects were divided into high and low average batter groups according to their 1975 season batting averages. The batting averages were computed from batting profile sheets submitted by the subject's respective coaches. A batting average of .420 or better constituted high average batting.

An H16 Bolex Reflex, 16 mm. movie camera with 17-85 mm. lens was used at 64 frames per second speed setting to film the subjects swinging a softball bat. The filming sequence incorporated the use of an eight feet by eight feet grid and a homemade beam splitter. The beam splitter was used to superimpose the grid on the subject while filming.

Demographic data including age, height, years of playing experience was collected on the day of the filming sequence. This data was used to supplement the batting average data for each subject.

Each subject was required to perform four test swings using a softball bat while being filmed. Two swings involved hitting a softball off an adjustable batting tee.

The second two trial swings were made at an imaginary pitched ball. Comparisons were made for batting average groups as well as with and without the batting tee.

Reliabilities were established for trials with the batting tee and for trials without the batting tee. Means and standard deviations were calculated for demographic, batting average, angular and linear ball contact, and bat path data. Correlation matrices were established for demographic and batting average data, and for variables at ball contact. ANOVA were used to determine differences between and within batting average groups and batting situations for ball contact and bat path data.

The high average batter group used a shorter, more compact swing and a greater upward angle of swing through bat contact with the ball than the low average batter group. The angle of the lead elbow in the high average batter group was smaller than the corresponding angle for the low average batter group. The high average batter group exhibited these traits with and without the batting tee.

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A Thesis Presented to the Faculty of
The School of Health, Physical
Education, and Recreation
Ithaca College

In Partial Fulfillment of the
Requirements for the Degree
Master of Science

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by
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August, 1976

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Ithaca, New York

CERTIFICATE OF APPROVAL

MASTER OF SCIENCE THESIS

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Date: November 12, 1976

ACKNOWLEDGEMENTS

The author wishes to acknowledge Dr. H. H. Merrifield for his constant assistance and encouragement without which this study would never have been a reality. Special recognition goes to Jane Ingraham, the author's unfailing typist, and to Mr. and Mrs. Howard Ware for their invaluable work in the photography reproductions.

A special thanks to the author's parents who encouraged and never doubted that this study would be completed.

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Chapter 1

INTRODUCTION

The continuing growth of sports competition in high schools has begun to affect the female athlete. With the adoption of Title IX of the Elementary and Secondary Education Act, a tremendous increase in both the number of athletic teams for girls and the number of coaches needed for girls' teams can be observed. Title IX mandates that equal opportunity in athletics be offered to both sexes and shall include such factors as ". . . whether the sports selected reflect the interests and abilities of both sexes; . . . [provide] coaching and academic tutoring opportunities and the assignment and pay of coaches and tutors . . ." (55:2). The New York State Public High School Athletic Association Sports Report for 1974-1975 showed an increase from 76 percent to 82 percent for the number of member schools participating in softball. The rapid growth in interscholastic sports has found many public school women teachers unprepared to accept positions as coaches of girls' sports.

To offer capable coaching as now required by law. coaches must further their education on the undergraduate level, as well as during their years in the active coaching role. Indepth sports analyses of motor skills completed by researchers can assist women coaches in acquiring the

knowledge necessary to accept coaching positions and assist their schools in fulfilling Title IX regulations.

The coaching techniques necessary to develop softball playing performance in young, and often inexperienced players are frequently unknown to the new coach. Coaching experience and utilization of available pertinent information should be considered in order to improve coaching techniques. The high school coaches' ability to utilize the tools of kinesiological analysis is minimal. This ability, if present, is handicapped by the unavailability of equipment to the coach which is necessary to analyze motor performance.

Information gained, as a result of film analyses, could be made available to other high school coaches. In addition, summarized research findings and conclusions made by other researchers would assist in the improvement of the performances of high school players.

High school girls' softball is one of the sports, as mentioned earlier, that continues to demonstrate increased interscholastic competition. Batting, an obviously important complex skill, needs further investigation.

Statement of Problem

The purpose of this study was to conduct a kinematic analysis of selected phases in the softball batting form of eight high school female softball players.

Significance of Study

Softball is an accepted sport for girls as noted in the Sports Report for 1974-1975 compiled by the New York State Public High School Athletic Association (NYSPHSAA). The 776 member schools, grades 10-12, reported a participation of 82 percent in softball for the report year. This percentage indicates that 638 high schools in New York participate in softball. Twelve of these schools field boys' softball teams and 637 field girls' softball teams. The schools surveyed in this report were divided by enrollment with 199 C-schools (less than 300 students) participating in softball, representing 80 percent of the C-schools; 116 B schools (301-500), 82 percent of the B-schools; 157 A schools (501-1000), 80 percent of the A-schools and 166 AA schools (over 1000), 88 percent of the AA-schools, participating. The increase in the percentage of schools participating in softball and the increase in the number of softball camps support the acceptance of softball as a sport for girls. Further support can be seen in the publication of Softball Rules Guides by the National Association of Girls' and Women's Sports. These guides include coaching hints from women all over the United States.

Softball confronts the coach with unique problems that do not occur in other sports. One difficulty novice players encounter is developing the ability to bat the ball effectively and consistently. Hay (8:207) has stated: "As the principal offensive weapon in baseball, batting is one

of the most important skills in the game." Without a team that can bat and hence score, a ball game is a disappointment to the coach and to the players, as well as to parents and other spectators.

The coaching experience of this investigator suggests that the recognition of batting faults often escapes inexperienced coaches and players. The relatively short time it takes a player to execute a complete swing allows minimum time for recognition of errors and an indepth analysis. Analysis may be possible by having the player repeatedly swing while being observed, but this observation is time consuming and can only continue as long as the player swings the bat. The use of films for observation by the player and the coach allows for visual recognition of faults and provides for a more indepth analysis than is possible through simple observation.

The lack of time and equipment available to high school coaches for filming and film study, plus the inexperience in analysis techniques indicate the possible significance of having analyses completed for the coach. The recognition of "good" and "poor" batting execution would then be provided by researchers. It is the belief of this investigator that careful investigation of the batting forms of several high school female softball players, may provide a basis for skill analysis to be used by other girls' coaches.

Recognition of the components of good batting form is the primary step in analysis and correction of faults. The research in existence at the present time considers only male baseball players. There is a need for research evidence on female high school softball players. The variable experience of high school female players and the range in batting averages, both the subjects in this study and the members of the investigator's high school softball team, tend to indicate a lack of refined skill on the part of female high school players. Further study involving female softball players may aid coaches in correcting faults and improving skill.

Scope of the Problem

The subjects in this study (N=8) were members of girls' interscholastic softball teams which participated in the Finger Lakes Athletic League. The players selected ranged from 15 to 19 years of age. The experience of the subjects ranged from one year to eight years in organized softball competition. The high schools ranged in enrollment from less than 300 students to schools over 1,000 students. The selected schools were randomly chosen from a list of all schools in the Finger Lakes Athletic League participating in softball in 1975.

Coaches from the six selected schools were contacted and requested to send a squad list of their 1975 softball team. The squad lists were used for the random selection of three players who were invited to participate in the study.

Eighteen subjects were initially invited to participate in this investigation. Last minute transportation problems and final exam conflicts caused 10 of the subjects to withdraw from participation in the study. The subjects that participated in the study were eight players, two from each of four selected schools.

Assignment of the eight subjects to high and low average batting groups was based on the batting averages obtained from the batting profiles provided by their respective coaches. After studying the batting averages of the investigator's high school girls' softball team for three seasons, a batting average of .420 or better was arbitrarily considered a high batting average.

Subproblems

The following subproblems were formulated from the problem statement:

1. What are the interrelationships of lever angles at the elbows, trail knee, trail ankle; stride length; linear distances between the wrists and elbows; perpendicular distances of hip, knee, and ankle to the tee; and batting average?

2. What is the comparison between bat path when batting balls using a batting tee and bat paths when not using a batting tee?

3. What is the comparison between bat paths of high average batters and low average batters using the batting tee?

4. What is the comparison between bat paths of high average batters and low average batters not using the batting tee?

Hypotheses

The following hypotheses were formulated after a careful review of the research and conceptual literature surrounding the problem area.

1. There was no significant interrelationship of demographic data including age, height, years experience, at bats, hits, and batting average for all subjects, high average batters only and low average batters only.

2. There was no significant interrelationship of linear and angular measurements at contact including angle of the trail and lead elbows, angle of the trail knee, angle of the trail ankle, distance between the wrists and the elbows; stride length and batting average with and without the tee; and perpendicular distance of the trail hip, knee, and ankle to the batting tee for all subjects, high average batters only and low average batters only.

3. There was no significant difference between batting averages of the high and low average batters.

4. There was no significant difference between individual angular and linear measures at contact for high and low average batters with and without the tee.

5. There was no significant difference between individual perpendicular distances at contact for high and low average batters, with and without the tee.

6. There was no significant difference between length of the stride for high and low averages, with and without the tee.

7. There was no significant difference between the vertical distance traveled by the bat for high and low average batters, with and without the tee.

8. There was no significant difference between the horizontal distance traveled by the bat for high and low average batters, with and without the tee.

9. There was no significant difference between the angle of upward trajectory of the bat through ball contact for high and low average batters, with and without the tee.

Definition of Terms

As a clarification of this study, the following terms are operationally defined:

1. Batting is that skill in which a player contacts a ball resting on a batting tee and imparts motion to it.

2. Batting form is the combination of prescribed factors which indicate proper execution of the skill. The phases of form considered include: grip, stance, swing, stride, and followthrough.

3. Batting success is the acquisition of a subject of a batting average of .420 or better. It should be noted that this average is considered extremely high for major league baseball, but the conditions of the girls' interscholastic softball in the study population lend themselves to averages this high and higher.

4. Kinematics involves the "description, measurement, and recording of bodily motion with due consideration of the character of joints and bony segments involved in motion." (2:1).

5. Lever angles are the angles measured between the joints under study as they move through the prescribed motion.

Assumptions

The following statements were assumed to be true for this investigation:

1. The criterion for analysis of the baseball batting form is equal to that of softball batting.

2. Subjects performed to the best of their ability during the filming.

3. Subjects had previous experience using a batting tee.

4. The batting profiles submitted by the team coaches were accurate.

5. The squad lists submitted to the investigator contained names of girls of varsity skill level.

Limitations

Due to the procedural problems including camera failure and subject final examination and transportation conflicts, the following limitations affected this investigation:

1. Eight subjects participated in the filming.

2. The measured angles were not always clearly visible throughout the film segments.

Delimitations

Because of limited time and facilities available, the following statements were adopted to delimit the study:

1. Three subjects from each school were invited to participate in the study.

2. The teams of six schools were used in selection of the subjects.

3. The phases of batting adopted for overall analysis of form were stance, stride, swing, and followthrough.

4. The flight of the ball was not considered for analysis of swing.

5. The phases of batting adopted for measurement included stride length, angles of elbows, trail knee, and trail ankle whenever visible through backswing, foreswing, contact, and followthrough.

6. Measurements, made at ball contact by the bat, were used to determine perpendicular distance to the batting tee of the trail hip, trail knee, and trail ankle; and linear distance between wrists and between elbows.

7. Measurements, made at ball contact by the bat, were used to determine the angle of the lead and trail elbows, trail knee, and trail ankle.

8. Bat paths were drawn for all subjects using the batting tee and when not using the batting tee.

9. Measurements were made whenever possible within the adopted points including stance, backswing, foreswing, contact (swings with batting tee only), and followthrough.

10. Measurements were taken every two frames of film starting at the beginning of the backswing for each subject.

Chapter 2

REVIEW OF RELATED LITERATURE

The initiation of a kinematic analysis of any sport's skill requires a search of the conceptual and research literature. Literature on the batting phase in the game of softball was not readily available, however, research information as well as conceptual literature was plentiful regarding the sport of baseball. This information was used as the main source of literature reviewed. The material within this chapter discusses general facets of cinematographic and kinematic analysis, as well as specific facets of batting techniques and batting studies.

Techniques of Cinematographic and Kinematic Analysis

Cinematographical analysis enables investigators to view body movements totally and to relate these movements to three dimensional space and external objects. This type of analysis allows for observation of body segment position, estimates of segmental centers of mass, gravitational line, displacement, velocities, and acceleration vectors. In addition, the investigator may study aspects of kinetics using cinematographical study. (1)

The techniques of analysis of human motion are varied. O'Connell and Gardner (13) make reference to 11

criteria necessary for an effective kinematic analysis. The criteria included mechanical descriptions, identifications of kinesiological movements, joints and forces involved in the movement. They recommend the filming of human movement in three views, front or back, side, and overhead. Techniques used by Noble and Kelley (34), and Engen and Spencer (29) concurred with the recommendation of filming in three planes. Northrip, et al., (12), Grieve, et al., (7), and Miller and Nelson (11) mention another method of filming with one or two cameras and using mirrors set in varying angles to the camera and subjects. This method enables viewing of the subject from more angles on one film.

In 1939, Cureton (25) made suggestions for the general techniques of film analysis. Included in his work were recommendations for filming equipment and the quantities measurable on films of human movement. Many of his recommendations remain in practice today. These include type of camera, editing equipment, and measurement of angles, linear distances, speed and force. The common use of the 16 mm. camera shown in studies by Blievernicht (22), Deshon (26), DeVries (27), and Watkins (45) substantiates Cureton's recommendations.

Further recommendations regarding filming equipment were made by Grieve, et al., (7), Miller and Nelson (11), and Northrip, et al., (12). All of these researchers agreed on the use of the 16 mm. camera and felt that a motor driven camera would offer more consistent accuracy of film

speed. Northrip, et al., (12) recommends a camera film speed of 16-80 frames per second for most skills. He further suggests 64-80 frames per second camera film speed for all high velocity ballistic skills. Grieve, et al., (7) recommends a camera film speed of 32-100 frames per second and states that higher speeds are wasteful of film. These researchers strongly recommend the inclusion of horizontal and vertical reference lines in the filming area and the use of an easily observable timing device for careful calibration of the camera film speed.

Hopper and Kane (10) and Gombac (6) in their studies offer further recommendations for consideration during film analysis. The use of segmentation for locating the center of gravity to aid in analysis was examined in 1968 by Hopper and Kane (10). Determination of the mass of segments was used. Through this method, the center of gravity was calculated for each analyzed segment. Walton (43) in 1970 presented a template for simplification of the process of locating centers of gravity. Gombac (6) in 1967 presented a film analysis technique, using contourograms and cyclograms, at the first Biomechanics International Seminar in Zurich, Switzerland. The method of filming with a high speed camera and making tracings of paths of selected body points and paths of body positions was evident in other research. Herrmann (9) studied gymnastic exercises using three body points which were traced throughout the movement. Adrian and Engberg (20) used a single camera and filmed three

subjects. They studied the movement of the body parts through the motion. Grunwald (52) analyzed the badminton serve using one subject and a film study of joint angles and kinematics of the movement.

Computer analysis methods recently have led to formulation of computer programs which are able to analyze kinematic data with satisfactory results. Computer printouts may include a listing of the muscles involved in the motion being studied, as in Ward's (44) investigation; or computations of centers of gravity, angular velocity, and plottings of the centers of gravity pathways as indicated by Garrett, et al. (31).

Under consideration is the recognition and control of filming errors. Noss (35) experimented with tri-axial filming to control perspective errors. Use of this method lead to a mean value for three sets of collected data. This mean value was used to represent the subject angles. He noted that "the practical application of tri-axial analysis lies in the determination of the mechanical efficiency and effectiveness of motor skills of all kinds." (35:84). Use of a correction factor to change film distance to true distance was indicated by Cureton (25). Further investigation and selection of an adequate method to determine perspective error was arrived at by Doolittle (28). He used simulated film frames and analysis by three operators to establish reliability of his correction factor techniques.

Adrian (1) discussed the correction of perspective

errors by placing the cameras used for filming at right angles to the plane of the movement. She also said that by placing the camera a long enough distance from the subject, that the linear distortion will become negligible. The exact distance can be found through trial filmings. Miller and Nelson (11) also discuss the problem of parallax error and further stated that the error experienced in cameras with offset viewfinders can be greatly minimized provided the lens-object distance is over six or seven feet.

The Technique of Batting

There is little agreement among the experts and researchers on the important factors needed for a batter to effectively execute one of the five or six phases of batting. Weiskopf (17) stated that:

> One of the most unique aspects of baseball is the fact that no two hitters hit exactly alike. Batting coaches declare that this is the way it should be because there is no set pattern of style to follow in becoming a good hitter. They believe that each hitter is a separate individual and must develop his own style to meet his own physical abilities. However, these same coaches point out that there are a number of basic rules and fundamentals that all hitters should follow because there are correct and incorrect ways to bat. (17:3).

Hay (8) lists the batting phases as stance, stride, swing, and followthrough. In addition to Hay's four phases, grip was included by Watkins (45), Williams (48), and McCord (32). Inclusion of these phases and one additional phase known as hitting action was mentioned in Watt's (46) article on "The Classroom Approach to Batting."

The batting grip was defined to include a finger grip as advocated by Williams (48), Watts (46), and Lopiano (53). Watts (46) further defined the proper grip as "knuckles-on down" (46:19). Two other components were mentioned which included a choke grip on the bat of one-half to one inch and a varying choke grip which included a choke, moderate choke and end grip. These choke grips were advocated by Lopiano (53) and McCord (32) respectively.

The components of the stance phase varied, with general agreement on four components. The hands high and away from the body position was advocated by Watts (46), Siedentop (16), and Lopiano (53). Williams (48), Watkins (45), McCord (32), and Weiskopf (17) agreed that the shoulders begin on a plane parallel to the ground. The head remaining still during stance and through the swing was advocated by Williams (48), Watkins (45), Siedentop (16), Lopiano (53), and Bunn (3). Having the wrists in a radial deviation position for maximum force application was advocated by Watts (46), Hay (8), McCord (32), Siedentop (16), and Lopiano (53). Watts (46), Williams (48), and Lopiano (53) also concurred on weight distribution. They believed that the weight should be equally distributed, on the metatarsophalangeal heads of the feet, and the body slightly crouched.

The greatest disagreement regarding stance was the component of bat angle relative to the ground. Bunn (3) advocated that the bat should be held at an acute angle.

Hay (8) stated that the batter was at a disadvantage if the bat was held at 90 degrees or at the vertical, and McCord (32) advocated a bat angle between the horizontal and the vertical.

The component of stride produced the most common agreement by researchers and experts. Hay (8), Siedentop (16), Lopiano (53), and Bunn (3) advocated a short stride, with Lopiano (53) stating a 13 inch increase in width of stance after stride. Striding consistently to the same area in the batter's box or to relatively the same area was recommended by Hay (8), Breen (23), and Siedentop (16).

The remaining two components, swing and follow through, were mentioned by the researchers and experts, but no common factors were found.

Studies of Batting Performance

Race (37) conducted a study in 1960 "to scrutinize the mechanics of hitting a baseball effectively." (37:394) Subjects of the study were 17 professional baseball players with batting averages of at least .275. Analysis was made of film segments in which the hits were defined as effective when they were 370 feet or a hard line drive. A mechanical analysis approach was used. Race (37) calculated bat velocities and relative forces, degrees of movement, velocities of body segments, body inclinations, forward knee extension, rear knee flexion, head level, and preparatory batting movements. Race (37) concluded that there were no significant correlations between batting average, slugging averages and

the above measures. He also concluded that rotary motion of the hips was a prime movement in his subjects.

Using batting averages as their definition for success, Vaughn (41) and Nieman (33) conducted separate studies to determine the relation of lever arm, bat velocity, and distance traveled by the bat to success; and the frequency of use of basic hitting fundamentals by successful college varsity baseball players. Vaughn (41) filmed 13 male subjects of a college varsity and junior varsity baseball team. He analyzed and computed the correlations between each batting variable and the criterion he considered relative to batting success. He concluded that bat velocity was of prime importance, and the use of a short swing with wrist action was most conducive to high average batting. He further concluded that a long bat swing with straight arms, good shoulder-arm rotation, and hip rotation was conducive to power hitting. Nieman (33) used six college varsity batters to determine whether successful batters used basic hitting fundamentals more than unsuccessful varsity batters. He analyzed nine batting fundamentals with 540 possible reference points. He concluded that there appeared to be very little relationship between high batting averages and performance of correct batting techniques.

Shapiro (54), using four subjects, examined the direction and length of stride and the amount of hip rotation. He found that stride lengths and hip rotation were similar to that described in the literature. In addition, he found

that secondary adjustment by the batter to pitch height was accomplished by knee flexion and bat inclination.

Swimley (40) used two subjects and did film comparisons of their baseball bat swings. He found strides of six inches and twelve inches in his two subjects; and only subject one employed a backswing. He concluded that in order to develop the maximum power when swinging through the hitting area, the hitters front leg and lower arm should be at full extension or nearly full extension. He also concluded from his study that to be effective, the action of the batter's hands must be delayed until the arms are well into the actual hitting area of the swing.

Ryan (39) studied five college varsity and five college freshman baseball players. He compared angles just prior to bat-ball contact and velocities of the bat and ball after contact. Through further analysis, he measured the contributions that the body segments had on the total velocity applied to the ball; and the relationship between "joint summation of velocities and the measured velocity of the ball." (39:81). He concluded that an initiation of the swing by hip joint rotations and the use of the wrists contribute approximately 50 percent of the linear velocity of the ball. The hip and wrist movements were considered the prime factors that differentiated the varsity players from the freshman players.

Summary

Discussion has been presented in this chapter concerning techniques of cinematography, film analysis, batting techniques and studies of batting performance. It was recommended that 16 mm filming be conducted in the plane of the motion being studied. It was pointed out that careful design of the experiment is necessary to minimize errors in filming and later in recording and analyzing the data. It can be seen that the research literature is limited and the existing literature offers many discrepancies. There was little agreement on the components and criteria to be followed for developing a successful batting technique. This information will be further discussed in Chapter 5 in light of this investigation.

Chapter 3

METHODS AND PROCEDURES

Kinematic analyses of sports skills have taken many forms since their inception in the 1930's. This study entailed a kinematic analysis of softball batting form, using a 16 mm. camera to film a sagittal view of subjects performing the skill. The eight subjects were randomly chosen high school girls, who had been members of their schools' interscholastic softball team from one to four years. The coaching experience of each softball coach differed and hence the batting techniques of their subject's also differed.

The basic phases of batting have been agreed upon by many experts including Breen (23), McCord (32), Nieman (33), Watkins (45), and Williams (48) as standard. Using the five phases of batting and the performance criteria adapted from Watkins (45), McCord (32), and Breen (23), a kinematic analysis was performed and the measurements compared with one another as well as with batting averages and other pertinent demographic data.

This chapter includes a description of the population and sample, and various equipment used for testing. Information regarding the actual filming layout, test administration, organization and analysis of the collected data, is also included. The diagrams and copies of all letters

and forms used in the administration of this test are included in the appendices.

Description of the Population

The population for this kinematic analysis of softball batting skills was limited to the 14 schools in the Finger Lakes section, Girls' Division, of the Wayne-Finger Lakes Athletic League located in the central part of New York State. The Wayne-Finger Lakes Athletic League was comprised of school districts varying in enrollment from a collegetown high school of over 1,000 students, to a small rural central school with an enrollment of under 400 students. The students in any one school came from a variety of social and economic backgrounds with varying degrees of exposure to sports experiences. The community center type programs in the towns were extensive, and offered both boys and girls opportunities to participate in many different sports, e.g., trampolining, gymnasium hockey, competitive softball and baseball, competitive basketball and basketball shooting tournaments. Many of the towns have active Elks' and Lions' Service Clubs which sponsored various events for youth.

The large population variation of town and city size, the wide range in economic backgrounds and sports experiences, and the fact that the Wayne-Finger Lakes Athletic League included four upstate New York counties, made it an excellent population to study.

Sampling Procedure

The nature of kinematic analysis and the time required for a complete investigation necessitated the use of only a representative sample from the chosen population rather than using the entire population. The names of six schools were randomly selected from a list containing all schools eligible for the study. The eligible schools were defined as those schools that participated in girls' interscholastic softball, and were members of the Wayne-Finger Lakes Athletic League at the time of the investigation.

The initial contact with the six selected schools was made through the respective high school building principals. On March 18, 1975, letters were sent introducing the investigation, the purpose of the study and what would be required of the school, coach, and selected players. (Appendix A). The school principals were requested to respond if they would prefer not to participate in the investigation.

After the six selected schools had been contacted, the respective coaches were sent letters the second week of April. (Appendix B). Each letter contained the batting profile sheets to be kept on the subjects, and the names of the three players selected from her team to participate in the investigation. (Appendix C).

The second week of May, 1975, letters were sent to the subjects giving them the specific information about the filming. (Appendix D). Enclosed with the letter was a

commitment sheet and a permission slip for the subject and her parents to fill out and return to the investigator by May 30, 1975. (Appendix E).

Three days prior to the actual filming date of June 18, 1975, all coaches were contacted by telephone to confirm receipt of all requested information and the subject's arrival time.

Sources of Data

Data were gathered through angular measurements of the elbows, the trail leg's knee and ankle; perpendicular distances of the hip, knee, and ankle of the trail leg from the tee; and the linear distance between elbows and wrists at ball contact. Film tracings, film timings, and demographic data provided additional data for the investigation. Batting profiles supplied by the coaches and collaborated by Ms. Y. Montana, the scorekeeper for the investigator's high school softball team for three previous softball seasons, supplied the necessary data for compiling subject batting averages. The phases of batting used for analysis were based on the criteria established by Hay (8), Breen (23), McCord (32), and Watkins (45).

Four facets in the execution of hitting were used for evaluation of batting form. The facets included stance, swing, stride, and followthrough. Data gathered on the phases of batting included angle measurements of selected joints at stance, and continued from the initial backswing through the followthrough with measurements being recorded

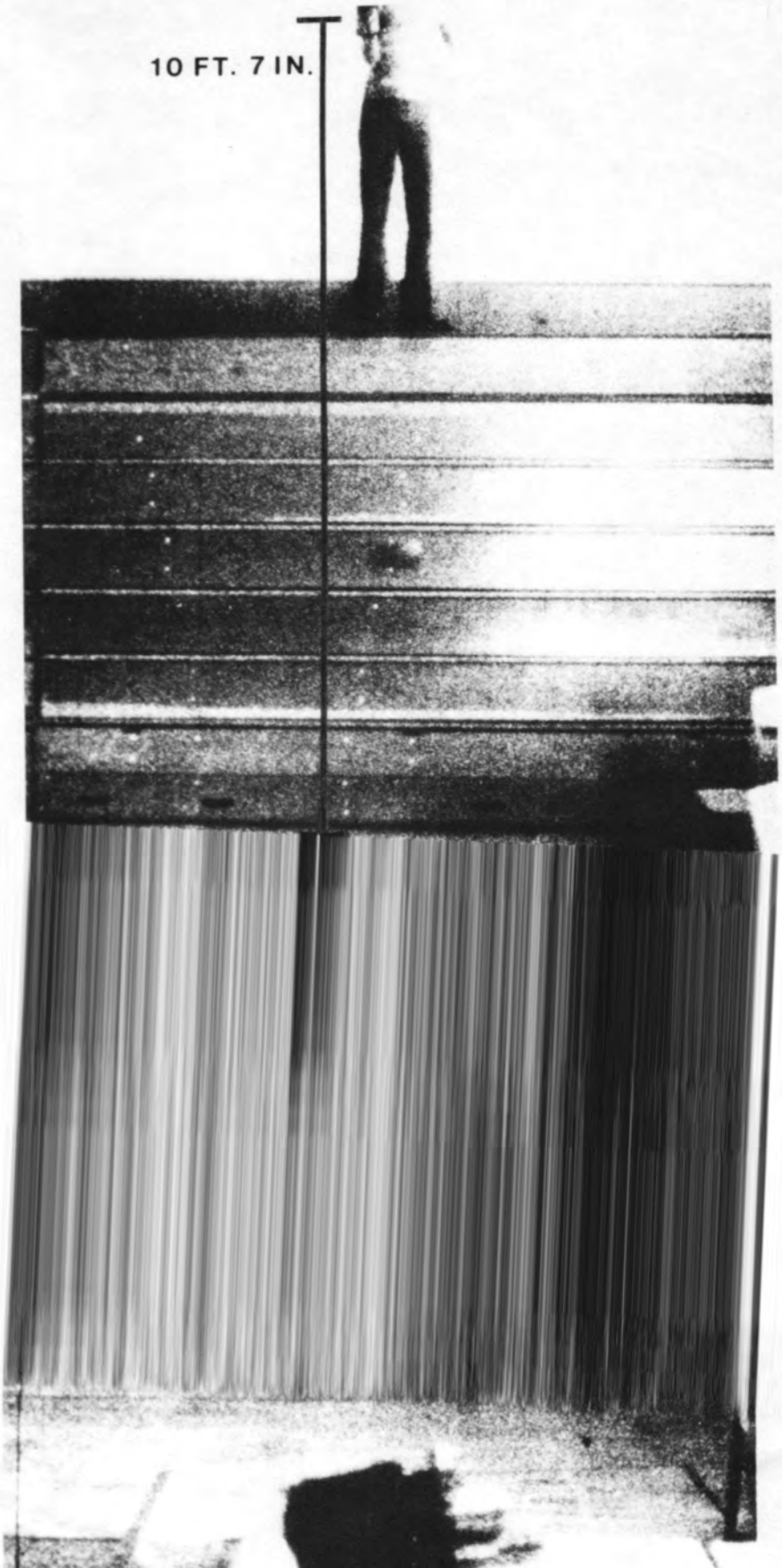
from every two frames of film. Film tracings were used to indicate paths of the measured joints, and the bat. Film tracings, when the batting tee was not used, included the same measurements with the exception of measurements taken at the point of contact.

Instrumentation

The investigator used one, H16 Bolex Reflex, 16 mm. movie camera, with an Angenieux 17-85 mm. lens and speed of 64 frames per second. The camera and lens were manufactured in Paris, France by Bolex. The film was 16 mm. Kodak Tri-X Reversal black and white film with an ASA of 200. The camera was mounted on an adjustable tripod with locking positions and calibrated by filming an object of known weight being dropped as was recommended by Cureton (25). The object was an eight pound indoor shot dropped from a height of 10 feet 7 inches as shown in Figure 1. Camera speed was found to be 58.02 frames per second. The camera was kept fully wound for each filming to minimize speed changes.

A grid 8' by 8' was placed against the wall 35 feet from and perpendicular to the camera. The grid was divided into squares 6" by 6" as shown in Figure 2, to enable the investigator to accurately determine the multiplier for conversion from film size to actual size, and determine any observable velocities.

A homemade beam splitter, shown in Figure 3, made similar to the dichroic mirror described by Cooper and Sorani (24), was used to superimpose the grid on the subject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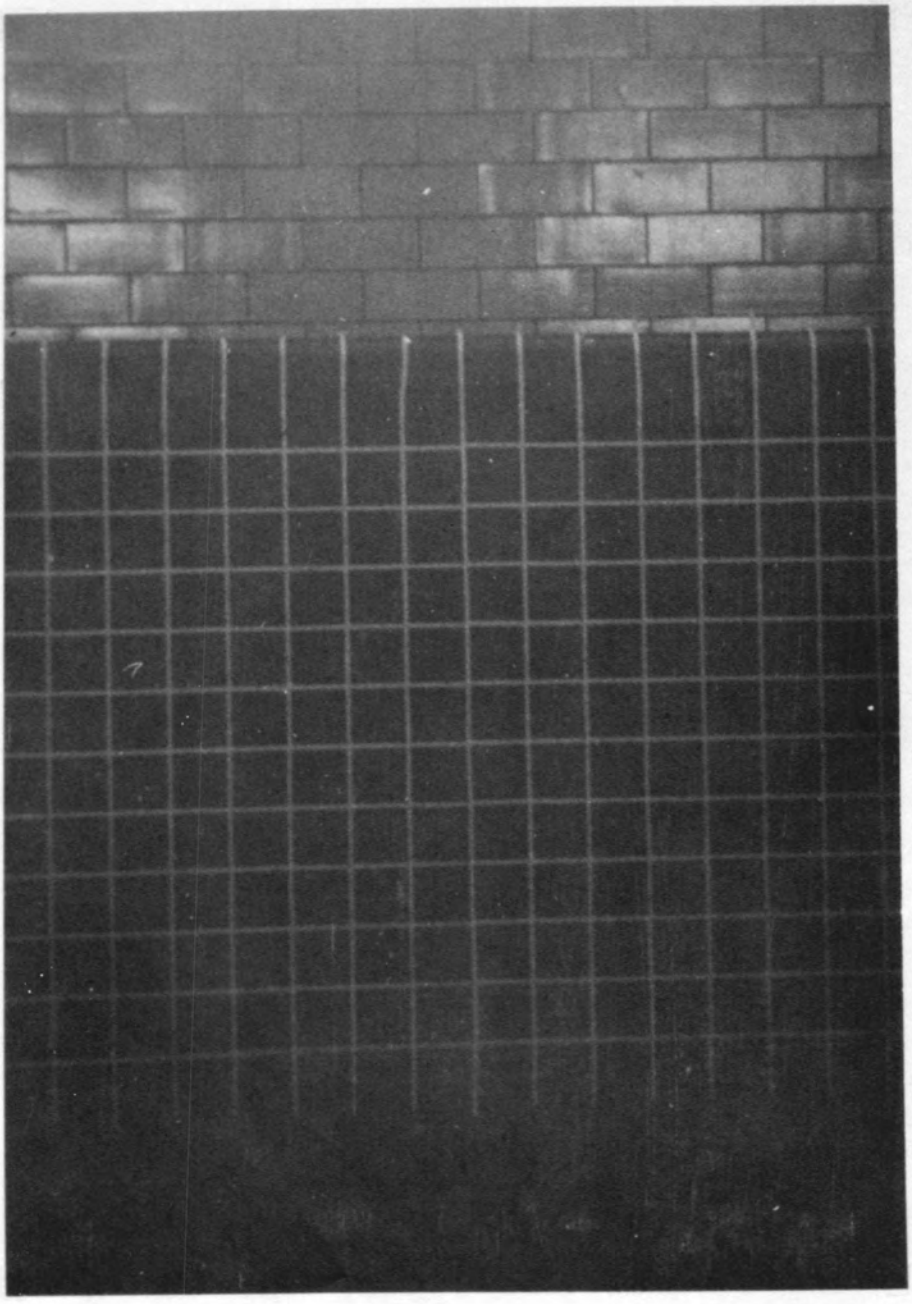


FIGURE 2

FILMING GRIDS

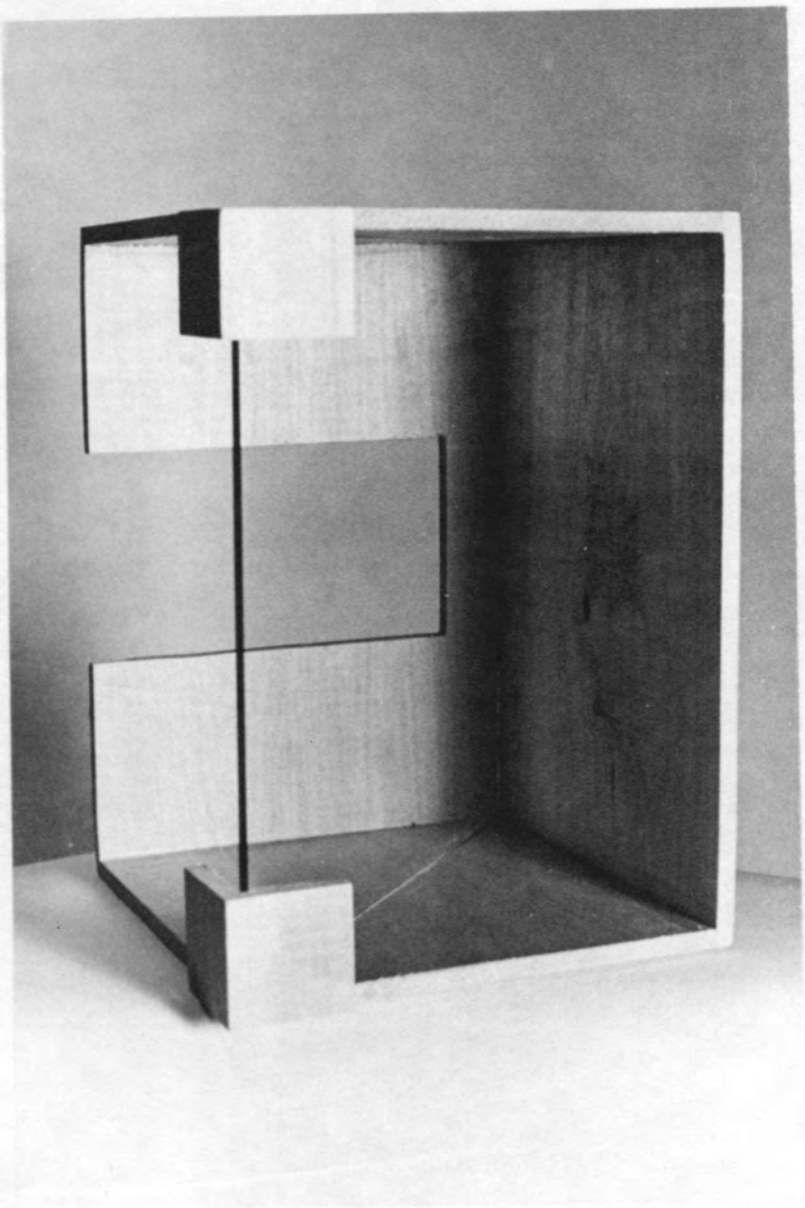


FIGURE 3

BEAM SPLITTER

and control the problem of parallax. An example of the operation of the beam splitter is shown in Figure 4. The beam splitter used was six inches square by eight and one-half inches high, and employed a piece of window glass eight inches by eight inches. The beam splitter was placed so the front edge of the camera lens was even with the inside edge of the beam splitter camera lens opening.

The 16 mm. developed films were read using a Recordak Film Reader, Model Number MPE-1, which is manufactured in Rochester, New York by Eastman Kodak Company. The Recordak enabled tracings to be made of body movements and paths of preselected points.

Test Administration

The filming situation involved a standard indoor home plate, one Dudley aluminium bat, 32 inches long, an adjustable batting tee, 12 softballs, the filming grid, a camera and tripod, and the beam splitter. The physical layout of the gymnasium used for testing can be seen in Figure 5.

The camera was placed on a locked tripod focusing at 90 degrees to the subject and grid which provided a sagittal view of the subjects. The camera was placed 35 feet from the middle of home plate, perpendicular to the subject. The camera was situated in conjunction with the beam splitter to enable filming of the subject with the grid superimposed on the subject. The grid for the camera was 35 feet from the

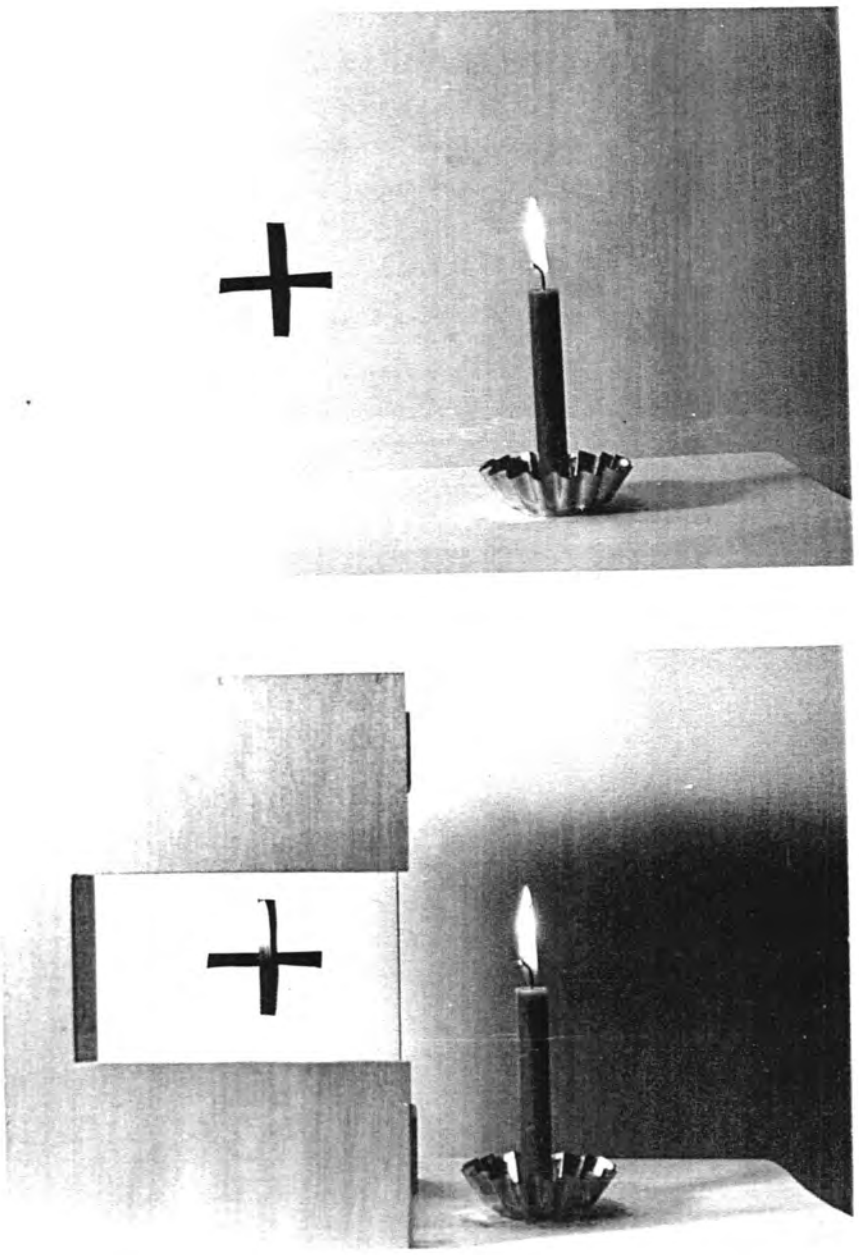
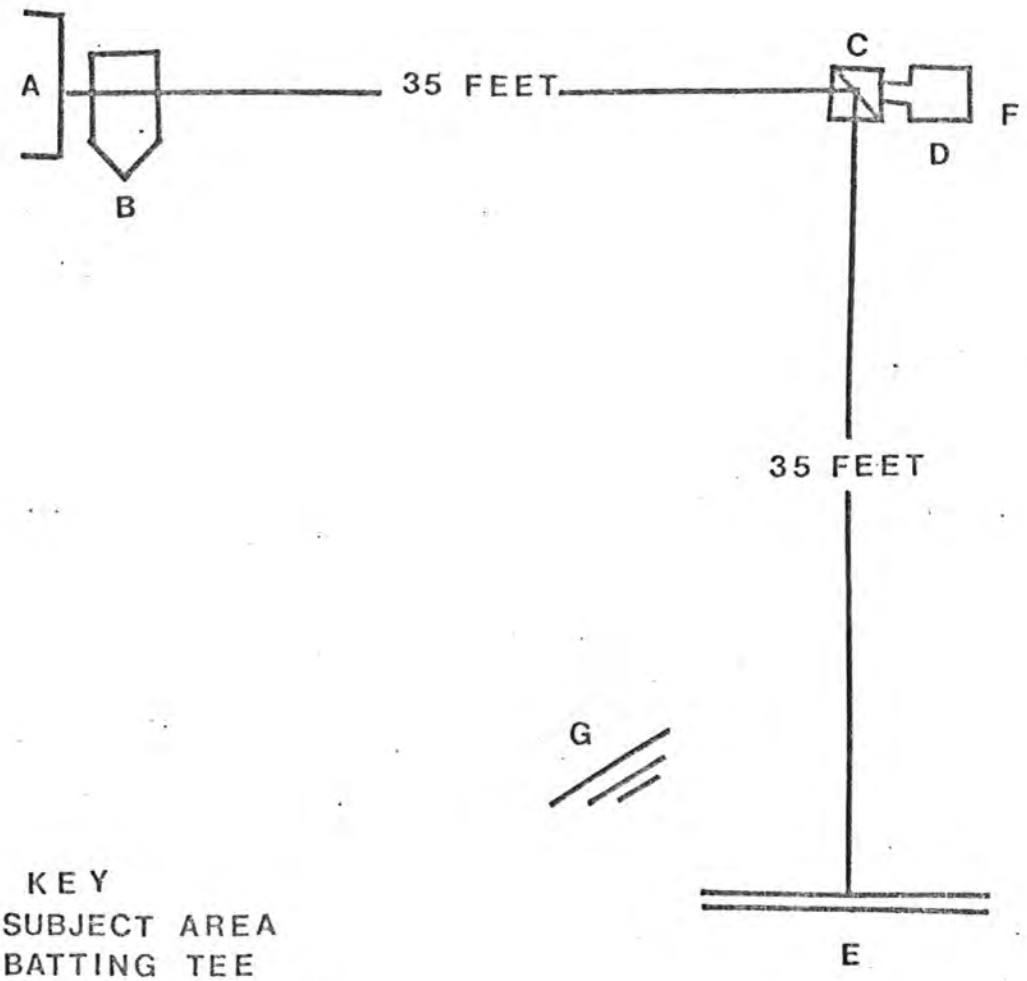


FIGURE 4

EXAMPLE EMPLOYING
BEAM SPLITTER



KEY

A	SUBJECT AREA
B	BATTING TEE
C	BEAM SPLITTER
D	CAMERA 16 MM
E	GRID
F	INVESTIGATOR
G	FLOODLIGHT BANK

FIGURE 5

SCHEMATIC DIAGRAM
SHOWING SUBJECT, CAMERA
AND GRID

camera on a line forming a 90 degree angle with the line from home plate to the camera.

The investigator was situated behind the camera and verbally signaled the subjects when to take their stance and swing. All subjects were given four practice swings to adjust to using the batting tee and make any necessary adjustments in the batting tee height. Prior to the practice hits, the subjects were individually given the following verbal instructions:

> The experiment you are about to participate in involves a filming of you hitting the softball placed on the batting tee, and taking two swings at an imaginary ball. You will be given four practice hits and you may adjust the batting tee to a height which you like. Take your time and concentrate on hitting the ball to the best of your ability. Use a complete swing, pretending to wait for the pitch. After your practices I will instruct you when to step into the batter's box and hit your first test ball. This is when I will start filming you. At the completion of each test hit please step out of the batter's box and wait until I tell you to step in for the next test hit. There will be four test hits in total. Two will be with the batting tee and two will be without the batting tee. Take your time and do your best. Do you have any questions? You may take your practice hits now.

The subject's task involved hitting a softball off a batting tee, and swinging at an imaginary ball without a batting tee. The batting tee was chosen to standardize the hitting procedure. The use of the batting tee in testing for softball batting performance was based on the research of Fox and Young (30). An example of a subject participating in the test can be seen in Figure 6.

To increase the reliability of the filming results, the investigator filmed four complete batting sequences for

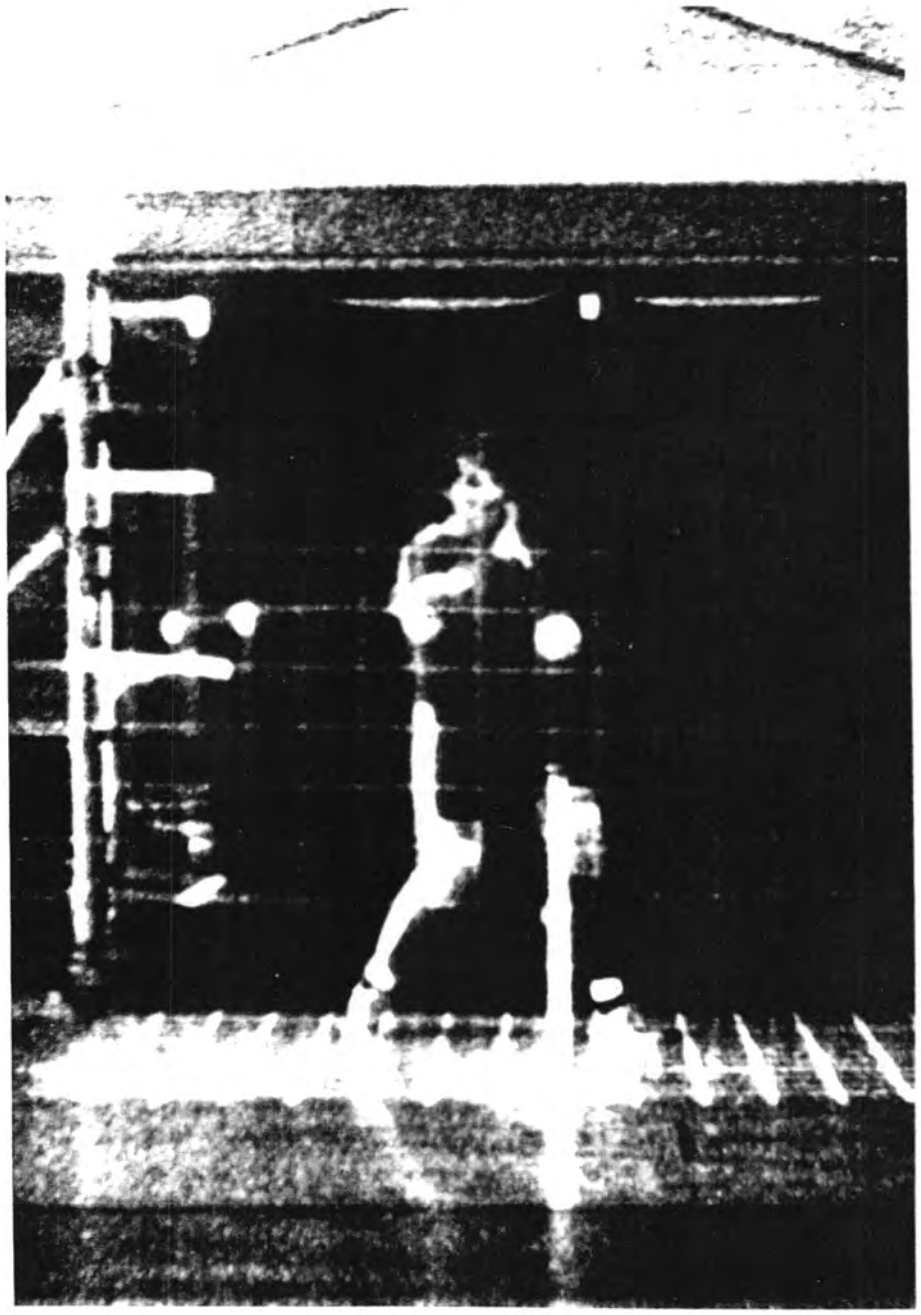


FIGURE 6

SUBJECT SWINGING AT BALL
ON BATTING TEE

each subject. Two sequences involved swings with the batting tee and two sequences involved swings without the batting tee. A sequence involving the batting tee and ball contact is shown in Figure 7. All subjects performed their swings in the order of practice swings, (1) swings with the tee and (2) swings without the tee.

Prior to each subject's filming sequence, she was given a data card as shown in Figure 8. The card already contained the name of the subject, school, and subject number code. Each subject was requested to add height, age, and number of years she had participated in organized softball. Participation was defined as the number of separate softball seasons played under the supervision of a coach.

At the time of testing, each subject was in the gymnasium alone with the investigator to eliminate the influence of performing before an audience.

One and one-half inch adhesive tape markings of joint areas and long axes of bones were placed on the subjects to facilitate analysis. The tape markings indicated the following anatomical areas and points:

1. The arms were marked with a long strip of tape from the supraclavicular fossa over the acromion process, down the lateral aspect of the arm and over the lateral epicondyle of the humerus. This strip of tape ended at the styloid process of the radius. The tape marking the arm was anchored by (a) a strip of tape over the epicondyles of the

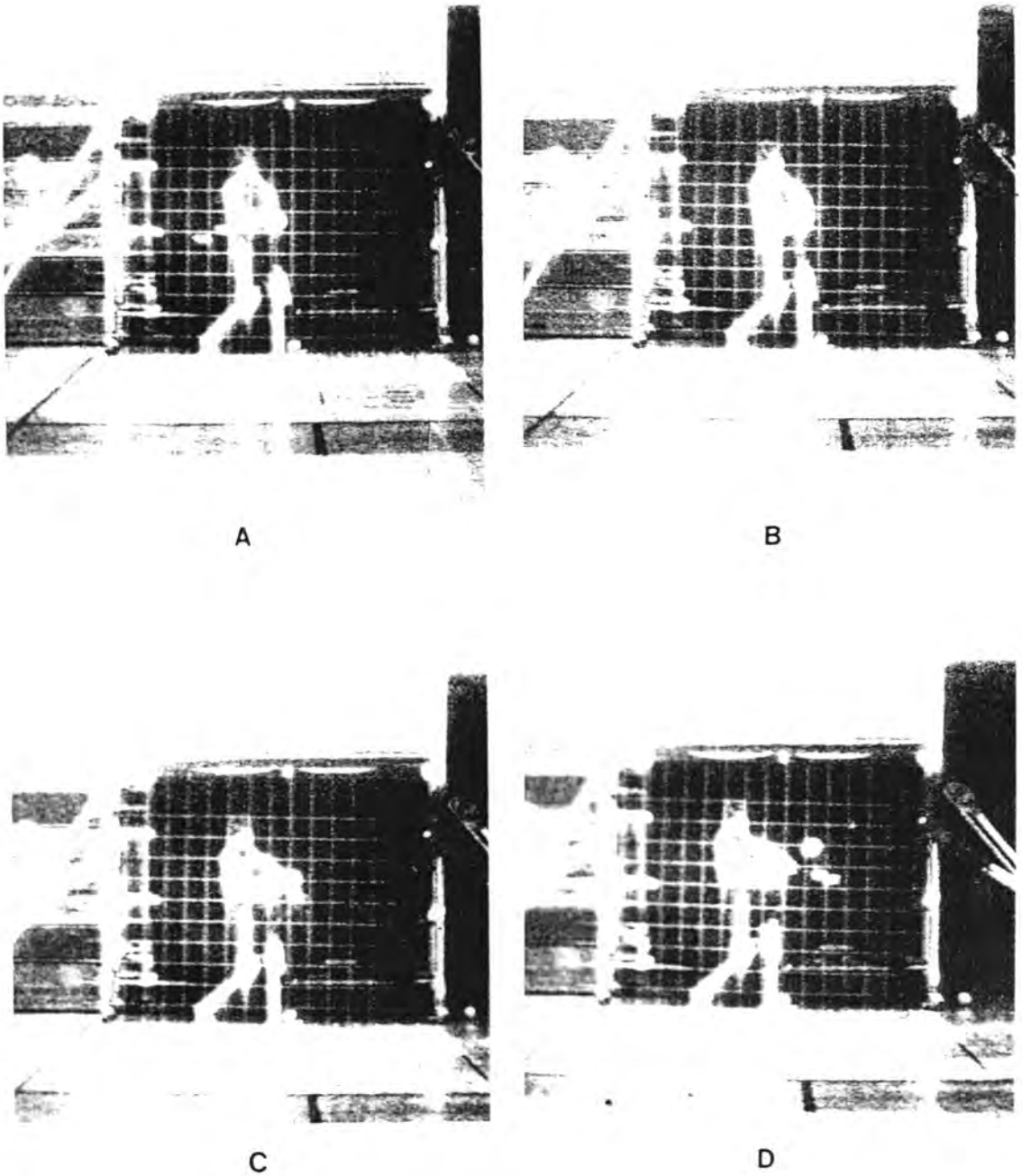


FIGURE 7

SEQUENCE OF SUBJECT MAKING
CONTACT WITH BALL

DATA CARD Subject No. 4

NAME Sally Jones

SCHOOL Altman Central

Please fill in the following information

Height_____

Age_____

#of years you have participated in organized softball

_____

FIGURE 8

SAMPLE SUBJECT DATA CARD

humerus and (b) a strip of tape over the styloid process of the radius and the head of the ulna.

2. The hands were marked by a strip of tape across the dorsal surface of the metacarpophalangeal articulations, two through five.

3. The subject's legs were marked by a tape strip from the middle of the iliac crest over the greater trochanter of the femur, down the lateral aspect of the femur to the head of the fibula. This strip of tape continued down the lateral aspect of the leg to the lateral malleolus. The strip of tape marking the leg was anchored by (a) a strip of tape superior to the patella, with the bottom edge of the tape touching the superior aspect of the patella, and (b) a strip of tape over the medial and lateral malleoli.

Data Organization

The 16 mm. developed films were viewed on a Recordak Film Reader. Tracings, of each subject's body parts to be analyzed as well as the points of the bat throughout the swing, were made on 7 by 8.5 inch Triad blue mimeo-bond paper. These tracings provided the means for angular and linear measurements of joints and the plotting of the bat paths for each subject. The results of the linear and angular measurements for each subject's swings with the tee and swings without the tee, were recorded separately on data sheets. (Appendix F).

Bat path tracings were developed for each subject. A line of best fit was determined for each subject using the

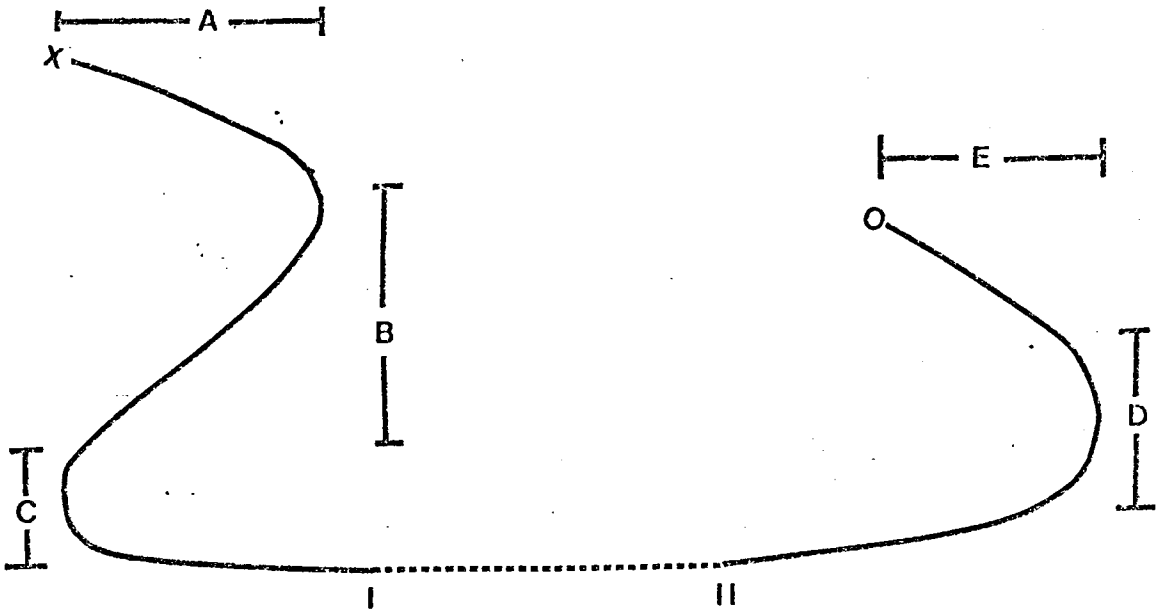
two trials with the tee for one tracing and the two trials without the tee for a second tracing. (Appendix G). It may be noted that the difference that exists in the size of the space between I and II in the bat path tracings as shown in Figure 9 was caused when the subject rotated the forearms enough to cause the end of the bat to face the camera and make the bat tape markings on the barrel invisible.

Summary data sheets were used to show the mean measurements calculated for all angular and linear data at ball contact. (Appendix H). Subjects were listed by batting group as high or low, and all data were designated according to the group. This division allowed for a comparison between groups on angular and linear measurements as well as demographic data.

Statistical Treatment

The data were analyzed using descriptive and inferential statistics to discover as much information about the differences and interrelationships of all available data. Reliability values were established for each subject with and without the tee. Reliability was determined from pairings of all angles available for each subject throughout the entire sequence of the bat swing. (Appendix I).

Pearson product moment correlations were performed on all measurements taken at ball contact and all demographic data. This descriptive statistical technique allowed the formation of correlation matrices for all subjects on demographic data, high average batters for



X SWING STARTS
O SWING ENDS
..... CONTACT AREA
A BACKSWING
B DOWNWARD PHASE OF FORESWING
C TURN OF FORESWING
D TURN OF FOLLOWTHROUGH
E END OF FOLLOWTHROUGH
B·C·I FORESWING
II·D·E FOLLOWTHROUGH

FIGURE 9

EXPLANATION KEY FOR

BAT PATHS

angular and linear measurements at ball contact, and low average batters for angular and linear measurements at ball contact. All correlations were tested for significance at the .01 and .05 levels.

Further inferential statistics used included a one-way analysis of variance and a two-way analysis of variance.* Simple analysis of variance was performed on perpendicular distance of the trail hip to the tee at contact for high and low average batters, on perpendicular distance of the trail knee to the tee at contact for high and low average batters and on the perpendicular distance of the trail ankle to the tee at contact for high and low average batters. All F tests were tested for significance at the .05 level.

Two-way analyses of variances were performed on the angle of the trail knee at contact for high and low average batters, with and without the tee; on angle of the trail ankle at contact for high and low average batters with and without the tee; on the angle of the lead elbow at contact for high and low average batters, with and without the tee; on the angle of the trail elbow at contact for high and low average batters, with and without the tee; on linear distance between the elbows at contact for high and low average batters, with and without the tee and on linear distance between wrists at contact for high and low average batters, with and without the tee. The results of each of the above

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*Analysis of Variance will be referred to as ANOVA in the remainder of this study.

analyses of variance was tested for significance at the .05 level of significance.

Two-way analysis of variance was also performed on measurements which involved the bat path of the subject groups. Analysis was performed on vertical distance traveled by the bat from the start of the foreswing to the area of contact for high and low average batters, with and without the tee. The other bat path measurement analyzed by this method was the horizontal distance traveled by the bat from the foreswing at the point of greatest convexity at the turn to the greatest point of convexity of the followthrough turn. Results of these two analysis of variance tests were tested for significance at the .05 level of significance.

Summary

This chapter presented a discussion of the study population, description of the study sample, and method of selection. The sources for data included the film measurements, tracings and the demographic data for each subject. The investigator used a Bolex 16 mm. camera and homemade beam splitter in producing the kinematic information.

The task for the investigation involved each subject swinging a bat four times, two times at a ball on a batting tee, and two times at an imaginary pitched ball. All subjects were given a standard set of instructions before performing the test. To facilitate analysis, tape markings were placed on the subjects at key anatomical points.

The treatment of the data included the employment of the Pearson product moment correlations and one- and two-way analysis of variances.

Chapter 4

ANALYSIS OF DATA

Data gathered from subjects, coaches, and tracings are analyzed in this chapter. For comparison, measurements were made from films with the batting tee and without the batting tee. Further comparisons were made by grouping subjects into high or low batting average group.

Batting Averages

Batting profiles were submitted for each subject by their respective coaches. From the profile sheets, batting averages were calculated. Table I shows each subject's number of times at bat, hits and batting average.

Batting averages ranged from 729.72 to 357.10. The mean and standard deviation for the batting averages for all subjects was 468.02 and 132.83, respectively.

Subject Data and Correlations

Table II shows the demographic data that were submitted by the subjects the day of the investigation filming. Years of playing experience, which included all spring and summer softball seasons played under the supervision of a coach, was included. Means and standard deviations were calculated for six variables on all subjects as shown in Table III.

TABLE I

1975 SEASON BATTING AVERAGES ON ALL SUBJECTS

	Subject	Subject Study Number	At Bats	Hits	Average
High	1	5	37	27	729.72
Average	2	3	39	24	615.38
Subjects	3	4	31	14	451.61
	4	6	38	16	421.05
	5	1	20	8	400.00
Low	6	2	13	5	384.62
Average	7	7	39	15	384.62
Subjects	8	8	28	10	357.14

TABLE II

DEMOGRAPHIC DATA--ALL SUBJECTS

Subject Number	Age	Height	Years Experience	At Bats	Hits	Batting Average
1	19 yrs.	63"	2	20	8	400.00
2	17	64	5	13	5	384.62
3	16	64	2	39	24	615.38
4	16	63	5	31	14	451.61
5	15	64	2	37	27	729.72
6	17	64	8	38	16	421.05
7	18	67	4	39	15	384.62
8	15	64	2	28	10	357.14

TABLE III

CORRELATION MATRIX-DEMOGRAPHIC DATA--ALL SUBJECTS

Mean and Standard Deviation

	$\bar{x}$	s	Bat Average	Age	Height	Years Experience	At Bats	Hits
Batting average	468.02	132.83	1.000	-.0498	-.1430	-.3677	.4780	.8954*
Age	16.62	1.41		1.000	.1933	.1971	-.3030	-.4877
Height	64.12	1.25			1.000	.0655	.4157	.1231
Years experience	3.75	2.19				1.000	.0619	-.2179
At bats	30.62	9.75					1.000	.8180**
Hits	14.88	7.57						1.000

*Significant beyond .01 level of significance

**Significant beyond .05 level of significance

All demographic data was correlated item by item for (a) all subjects, (b) high average batters (above .420 batting average) and (c) low average batters (below .420 batting average). The results of these analyses are as follows:

All subjects. Table III shows very low correlations for most items in subjects' demographic data. This table shows the independence between variables such as height, years experience, and age. Significant correlations were found for batting average versus hits r=.895 and for at bats versus hits r=.818, (.01 and .05 levels, respectively).

High average batters. Means, standard deviations and correlations on demographic data were completed for the high average batters which included subjects three, four, five, and six. Table IV shows that most of these correlations indicate an independence of the variables to one another. However, an inverse relationship of r=-.871, approaching significance at the .05 level, was found between batting average and age, and r=-.889, was found between batting average and years experience. Two significant correlations were found for high average batters at the .05 level. A correlation of r=.974 was found between height and at bats and r=.968 was found between batting average and hits.

Low average batters. The means, standard deviations, and correlations on demographic data were determined for the

TABLE IV

CORRELATION MATRIX-DEMOGRAPHIC DATA-HIGH AVERAGE

Batters--Mean and Standard Deviation

	$\bar{x}$	s	Batting Average	Age	Height	Years Experience	At Bats	Hits
Batting Average	554.44	144.69	1.000	-.8710	.4738	-.8894	.3881	.9680**
Age	16.00	.82		1.000	.0000	.8528	.1136	-.7199
Height	63.75	.50			1.000	-.1741	.9739**	.6679
Years Experience	4.25	2.87				1.000	-.1695	-.8232
At bats	36.25	3.59					1.000	.6059
Hits	20.25	6.24						1.000

**Significant beyond .05 level of significance

low average batters, which included subjects one, two, seven and eight. These correlations are found in Table V. The correlation for batting average versus age was r=.971, (.05 level), and for at bats and hits, was r=.994 (.01 level).

Correlations of Angular Measurements

In order to determine the level of consistency within each subject for (a) the two trials with the batting tee and (b) the two trials without the batting tee, the correlations were calculated using angles from trial one paired with angles corresponding in occurrence from trial two. These correlations were used to establish the reliability of the trials. The correlation values are shown in Table VI.

Using a two-tailed test of significance, four subjects (one, five, six, and eight) showed significant correlations (.05 level) for batting using the batting tee. Without the batting tee, four subjects (one, four, seven, and eight) showed significant correlations (three at .01 and one at .05 level) using a two-tailed test of significance. All other correlations with and without the tee were not significant.

These correlations substantiated the decision to use a mean value of two trials for measured angles and distances for each subject. It is recognized that a weakness exists, in that all subjects did not show high repeatability between trials.

TABLE V

CORRELATION MATRIX-DEMOGRAPHIC DATA-LOW AVERAGE

Batters--Mean and Standard Deviation

	$\bar{x}$	s	Batting Average	Age	Height	Years Experience	At Bats	Hits
Batting Average	381.59	17.84	1.000	.9708**	-.1006	.1884	-.2666	-.1636
Age	17.25	1.71		1.000	.0563	.0976	-.0350	.0697
Height	64.5	1.73			1.000	.4491	.8101	.8242
Years Experience	3.25	1.50				1.000	-.1592	.1322
At Bats	25.0	11.16					1.000	.9944*
Hits	9.5	4.20						1.000

*Significant beyond .01 level of significance

**Significant beyond .05 level of significance

TABLE VI

RELIABILITY VALUES FOR EACH SUBJECT WITH AND WITHOUT THE BATTING TEE--ALL ANGLES

Subject		r with tee	r without tee
Low Average Batters	1	.9602*	.8870*
	2	.6780	.6964
	3	.5755	.5244
High Average Batters	4	.6914	.8933*
	5	.9017*	.6405
	6	.9043*	.4813
Low Average Batters	7	.2735	.7670**
	8	.7816**	.9273*

*Significant beyond .01 level of significance

**Significant beyond .05 level of significance

Measures at Contact--All Subjects

Tracings were made from the 16 mm. films of the subjects performing the batting skill. The tracings showed joints and longitudinal bone axes which permitted measurements of angles and linear distances.

Perpendicular distance of the trail hip. This distance from the tee to the hip, was measured relative to the point of contact. The mean and standard deviation were 11.65 inches and 4.50, respectively. Table VII showed two significant correlations between other measures and the hip: r=.946 (.01 level) with the perpendicular distance of the trail knee, and r=.898 (.01 level) with the perpendicular distance of the trail ankle. All other correlations with the trail hip were not significant.

Perpendicular distance of the trail ankle. The mean and standard deviation of this measure were 22.56 inches and 4.12, respectively. This measure compared to the perpendicular distance of the trail knee yielded a significant correlation of r=.98 (.01 level).

Perpendicular distance of the trail knee. This measure correlated significantly with the perpendicular distance of the trail ankle (.01 level) with a correlation of r=.98. The mean and standard deviation of the trail knee were 13.27 inches and 4.70, respectively.

TABLE VII

CORRELATION MATRIX--MEASUREMENTS AT CONTACT--ALL SUBJECTS

		$\bar{x}$	s	BAV	LAW	LAWO	RAW
Bat average	BAV	468.02	132.83	.00	-.7950**	-.6459	-.3093
Lead elbow with tee	LAW	160.25	11.94		1.00	.6749	.4041
Lead elbow without tee	LAWO	171.19	5.21			1.00	.4268
Trail elbow with tee	RAW	129.69	14.61				1.00
Trail elbow without tee	RAWO	120.81	12.53				
Trail knee with tee	RKW	150.31	9.95				
Trail knee without tee	RKWO	149.50	8.58				
Trail ankle with tee	RFW	132.00	27.10				
Trail ankle without tee	RFWO	140.00	12.44				
Perpendicular distance-hip	HIP	11.65	4.50				
Perpendicular distance-knee	KNE	13.27	4.70				
Perpendicular distance-ankle	ANK	22.56	4.12				
Between hands with tee	HANW	5.13	1.06				
Between hands without tee	HAWO	4.52	1.07				
Between elbows with tee	ELW	11.48	1.86				
Between elbows without tee	ELWO	10.83	.88				
Stride with tee	STW	5.59	5.03				
Stride without tee	STWO	7.91	6.28				

*Significant beyond .01 level of significance

**Significant beyond .05 level of significance

TABLE VII (continued)

	RAWO	RKW	RKWO	RFW	RFWO	HIP	KNEE	ANK	HANW	HAWO
BAV	-.0843	.0641	-.0764	.0511	-.4346	.0816	.0395	-.0117	.1015	-.2018
LAW	.2233	.2777	.2317	-.1806	.2419	.0404	.2377	.3272	-.3915	.1926
LAWO	-.2604	.3006	.5797	-.1624	.1003	-.2434	-.0360	.0455	.2216	.2402
RAW	.3583	.1543	.1084	.0732	-.2203	-.5977	-.4148	-.4313	-.3606	-.4760
RAWO	1.00	-.0826	-.3054	.1051	.2154	-.0863	-.0169	.0002	-.3539	.1559
RKW		1.00	.8432*	.3970	.2061	.5565	.7383**	.7047	-.0653	-.0064
RKWO			1.00	.1609	.3729	.3982	.5664	.5384	.4094	.2132
RFW				1.00	.0375	.2417	.1897	.1421	-.1091	-.1424
RFWO					1.00	.5871	.5316	.4770	.3759	.5055
HIP						1.00	.9461*	.8976*	.0292	.2939
KNE							1.00	.9804*	-.0271	.3359
ANK								1.00	-.0370	.4488
HANW									1.00	.5478
HAWO										1.00
ELW										
ELWO										
STW										
STWO										

*Significant beyond .01 level of significance

**Significant beyond .05 level of significance

TABLE VII (continued)

	ELW	ELWO	STW	STWO
BAV	.5419	.5685	.2380	.1338
LAW	-.7571**	-.4645**	-.3220	-.1355
LAWO	-.3642	-.0538	-.7253**	-.5580
RAW	-.7802**	-.6177	-.2164	-.2786
RAWO	-.4261	-.3329	-.1018	-.0621
RKW	-.1794	.2097	-.4504	-.4922
RKWO	-.0102	.3960	-.8092**	-.7978**
RFW	.1557	-.0635	.2491	-.0606
RFWO	-.0139	.0369	-.4268	-.4820
HIP	.2282	.3110	-.0346	-.0467
KNE	.0564	.3262	-.2277	-.2027
ANK	.0548	.3627	-.2475	-.1859
HANW	.6638	.6960	-.6038	-.6366
HAWO	.3736	.5686	-.4584	-.4035
ELW	1.00	.7950**	.0817	.0020
ELWO		1.00	-.3786	-.3656
STW			1.00	.9226**
STWO				1.00

*Significant beyond .01 level of significance

**Significant beyond .05 level of significance

Linear distance between the wrists. This variable was measured with and without the batting tee. The mean and standard deviation were 5.13 inches and 1.06 inches with the tee, and 4.52 inches and 1.07 inches without the tee, respectively. No significant correlations were found for either situation relative to this contact measure as noted in Table VII.

Linear distance between the elbows. This variable was calculated with and without the batting tee. The mean and standard deviation were 11.48 inches and 1.86 inches with the tee, and 10.83 inches and .88 without the tee, respectively. A significant correlation of r=.795 (.05 level), was found between the elbows with the tee and the elbows without the tee, as shown in Table VII.

Stride. This variable was determined with and without the batting tee. The mean and standard deviation were 5.59 inches and 5.03 with the tee and 7.91 inches and 6.28 without the tee, respectively. Table VII shows a significant correlation of r=.923 between the stride with the tee and the stride without the tee (.01 level).

Angle of the lead elbow. This variable was measured with and without the tee. The mean and standard deviation with and without the tee were 160.25 degrees and 11.94, and 171.19 degrees and 5.21, respectively. Table VII shows a significant correlation of r=-.757 (.05 level) between the

angle of the lead elbow with the tee and the distance between the elbows with the tee. Another correlation r=-.725 (.05 level) was found between the angle of the lead elbow without the tee and the length of the stride with the tee. A correlation of r=-.795 (.05 level) was found between the angle of the lead elbow with the tee and batting average.

Angle of the trail elbow. This variable was measured with and without the batting tee. The mean and standard deviation with and without the tee, respectively, were 129.69 degrees and 14.61; and 120.81 degrees and 12.53. Table VII shows one significant correlation r=-.780 (.05 level), found between the angle of the trail elbow with the tee and the distance between the elbows with the tee.

Angle of the trail knee. This variable was determined with and without the batting tee. The mean and standard deviation with and without the tee, respectively, were 150.31 degrees and 9.95; and 149.50 degrees and 8.58. Two significant correlations involved the trail knee with the tee. These correlations were r=.843 relative to the trail knee without the tee, (.05 level) and r=.738 relative to the perpendicular distance of the trail knee to the tee (.05 level). The angle of the trail knee without the tee yielded significant correlation values when correlated with the length of the stride. Values of r=-.809, (.05 level) was found for the stride with the tee and r=-.798, (.05

level) was found relative to the stride without the tee. These values are shown in Table VII.

Angle of the trail ankle. This variable was measured with and without the batting tee. The mean and standard deviation with and without the tee respectively were 132.00 degrees and 27.10 and 140.00 degrees and 12.44. As can be seen in Table VII, no significant correlations were found.

A correlation worth noting was found between the angle of the trail knee with the tee and perpendicular distance of the trail ankle to the tee. This correlation r=.705, was approaching significance at the .05 level. All other correlations between the measures at contact for all subjects were not significant.

Measures at Contact for High Average Batters

A correlation matrix, shown in Table VIII, for all measures taken at contact, was developed for high average batters. Six significant correlations were found.

Batting average. This variable was correlated with all other contact measures. Mean and standard deviation were calculated for this variable and were 544.44 and 144.69, respectively. A negative correlation of r=-.975, (.05 level) was found between batting average and the angle of the lead elbow with the tee.

TABLE VIII

CORRELATION MATRIX--MEASUREMENTS AT CONTACT--HIGH AVERAGE BATTERS

		$\bar{x}$	S	BAV	LAW	LAWO	RAW
Batting average	BAV	544.44	144.69	1.00	-.9752**	-.6242	.0535
Lead elbow with tee	LAW	155.50	12.44		1.00	.6701	-.2468
Lead elbow without tee	LAWO	169.50	6.98			1.00	.0670
Trail elbow with tee	RAW	123.50	7.84				1.00
Trail elbow without tee	RAWO	121.50	16.90				
Trail knee with tee	RKW	149.25	8.07				
Trail knee without tee	RKWO	149.12	8.60				
Trail ankle with tee	RFW	119.25	29.07				
Trail ankle without tee	RFWO	138.50	8.91				
Perpendicular distance-hip	HIP	12.01	3.33				
Perpendicular distance-knee	KNE	13.78	2.97				
Perpendicular distance-ankle	ANK	23.15	2.44				
Between hands with tee	HANW	5.46	0.88				
Between hands without tee	HAWO	4.90	1.16				
Between elbows with tee	ELW	12.30	1.12				
Between elbows without tee	ELWO	11.43	0.70				
Stride with tee	STW	4.90	5.42				
Stride without tee	STWO	7.52	6.05				

**Significant beyond the .05 level of significance

TABLE VIII (continued)

	RAWO	RKW	RKWO	RFW	RFWO	HIP	KNE	ANK	HANW	HAWO
BAV	-.1601	.5593	.0458	.8379	-.8465	.2288	.0863	-.2071	-.3014	-.8733
LAW	-.0432	-.4109	.0770	-.9156	.7805	-.0541	.1226	.4151	.2788	.7929
LAWO	-.4439	.2310	.7329	-.4159	.1127	-.3709	-.0454	.2748	.8638	.7693
RAW	.5949	-.2397	-.0889	.5856	-.0978	-.9449	-.9805**	-.9382	.4925	.3799
RAWO	1.00	-.8644	-.8390	.1402	.5172	-.4833	-.7185	-.7686	-.2730	.2155
RKW		1.00	.8300	.3756	-.8744	.2536	.4236	.3766	.3257	.4205
RKWO			1.00	.0565	-.5610	-.0708	.2325	.3822	.7414	.1536
RFW				1.00	-.7738	-.3390	-.0452	-.6554	.0781	-.4844
RFWO					1.00	-.0532	-.0948	.0608	-.1987	.5929
HIP						1.00	.9417	.7902	-.6941	-.6491
KNE							1.00	.9409	-.4164	-.4644
ANK								1.00	-.1620	-.1437
HANW									1.00	.6694
HAWO										1.00
ELW										
ELWO										
STW										
STWO										

**Significant beyond the .05 level of significance

TABLE VIII (continued)

	ELW	ELWO	STW	STWO
BAV	.6980	.2077	.5730	.2673
LAW	-.6603	-.1362	-.5910	-.2011
LAWO	.1086	.6336	-.9871**	-.7679
RAW	.2910	.1864	-.2217	-.6592
RAWO	-.4808	-.6782	.3640	.0868
RKW	.8465	.8230	-.2224	-.2078
RKWO	.6748	.9507**	-.7262	-.6107
RFW	.7679	.3345	.2902	-.1881
RFWO	-.9589**	-.6949	-.0587	.1739
HIP	-.1976	-.2842	.5058	.8246
KNE	-.0973	-.0214	.1904	.5928
ANK	-.1740	.0908	-.1244	.3586
HANW	.4587	.8025	-.9298	-.9789**
HAWO	-.3444	.1187	-.7908	-.6826
ELW	1.00	.8339	-.1863	-.4456
ELWO		1.00	-.6756	-.7252
STW			1.00	.8602
STWO				1.00

**Significant beyond the .05 level of significance

Angle of the lead elbow. This variable was determined with and without the tee. The mean and standard deviation were 155.50 degrees and 12.44 with the tee; and 169.50 degrees and 6.98 without the tee respectively. A negative correlation of r=-.987 (.05 level) was found between the angle of the lead elbow without the tee and the length of the stride with the tee.

Angle of the trail elbow. This variable was calculated with and without the batting tee. The mean and standard deviation were 123.50 degrees and 7.84 with the tee; and 121.50 degrees and 16.90 without the tee, respectively. This angle with the tee correlated r=-.981, (.05 level) relative to the perpendicular distance of the trail knee to the tee.

Angle of the trail knee. This variable was measured with and without the batting tee. The mean and standard deviation with and without the tee were 149.25 degrees and 8.07; and 149.12 degrees and 8.60, respectively. A correlation of r=.951, (.05 level) was found between the angle of the trail knee without the tee and the distance between elbows without the tee.

Angle of the trail ankle. This variable was calculated with and without the batting tee. The mean and standard deviation with and without the tee were 119.25 degrees and 29.02; and 138.50 degrees and 8.91, respectively.

This measure, without the tee, correlated r=-.959 (.05 level) with the distance between the elbows with the tee.

Perpendicular distance of the trail hip. This variable was measured with the batting tee. The mean and standard deviation were 12.01 inches and 3.33, respectively. This measure did not correlate significantly with any of the other measures for high average batters.

Perpendicular distance of the trail knee. This variable was determined with the batting tee. The mean and standard deviation were 13.78 inches and 2.97, respectively. This measure yielded no significant correlations relative to the other measures at contact.

Perpendicular distance of the trail ankle. This variable was measured with the batting tee. The mean and standard deviation were 23.15 inches and 2.44, respectively. This variable did not correlate significantly with any of the other measures at contact.

Linear distance between the wrists. This variable was calculated with and without the batting tee. The mean and standard deviation with and without the tee, respectively, were 5.46 inches and .88; and 4.90 inches and 1.16. A significant correlation r=-.959 (.05 level) was found when linear distance between the wrists with the tee was correlated with the length of the stride without the tee.

Linear distance between the elbows. This variable was measured with and without the batting tee. The mean and standard deviation were 12.30 inches and 1.12 with the tee, respectively; and 11.43 inches and .70 without the tee, respectively. This measure did not correlate significantly with any variables other than those already mentioned.

Stride. This variable was determined with and without the batting tee. The mean and standard deviation were 4.90 inches and 5.42 with the tee, respectively; and 7.52 inches and 6.05 without the tee, respectively. This measure did not yield any further significant correlations relative to any other of the contact measures being analyzed other than those previously mentioned.

The .05 level of significance for the correlations of the high average batters required a value of r=.95. The following correlations were worth noting as they approached significance at the .05 level. A correlation between the angle of the trail ankle with the tee and the angle of the lead elbow with the tee yielded a value of r=.916. A correlation between the angle of the trail elbow with the tee and the perpendicular distance of the trail hip to the tee yielded a value of r=-.945. When correlated, the perpendicular distance of the trail hip and the perpendicular distance of the trail knee yielded a correlation of r=.942. The perpendicular distance of the trail ankle to the tee yielded a correlation of r=-.938 with the angle of the trail elbow with the tee, and a correlation of r=.941 with the

perpendicular distance of the trail knee to the tee. The last correlation worth noting was r=.93 between the length of the stride with the tee and the distance between the wrists with the tee.

Measures at Contact for the Low Average Batters

The correlation matrix shown in Table IX for all measures taken at contact, was developed for low average batters. Six significant correlations were found.

Batting average. The mean and standard deviation for this measure were 381.59 and 17.84, respectively. Batting average, when correlated with the angle of the trail knee without the tee, yielded a significant correlation of r=-.987 (.05 level).

Angle of the lead elbow. This variable was measured with and without the batting tee. The mean and standard deviation were 165.00 degrees and 10.85 with the tee; and 172.88 degrees and 2.66 without the tee, respectively. This angle with the tee correlated r=.99 (.05 level), with the angle of the trail elbow without the tee.

Angle of the trail elbow. This variable was determined with and without the batting tee. The mean and standard deviation with and without the tee, respectively, were 135.88 degrees and 18.30; and 120.12 degrees and 8.92. This measure yielded no further correlations than the one already mentioned relative to the angle of the lead elbow.

TABLE IX

CORRELATION MATRIX--MEASUREMENTS AT CONTACT--LOW AVERAGE BATTERS

		$\bar{x}$	s	BAV	LAW	LAWO	RAW
Batting average	BAV	381.59	17.84	1.000	-.4724	-.5051	-.1088
Lead elbow with tee	LAW	165.00	10.85		1.000	.6389	.5555
Lead elbow without tee	LAWO	172.88	2.66			1.000	.9114
Trail elbow with tee	RAW	135.88	18.30				1.000
Trail elbow without tee	RAWO	120.12	8.92				
Trail knee with tee	RKW	151.38	12.76				
Trail knee without tee	RKWO	149.88	9.88				
Trail ankle with tee	RFW	144.75	20.86				
Trail ankle without tee	RFWO	141.50	16.60				
Perpendicular distance hip	HIP	11.30	5.98				
Perpendicular distance knee	KNE	12.76	6.49				
Perpendicular distance ankle	ANK	21.97	5.71				
Between hands with tee	HANW	4.80	1.24				
Between hands without tee	HAWO	4.14	.98				
Between elbows with tee	ELW	10.66	2.24				
Between elbows without tee	ELWO	10.23	.60				
Stride with tee	STW	6.28	5.34				
Stride without tee	STWO	8.30	7.41				

**Significant beyond the .05 level of significance

TABLE IX (continued)

	RAWO	RKW	RKWO	RFW	RFWO	HIP	KNE	ANK	HANW
BAV	-.5943	-.9245	-.9871**	-.4201	-.8068	-.7332	-.8399	-.7653	-.1897
LAW	.9896**	.7570	.3959	.1473	-.1203	.1816	.4702	.5228	-.7736
LAWO	.6653	.5476	.5643	-.4788	.0321	-.1943	.0685	.0167	-.2978
RAW	.5246	.2149	.1747	-.7233	-.3673	-.5587	-.2970	-.3139	-.4830
RAWO	1.00	.8417	.5224	.2031	.0220	.2855	.5662	.6020	-.6750
RKW		1.00	.8676	.4715	.5575	.6852	.8685	.8450	-.1885
RKWO			1.00	.2934	.8196	.6478	.7479	.6550	.2751
RFW				1.00	.5164	.9110	.8337	.8698	.0734
RFWO					1.00	.8022	.7158	.6118	.6991
HIP						1.00	.9509**	.9304	.2766
KNE							1.00	.9890**	.0405
ANK								1.00	-.0770
HANW									1.00
HAWO									
ELW									
ELWO									
STW									
STWO									

**Significant beyond the .05 level of significance

TABLE IX (continued)

	HAWO	ELW	ELWO	STW	STWO
BAV	-.4489	.2593	-.3591	.8450	.8755
LAW	-.0837	-.8082	-.4012	-.2422	-.1675
LAWO	-.5335	-.9043	-.6059	-.7160	-.6049
RAW	-.8165	-.9385	-.8777	-.4000	-.2562
RAWO	-.0030	-.7797	-.3074	-.3588	-.2957
RKW	.3883	-.4566	.1740	-.6584	-.6626
RKWO	.3547	-.2734	.3128	-.9183	-.9413
RFW	.9581**	.4545	.7970	.0914	-.0267
RFWO	.6851	.3246	.7654	-.7026	-.8022
HIP	.9333	.3294	.8237	-.3231	-.4362
KNE	.7932	.0244	.6081	-.4244	-.5005
ANK	.7932	.0125	.5711	-.3028	-.3754
HANW	.3561	.6728	.6556	-.3698	-.4670
HAWO	1.00	.6187	.9351	-.0213	-.1599
ELW		1.00	.7953	.3692	.2356
ELWO			1.00	-.0799	-.2301
STW				1.00	.9884**
STWO					1.00

**Significant beyond the .05 level of significance

Angle of the trail knee. This variable was measured with and without the batting tee. The mean and standard deviation with and without the tee, respectively, were 151.38 degrees and 12.76; and 149.88 degrees and 9.88. This measure yielded no further significant correlations than the one previously mentioned relative to batting average.

Angle of the trail ankle. This variable was calculated with and without the batting tee. The mean and standard deviation were, respectively, 144.75 degrees and 20.86 with the tee; and 141.50 degrees and 16.60 without the tee. This measure correlated r=.958 (.05 level) with the distance between the wrists without the tee.

Perpendicular distance of the trail hip. This variable was calculated with the batting tee. The mean and standard deviation were, respectively, 11.30 inches and 5.98 with the tee. A significant correlation of r=.951 (.05 level) was found between this measure and the perpendicular distance of the trail knee.

Perpendicular distance of the trail knee. This variable was measured with the batting tee. The mean and standard deviation were 12.76 inches and 6.49, respectively. A correlation of r=.989 (.05 level) was found between the above measure and the perpendicular distance of the trail ankle. The other significant correlation involving the

perpendicular distance of the trail knee was previously mentioned, and involved the perpendicular distance of the trail hip.

Perpendicular distance of the trail ankle. This variable was determined with the batting tee. The mean and standard deviation were 21.97 inches and 5.71, respectively. The significant correlations involving this measure have been mentioned previously, and involved the perpendicular distance of the trail knee.

Linear distance between the wrists. This variable was measured with and without the batting tee. The mean and standard deviation were 4.80 inches and 1.24 with the tee, respectively; and 4.14 inches and .98 without the tee, respectively. The significant correlation involving these linear measures were previously mentioned relative to the angle of the trail ankle with the tee.

Linear distance between the elbows. This variable was determined with and without the batting tee. The mean and standard deviation were 10.66 inches and 2.24 with the tee, respectively; and 10.23 inches and .60 without the tee, respectively. No significant correlations were found for either of the situations involving this linear measure.

Stride. This variable was calculated with and without the batting tee. The mean and standard deviation were 6.28 inches and 5.34 with the tee, respectively; and 8.30

inches and 7.41 without the tee, respectively. When these two measures were correlated with one another, a correlation of r=.988 (.05 level) was found. No further significant correlations were found for stride length and other contact measures.

Some correlations for measures at contact for the low average batters were approaching the .05 level of significance of r=.950. Correlations of the angle of the trail knee with the tee included r=-.924 relative to the batting average; r=-.918 relative to stride length with the tee; and -.941 relative to the stride length without the tee. Correlations involving the perpendicular distance of the trail hip to the tee included a correlation of r=.911 with the angle of the trail ankle with the tee; r=.93 with the perpendicular distance of the trail ankle to the tee; and r=.933 with the linear distance between the wrists without the tee.

Analysis of Variance for Batting Averages

A one-way ANOVA was calculated for the batting averages of the high and low average batters. As shown in Table X, the F-test value of 5.62 was not significant at the .05 level. The necessary F value for significance was 5.99.

Analysis of Variance for Measures at Contact

One-way and two-way ANOVA were conducted for all angular and linear measurements taken at ball contact. These ANOVAs compared high average batters, low average batters, swings with the tee, and swings without the tee.

TABLE X

ANALYSIS OF VARIANCE OF BATTING AVERAGES

Source of Variation	df	SS	MS	F*
Between groups (High average-low average)	1	59750.7	59750.7	5.623
Within groups	6	63758.7	10626.45	
Total	7	123509.4	xx	xx

*F $\geq$ 5.99 at .05 level of significance

ANOVA were performed for (1) perpendicular distance of the trail hip to the tee, (2) perpendicular distance of the trail knee to the tee, (3) perpendicular distance of the trail ankle to the tee, (4) the angle of the trail knee, (5) the angle of the trail ankle, (6) angle of the trail elbow, (7) the linear distance between the wrists, and (8) the length of the stride. All ANOVA yielded no significant values. The above results are presented in Tables XI, XII, XIII, XIV, XV, XVI, XVII, and XVIII.

An F value worth mentioning was recorded for ANOVA for linear distance between elbows with a value of 4.52 relative to the measure with the tee and without the tee as shown in Table XIX. The F-test value needed for significance was 4.75 at the .05 level.

The angle of the lead elbow yielded the only significant F value for all measures at contact. Table XX shows value of 5.83, (.05 level) relative to the high average and low average batters' scores.

TABLE XI

ANALYSIS OF VARIANCE OF PERPENDICULAR DISTANCE OF TRAIL HIP TO TEE AT CONTACT

Source of Variation	df	SS	MS	F*
Between groups (High Avg-Low Avg)	1	1.0	1.0	.043
Within groups	6	140.47	23.41	
Total	7	141.47	xx	xx

*$F \geq 5.99$ at .05 level of significance

TABLE XII

ANALYSIS OF VARIANCE OF PERPENDICULAR DISTANCE OF TRAIL KNEE TO TEE AT CONTACT

Source of Variation	df	SS	MS	F*
Between groups (High Avg-Low Avg)	1	2.09	2.09	.082
Within groups	6	152.78	25.46	
Total	7	154.87	xx	xx

*F $\geq$ 5.99 at .05 level of significance

TABLE XIII

ANALYSIS OF VARIANCE OF PERPENDICULAR DISTANCE OF TRAIL ANKLE TO TEE AT CONTACT

Source of Variation	df	SS	MS	F*
Between groups (High Avg-Low Avg)	1	2.8	2.8	.145
Within groups	6	115.74	19.29	
Total	7	118.54	xx	xx

*F $\geq$ 5.99 at .05 level of significance

TABLE XIV

ANALYSIS OF VARIANCE OF ANGLE OF TRAIL KNEE AT CONTACT

Source of Variance	df	SS	MS	F*
Between cells	xx	xx	xx	xx
A (High Average-Low Average)	1	8.26	8.26	.08
B (With Tee-Without Tee)	1	2.64	2.64	.03
AB (Interaction)	1	1.9	1.9	.02
Within cells	12	1198.32	99.86	xx
Total	15	1211.12	xx	xx

*F $\geq$ 4.75 at 0.5 level level of significance

TABLE XV

ANALYSIS OF VARIANCE OF ANGLE OF TRAIL ANKLE AT CONTACT

Source of Variation	df	SS	MS	F*
Between cell	xx	xx	xx	xx
A (High Average-Low Average)	1	812.24	812.24	1.99
B (With Tee-Without Tee)	1	256.0	256.0	.63
AB (Interaction)	1	506.26	506.26	1.24
Within cell	12	4905	408.75	xx
Total	15	6479.5	xx	xx

*$F \geq 4.75$ at .05 level of significance

TABLE XVI

ANALYSIS OF VARIANCE OF ANGLE OF TRAIL ELBOW AT CONTACT

Source of Variance	df	SS	MS	F*
Between cell	xx	xx	xx	xx
A (High Average-Low Average)	1	123.77	123.77	.645
B (With Tee-Without Tee)	1	319.51	319.51	1.665
AB (Interaction)	1	290.64	290.64	1.514
Within cell	12	2303.07	191.92	xx
Total	15	2931.99	xx	xx

*$F \geq 4.75$ at .05 level of significance

TABLE XVII

ANALYSIS OF VARIANCE OF LINEAR DISTANCE BETWEEN WRISTS AT CONTACT

Source of Variation	df	SS	MS	F*
Between cell	xx	xx	xx	xx
A (High Average-Low Average)	1	0.01	.01	.002
B (With Tee-Without Tee)	1	.10	.10	.02
AB (Interaction)	1	2.52	2.52	.43
Within cell	12	70.47	5.87	xx
Total	15	73.1	xx	xx

*$F \geq 4.75$ at .05 level of significance

TABLE XVIII

ANALYSIS OF VARIANCE OF LENGTH OF STRIDE

Source of Variation	df	SS	MS	F*
Between cells	xx	xx	xx	xx
A (High Average-Low Average)	1	4.62	4.62	.124
B (With Tee-Without Tee)	1	21.62	21.62	.579
AB (Interaction)	1	.36	.36	.010
Within cell	12	448.04	37.34	xx
Total	15	474.64	xx	xx

*F $\geq$ 4.75 at .05 level of significance

TABLE XIX

ANALYSIS OF VARIANCE OF LINEAR DISTANCE BETWEEN ELBOWS AT CONTACT

Source of Variation	df	SS	MS	F*
Between cell	xx	xx	xx	xx
A (High Average-Low Average)	1	1.67	1.67	.938
B (With Tee-Without Tee)	1	8.05	8.05	4.52
AB (Interaction)	1	0.2	0.2	.112
Within cell	12	21.34	1.78	xx
Total	15	31.26	xx	xx

*$F \geq 4.75$ at .05 level of significance

TABLE XX

ANALYSIS OF VARIANCE OF ANGLE OF LEAD ELBOW AT CONTACT

Source of Variation	df	SS	MS	F*
Between cell	xx	xx	xx	xx
A (High Average-Low Average)	1	478.51	478.51	5.83**
B (Tee-Without Tee)	1	165.76	165.76	2.02
AB (Interaction)	1	37.53	37.53	0.457
Within cell	12	984.69	82.06	xx
Total	15	1666.49	xx	xx

*$F \geq 4.75$ at .05 level of significance

**Significant at the .05 level of significance

Bat Paths

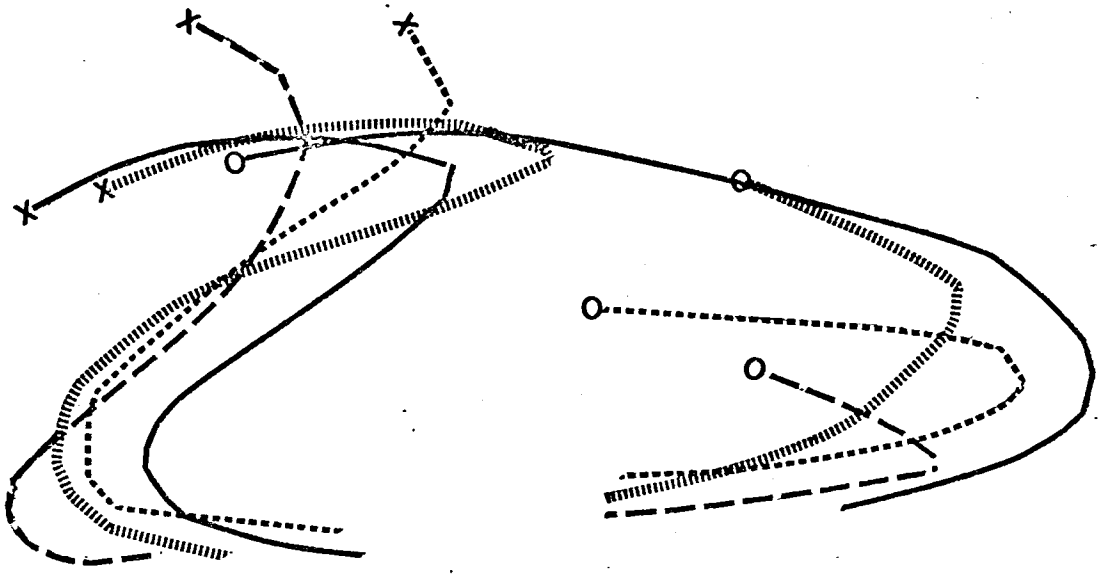
Bat paths of all subjects were developed for (a) swings using the batting tee, and (b) for swings not using the batting tee. To facilitate the analysis, a line of best fit was determined to have a single bat path for each subject using the batting tee and a single bat path for each subject when not using the batting tee. These calculations for the paths are found in Appendix G. The bat paths were analyzed according to the information shown in Figure 9. (page 40). This sample bat path describes the area covered in the swing and the terminology employed in the following discussion.

Bat Paths of High Average Batters with the Batting Tee

When compared to one another several similarities were observed among the subjects' swings. These can be observed in Figure 10. The overall paths of the high average batters were smooth and flowed from the starting point to the followthrough with no abrupt change in direction.

All subjects approached thebatting tee on a fairly low upward trajectory. Table XXI shows the subject with the greatest angle was subject three. The angle of swing through the ball was 12 degrees above the horizontal. The other subjects ranged in upward angles from six degrees to nine degrees.

The linear distance from the point of greatest convexity of the turn of the foreswing to the point of greatest convexity of the turn of the followthrough shown in Table XXI ranged from 75.04 inches to 76.96 inches. The mean and



SUBJECT 3
SUBJECT 4
SUBJECT 5
SUBJECT 6

FIGURE 10

BAT PATHS WITH THE TEE
OF HIGH AVERAGE BATTERS

LINE OF BEST FIT

TABLE XXL

BAT PATH MEASUREMENTS FOR BOTH GROUPS

Group	Height (inches)	Width (inches)	Upward Angle (degrees)
High Average Batters			
With the tee			
Subject 3	28.00	75.04	12
4	33.92	75.04	6
5	28.96	76.96	6
6	32.96	76.00	9
$\bar{x}$	30.96	75.76	8.25
S	3.34	1.06	3.31
Without the tee			
Subject 3	24.00	73.92	10
4	28.96	72.00	13
5	24.96	79.04	13
6	32.00	79.04	13
$\bar{x}$	27.48	76.00	11.50
S	4.26	4.15	1.998
Low Average Batters			
With the tee			
Subject 1	32.96	80.00	5
2	25.92	80.00	3
7	33.92	89.92	4
8	25.92	84.00	8
$\bar{x}$	29.68	83.48	5.00
S	5.03	5.41	2.49
Without the tee			
Subject 1	32.00	78.08	-3
2	22.08	84.00	-2
7	36.00	96.00	11
8	32.96	78.08	8
$\bar{x}$	30.76	84.04	3.5
S	6.95	9.74	8.15

standard deviation for this distance were 75.76 inches and 1.06, respectively.

Table XXI shows vertical distance traveled by the bat from the start of the downward phase of the foreswing to the area of contact. This variable ranged from 28 inches to 33.92 inches. The mean and standard deviation were 30.96 inches and 3.34, respectively.

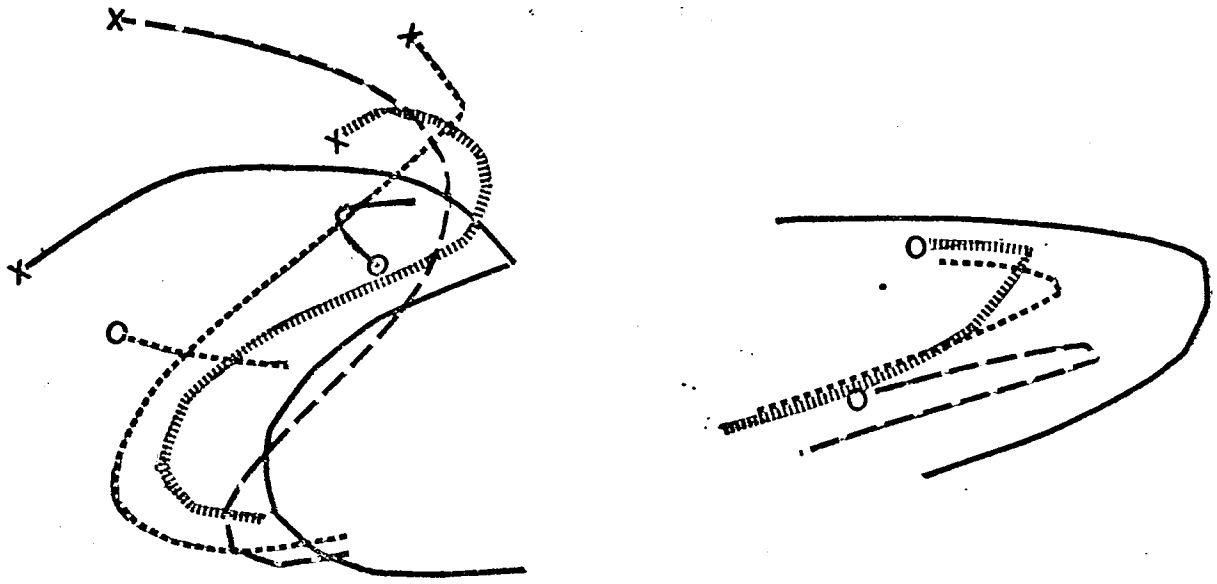
Bat Paths of High Average Batters Without the Batting Tee

The bat paths when not using the batting tee resembled a much flatter circle, as shown in Figure 11. The distance from the beginning of the downward phase of the foreswing to the area of contact is shown in Table XXI and ranged from 24.00 inches to 32.00. The mean and standard deviation were 27.48 inches and 4.26, respectively.

Upward angles of swing, when moving through the area of contact, ranged from 10 to 13 degrees. Three of the high average batters exhibited greater angles without the tee than with the tee.

The paths for the high average batters without the tee were smooth. Subject five showed an abrupt change in direction from backswing to foreswing. The followthrough of subject four was very close in the path to the end of the foreswing of subject four. Followthroughs for subjects five and six continued beyond their backs and were visible near the downward phase of the foreswing.

The horizontal distance traveled by the bat was measured from the point of greatest convexity of the turn of



SUBJECT 3
SUBJECT 4
SUBJECT 5
SUBJECT 6

FIGURE 11

BAT PATHS WITHOUT THE TEE
OF HIGH AVERAGE BATTERS

LINE OF BEST FIT

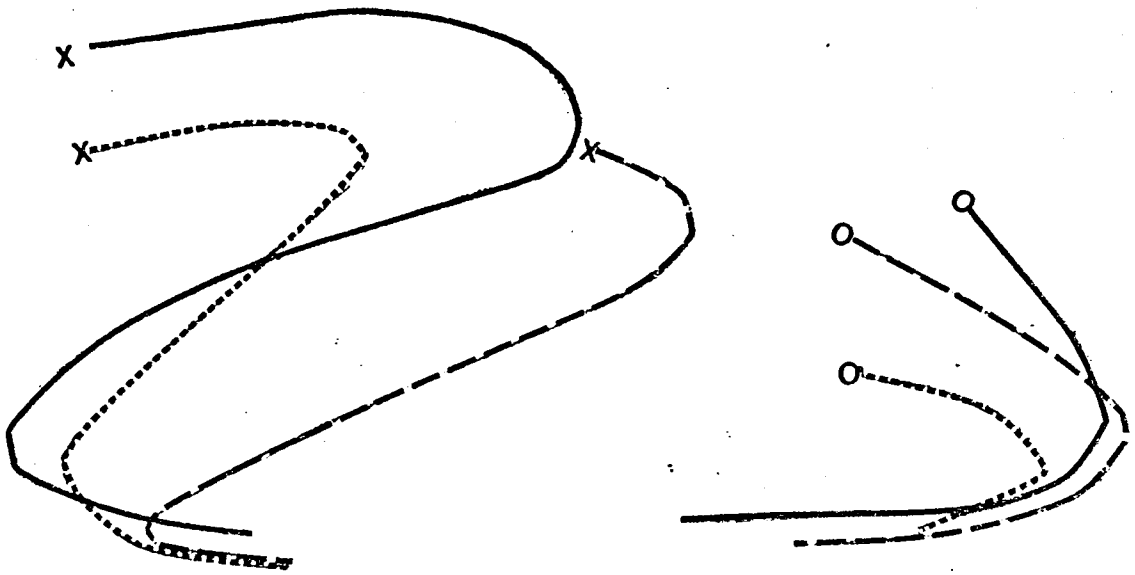
the foreswing to the point of greatest convexity of the followthrough, and ranged from 72 inches to 79.04 inches (Table XXI). The mean and standard deviation were 76.00 inches and 4.15, respectively.

Bat Paths of Low Average Batters With the Tee

The paths of the subjects' bats during the phase of the foreswing when moving through the ball were almost flat. The upward angles of swing through contact ranged from three to eight degrees. As shown in Figure 12, the overall bat paths of these subjects were flatter and resembled an ellipse rather than a circular or oblong figure as with the high average batters. Subject eight, a left-handed batter, used no backswing and showed an abrupt turn to the followthrough. This is shown in Figure 13.

The vertical distance traveled by the bat was measured from the start of the downward phase of the foreswing to the area of contact. Table XXI shows the low average batters' distances which ranged from 25.92 inches to 33.92 inches. The mean and standard deviation were 29.68 inches and 5.03, respectively.

The low average batters' horizontal distances, shown in Table XXI, ranged from 80 inches to 89.92 inches. The mean and standard deviation were 83.48 inches and 5.41, respectively. The low average batters reached back farther away from the tee before turning the direction of the bat to swing through the ball on the tee.



SUBJECT 1
SUBJECT 2
SUBJECT 7

FIGURE 12

BAT PATHS WITH THE TEE
OF LOW AVERAGE BATTERS

LINE OF BEST FIT

SUBJECT 8

FIGURE 13

BAT PATH WITH THE TEE
OF SUBJECT EIGHT

LINE OF BEST FIT

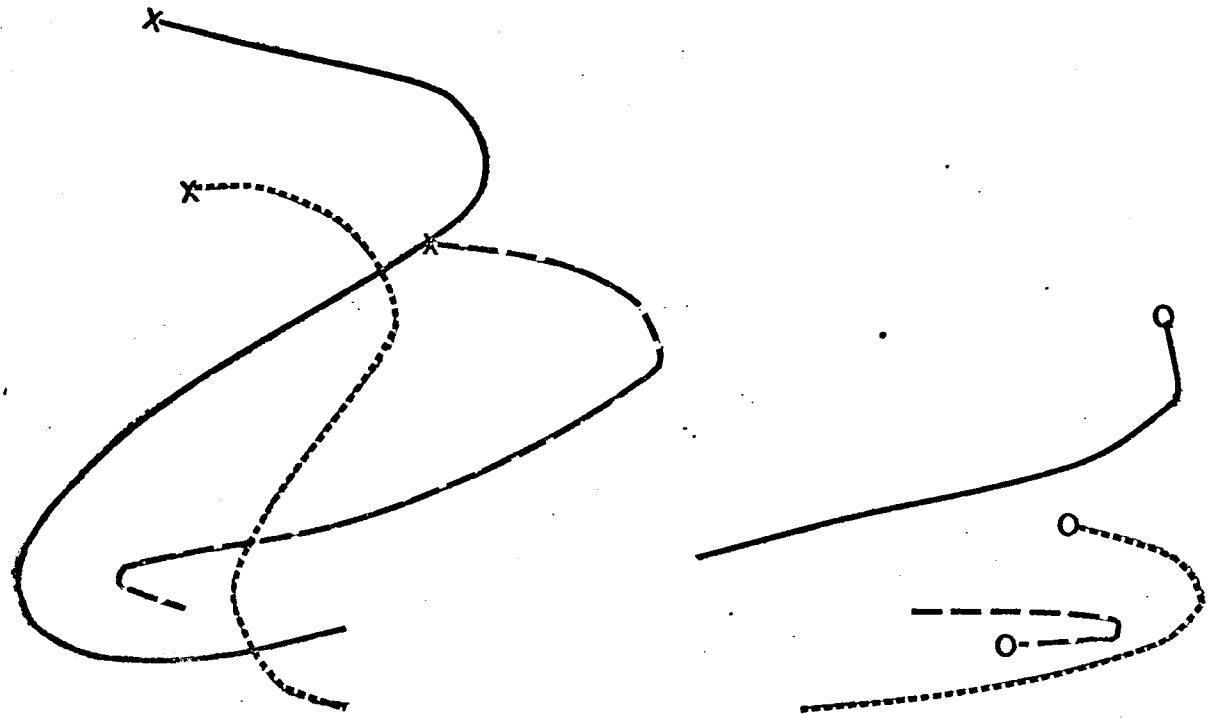
Bat Paths of the Low Average Batters Without the Tee

Reference to Figure 14 will show that the paths of these three subjects were very dissimilar. Subject seven was the only subject that smoothly moved through the swing but began by holding the bat high and had a sharp upswing on the end of the followthrough. Subject two dropped the bat on the downward phase of the foreswing and was only 11 degrees from the horizontal prior to the turn of the foreswing. After contact phase, this subject's followthrough moved downward from the horizontal instead of upward as previously found with other followthroughs.

The upward angle of swing through the approximate point of contact, ranged from negative three to eleven degrees as shown in Table XXI.

The overall paths of these subjects had very little resemblence to one another. As can be seen in Figure 14, the paths were all very different in shape. Subject seven's path was smooth from start to end, and subject two showed an abrupt turn and a drop at the followthrough. Subject eight was a lefthanded batter. As can be seen in Figure 15, this subject had no backswing. Subject eight's swing is rounded at the foreswing end of the swing and pointed at the followthrough area of the swing.

The vertical distance traveled by the subjects' bats from the beginning of the downward phase of the foreswing to the designated area of contact, varied greatly. Table XXI indicates a range from 22.08 inches to 36 inches. The mean

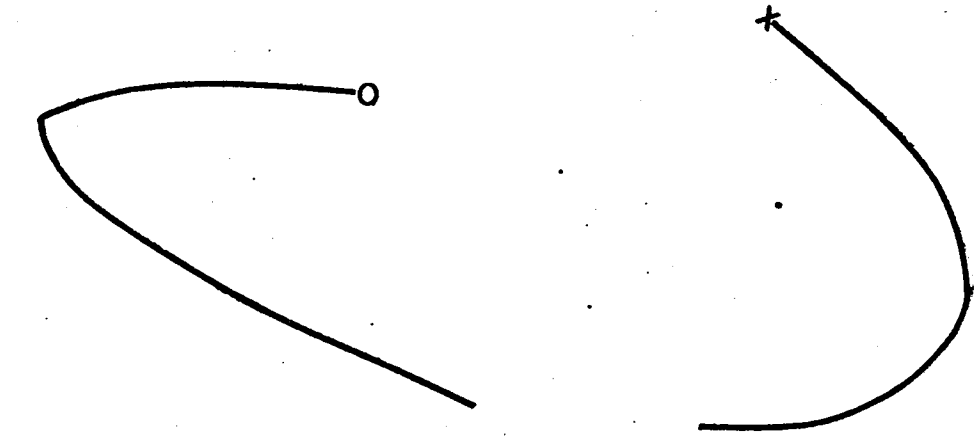


SUBJECT 1
SUBJECT 2
SUBJECT 7

FIGURE 14

BAT PATHS WITHOUT THE TEE
OF LOW AVERAGE BATTERS

LINE OF BEST FIT



SUBJECT 8

FIGURE 15

BAT PATH WITHOUT THE TEE
OF SUBJECT EIGHT

LINE OF BEST FIT

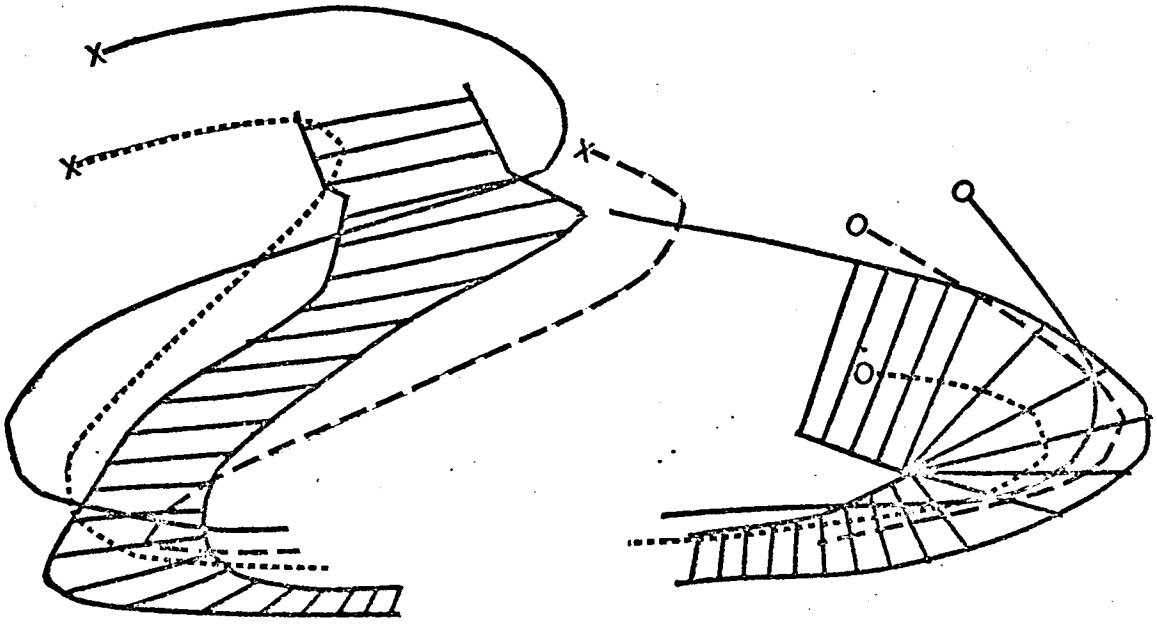
and standard deviation were 30.76 inches.

Table XXI shows the range of horizontal distances for low average batters to be from 78.08 inches to 96 inches. The mean and standard deviation were 84.04 inches and 9.74, respectively.

Comparison of Bat Paths of High versus Low Average Batters With the Tee

As can be seen in Figure 16, the low average batters' paths fell outside the band containing the high average bat paths. All of the followthrough of the low average bat paths was contained within the high average band except the extreme end of subject two's and seven's paths. All low average bat paths at the point just prior to the area of contact were above the paths of the high average band. The angle of upward swing through contact ranged from six to twelve degrees for the high average batters, and three to five degrees for the low average batters.

If the high average band during followthrough was extended, it would intersect the foreswing band of the paths. For the low average batters, only subject one would intersect the foreswing area. The low average batters' paths were wider and shorter overall, than the high average batter's paths. Low average bat paths were from 80.00 inches to 89.92 inches wide and from 25.92 to 33.92 inches high. The high average bat paths were from 75.04 to 76.96 inches wide and from 28.00 to 33.92 inches high.



SUBJECT 1
SUBJECT 2
SUBJECT 7
HIGH AVERAGE BATTERS

FIGURE 16

COMPARISON OF BAT PATHS
WITH THE TEE OF
HIGH AVERAGE AND LOW AVERAGE BATTERS

LINE OF BEST FIT

Comparison of Bat Paths of High versus Low Average Batters Without the Tee

All high average batters started the backswing at a lower point relative to where the low average batters started. This can be seen in Figure 17. After the turn of the foreswing, the high average batters' paths coincided with one another and then spread apart after contact. Subject one, a low average batter, had a path that was included in the high average band during the downward phase of the foreswing.

The followthroughs of all low average batters' intersect the high average band for small sections of the followthrough.

If extended during followthrough, all high average batters' paths would intersect the downward phase of their foreswings. Only subject one of the low average batters had a path that would intersect its own foreswing. The low average bat paths were from 78.08 to 96 inches wide, and from 22.08 to 32.96 inches high. The high average bat paths were from 72 to 79.04 inches wide and from 24 to 32 inches high.

Analysis of Variance of Bat Paths

A two-way ANOVA relative to the vertical distance traveled by the bat yielded no significant F value. This is shown in Table XXII.

An F value of 9.25 (.05 level) was determined by a two-way ANOVA relative to the horizontal distance traveled by the bat during the swing. This significant value

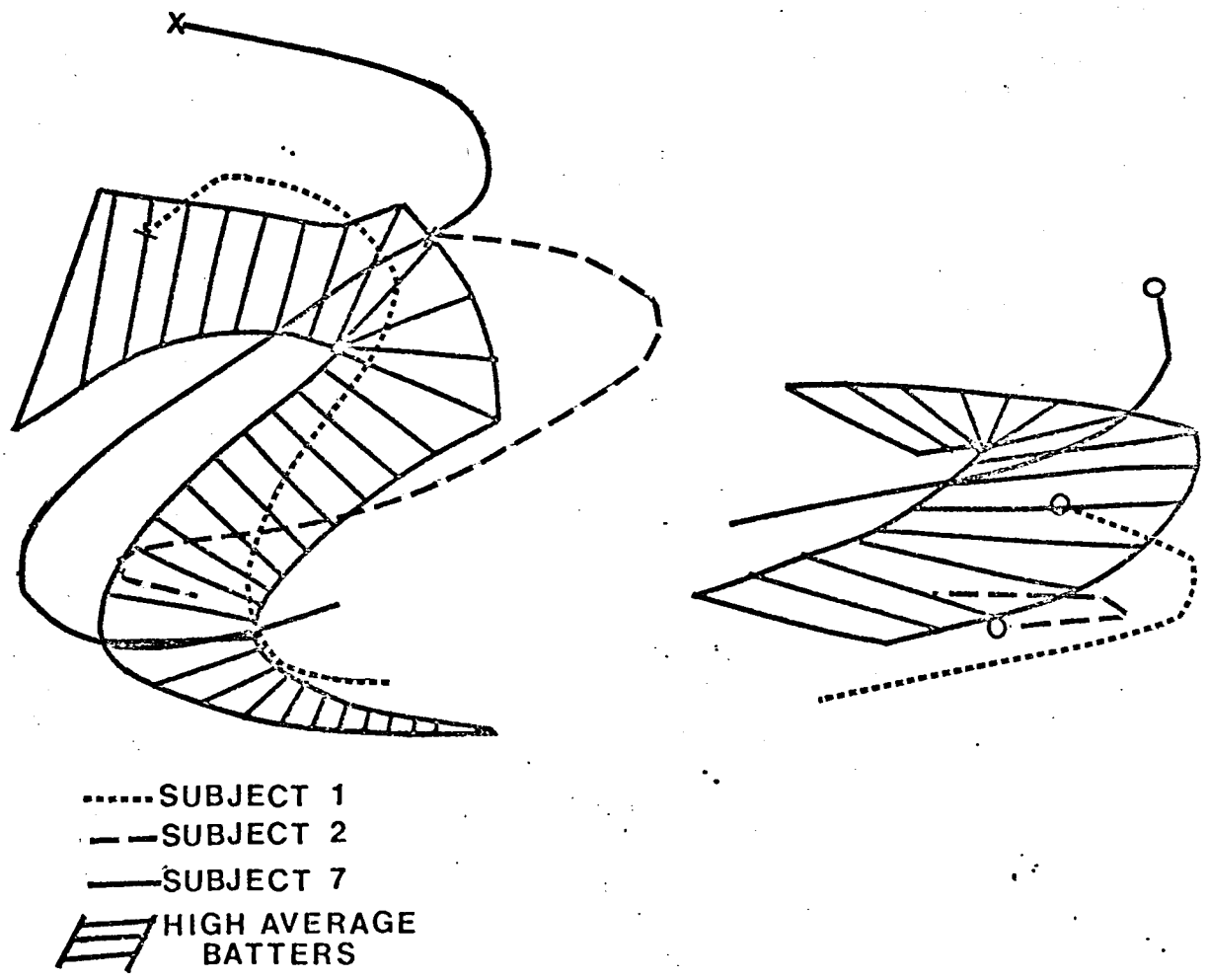


FIGURE 17

COMPARISON OF BAT PATHS
WITHOUT THE TEE OF
HIGH AVERAGE AND LOW AVERAGE BATTERS

LINE OF BEST FIT

TABLE XXII

ANALYSIS OF VARIANCE OF VERTICAL DISTANCE TRAVELED BY BAT FROM START OF FORESWING TO AREA OF CONTACT

Source of Variation	df	SS	MS	F*
Between cells	xx	xx	xx	xx
A (High Average-Low Average)	1	5.77	5.77	.297
B (With Tee-Without Tee)	1	4.01	4.01	.207
AB (Interaction)	1	16.77	16.77	.864
Within cell	12	232.79	19.40	xx
Total	15	263.35	xx	xx

*$F \geq 4.75$ at .05 level of significance

indicated a real difference between the high and low average batters. No significant F-test values were yielded relative to with and without the tee measures, as shown in Table XXIII.

Table XXIV shows an ANOVA performed for the upward angle of swing through the ball. This value of 7.71 (.05 level) demonstrated a significant difference between the high and low average batters. All other F values were not signficant.

Hypotheses Decisions

Based on the data analyzed in this investigation, the results failed to reject the null hypothesis in the following situations:

1. There were no significant interrelationships between age, height, and years experience for the all subject group, and any other demographic and batting average data.

2. There were no significant interrelationships between age and years experience for the high average batter group and any other demographic and batting average data.

3. There were no significant interrelationships between height and years experience and the other demographic and batting average data for the low average group.

4. There were no significant interrelationships between lead elbow without the tee, trail knee with the tee, trail ankle without the tee, distance between the wrists with and without the tee, and the other 13 variables at contact for the all subject group.

TABLE XXIII

ANALYSIS OF VARIANCE OF HORIZONTAL DISTANCE TRAVELED BY BAT FROM FORESWING TURN TO FOLLOWTHROUGH TURN OF SWING

Source of Variation	df	SS	MS	F*
Between cell	xx	xx	xx	xx
A (High Average-Low Average)	1	248.38	248.38	9.25**
B (With Tee-Without Tee)	1	.64	.64	.023
AB (Interaction	1	-.66	-.66	-.024
Within cell	12	322.16	26.85	xx
Total	15	570.52	xx	xx

*F - 4.75 at .05 level of significance

**Significant at the .05 level of significance

TABLE XXIV

ANALYSIS OF VARIANCE OF ANGLE OF UPWARD TRAJECTORY OF BAT THROUGH BALL CONTACT

Source of Variation	df	SS	MS	F*
Between cells	xx	xx	xx	xx
A (High Average-Low Average)	1	126.56	126.56	7.71**
B (With Tee-Without Tee)	1	3.06	3.06	.19
AB (Interaction)	1	22.57	22.57	1.38
Within cells	12	196.75	16.40	xx
Total	15	348.94	xx	xx

*F - 4.75 at .05 level of significance

**Significant at the .05 level of significance

5. There were no significant interrelationships between trail elbow without the tee, trail knee with the tee, trail ankle with the tee, perpendicular distance of the hip, perpendicular distance of the ankle, distance between wrists without the tee, and the remaining 12 variables.

6. There were no significant interrelationships between the lead elbow without the tee, trail elbow with the tee, trail knee with the tee, trail ankle without the tee, distance between the wrists with the tee, distance between elbows with and without the tee, and the remaining 11 variables at contact for low average batters.

7. There was no significant difference in batting averages between high and low average batters.

8. There was no significant difference between high and low average batters for the perpendicular distance of the trail hip, trail knee, and trail ankle to the tee.

9. There was no significant difference between high and low average batters with and without the tee for the following contact measures; angle of the trail knee, angle of the trail elbow, distance between the wrists, and length of stride.

10. There was no significant difference between high and low average batters with and without the tee for the vertical distance traveled by the bat from the start of the foreswing to the area of contact.

The results of this investigation warranted rejection of the null hypothesis in the following situations:

1. There was a significant relationship between batting average and hits, and at bats and hits for the all subject group.

2. There was a significant relationship between batting average and hits, and subject's height and at bats for the high average batter group.

3. There was a significant relationship between batting average and age, and at bats and hits for the low average batter group.

4. There were significant relationships between the following measures at contact for the all subject group: batting average and angle of the lead elbow with the tee; angle of the trail knee with the tee and angle of the trail knee without the tee; angle of the trail knee with the tee and perpendicular distance of the trail knee; perpendicular distance of trail hip and perpendicular distance of the trail knee to the tee; perpendicular distance of the trail hip to the tee and perpendicular distance of the trail ankle to the tee; perpendicular distance of the trail knee to the tee and perpendicular distance of the trail ankle to the tee; angle of the lead elbow with the tee and distance between the elbows with the tee; angle of the trail elbow with the tee and distance between elbows with the tee; distance between elbows with the tee and distance between the elbows without the tee; angle of the lead elbow without the tee and length of stride with the tee; angle of trail knee without the tee and length of stride with the tee; angle of the trail

knee without the tee and length of stride without the tee; and length of stride with the tee and length of stride without the tee.

5. There were significant relationships between the following measures at contact for the high average batter group: batting average and angle of the lead elbow with the tee; angle of the lead elbow without the tee and length of the stride with the tee; angle of the trail ankle without the tee and distance between the elbows with the tee; angle of the trail elbow with the tee and perpendicular distance of trail knee from the tee; angle of the trail knee without the tee and distance between the elbows without the tee, and distance between the wrists with the tee and length of stride without the tee.

6. There were significant relationships between the following measures at contact for the low average batter group: perpendicular distance of the trail hip to the tee and perpendicular distance of the trail knee to the tee; perpendicular distance of the trail knee to the tee and perpendicular distance of the trail ankle to the tee, length of the stride with the tee and length of the stride without the tee; angle of the lead elbow with the tee and angle of the trail elbow without the tee; batting average and angle of the trail knee without the tee; and angle of the trail ankle with the tee and distance between the wrists without the tee.

7. There was a significant difference of the angle of the lead elbow at contact between the high average batter group and the low average batter group.

8. There was a significant difference in horizontal distance traveled by the bat between the high average batter group and the low average batter group.

9. There was a significant difference in the angle of upward trajectory of the bat through the ball contact between the high average batter group and the low average group.

Summary

Data for analysis were gathered from batting profile sheets from the subjects' respective coaches, demographic data supplied by the subjects, angular and linear measurements from the films, and plotted bat paths for all subjects. Angle pairs were correlated to establish a reliability of trial to trial, with and without the batting tee for each subject. As a result of the reliabilities, a mean value was utilized for all measurements from the film. Means and standard deviations were calculated for each variable analyzed in the study.

Pearson Product Moment Correlations were done for all demographic data and all contact measurement data for the three groups: all subjects, high average batters and low average batters. The significant and nonsignficant correlations were presented in this chapter.

ANOVA's were performed relative to high average batters, low average batters, swings with the batting tee, and swings without the batting tee for each measure at contact, batting average, and all bat path measurements.

Chapter 5

DISCUSSION OF RESULTS

Data for this investigation included batting profiles, subjects' demographic information, and angular and linear measurements taken from film tracings. Discussion will include the significant aspects of demographic data and the batting film tracings.

Demographic Data

For all subjects, significant correlations were found for hits and batting average, and hits and at bats. These correlations, significant at the .01 and .05 levels respectively, could be expected. The batting average of a subject was directly related to the number of hits granted to the batter and the number of times at bat. The correlation between batting average and hits was also significant (.05 level) for high average batters. This relationship may be explained because the batting average is directly related to the number of hits a batter gets. A correlation of $r=.974$ (.05 level) between subject height and at bats for high average batters was found. There is no concrete evidence to explain this correlation. It is possible that because of body height, which would increase the area of playing field that a player could cover, the taller players were given more opportunity to play and hence more times at bat.

It must also be recognized that taller players have longer body levers. The correlation between at bats and hits was r=.994 (.01 level) for the low average batter group. This relationship can be explained logically because as hits increase, the number of times at bat must also increase. Batting average and age correlated r=.971 (.05 level), for low average batters. There was no available evidence to explain this correlation. However, it is feasible that the older players were able to better utilize the coaching hints and verbal feedback they received from coaches, umpires, and other players. This ability could have lead to more success in batting and an increase in batting average.

It should be noted that the years of playing experience and batting average correlated only r=.188 for low average batters, and r=-.889 for high average batters. Again, there is no available evidence to explain this result. The investigator believes that the negative correlation for the high average batters was due to the possibility that the advanced players were required, by their coaches, to perform more advanced plays including bunting, place hitting, and hit and run plays. These plays can easily lead to a lowered batting average and placing the hitter in jeopardy of being put out more often, than if the hitter was only required to go to the plate and hit the ball.

Individual Measures at Contact

ANOVA applied to the linear and angular data with and without the tee resulted in no significant differences.

Thus, the discussion is limited to batting with the tee. Race (37), in his study, found that the rear (trail) elbow flexion of his subjects was under 135 degrees as they approached bat contact with the ball. A mean angle of 129.69 degrees with the tee was found for the all subject group. When the mean angle was calculated for the high average group, the angle was 123.5 degrees with the tee. A mean angle of 135.88 degrees with the tee was calculated for the low average batters. The more successful batters demonstrated a smaller angle with the rear (trail) elbow. Bunn (3) and Swimley (40) advocated an increase in the extension of the forearms and the lower (trail) arm, respectively, as the batter approached contact. The results of this investigation uphold Race's (37) findings and refute Swimley's (40) and Bunn's (3) statements.

McCord (32) believed that the angle of the lead elbow should be slightly more than 120 degrees. The mean lead elbow angle with the tee was 160.25 degrees for the all subject group; 155.5 degrees for the high average group; and 165 degrees for the low average group. These results directly refute McCord's (32) findings, as the subjects all approach angles of 180 degrees; thus straightening arms at contact. Breen (23) stated that the leading forearm should tend to straighten at the beginning of the swing for greater bat speed. Bunn (3) advocates increased extension of the forearms to increase the linear velocity. Hay (8) stated that good batters hold the lead arm straight or nearly

straight. The findings of this investigation, as previously stated, agree with these three experts.

McCord (32) advocated that the angle of the trail knee be approximately 140 degrees. He believed that this was the best force producing angle for takeoff after the hit. The mean measurements with the tee were 150.32 degrees for the all subject group, 149.25 degrees for high average group, and 151.38 degrees for the low average group. All mean values for this investigation were greater for the trail knee than advocated by McCord (32). This difference, in degrees, was slight and not of enough magnitude to refute McCord (32). Watts (46) also pointed out that a slight bend in the trail knee was necessary at stride for effective hitting.

Lopiano (53) has suggested that the average stride for female players should be 13 inches. Breen (23), Lopiano (53) and Siedentop (16) have all stated that an efficient stride was consistent in length and in the spot placement. The results of this investigation refuted this information. The mean stride with the tee was 4.9 inches for all subjects, 6.28 inches for high average batters and 5.59 inches for low average batters. Though these means appear fairly consistent, further statistical analysis showed large standard deviations of 5.42 inches for all subjects, 5.34 inches for high average batters, and 5.03 inches for low average batters with the tee. This result indicated that the range of the strides was great. (0 to 18.2 inches) It should be

noted that the variables of age and body height had low standard deviations of 1.41 years and 1.25 inches, respectively. Thusly, age and body height do not appear as contributors to the stride length. Bunn (3) stated that if the stride was too far the batter would fall away from the pitch and lose the force from the bat. Hay (8) advocated a short stride but was not specific as to length. McCord (32) elaborated on the problems of a long stride. He suggested that a longer stride caused an increase in head movement which would cause an increase in the difficulty of watching the ball and a greater distance for the bat to travel to contact the ball. Weiskopf (17) also advocated a short stride. Subjects ranged from 0.0 inches to 18.2 inches with the tee. These mean stride lengths agree with the experts advocating a short stride. The investigator believes that the subjects who strided under eight inches were not striding far enough to be as effective as possible, due to the batting tee and experimental situation.

Correlated Measures at Contact

Relative to the results of this investigation, various correlations were found to be significant. Explanations as to the reasons for their significance were difficult in some instances due to the lack of literature discussing these measures and correlations.

As batting average increased, the angle of the lead elbow with the tee decreased (increased flexion) in both the all subject group r=-.795 (.05 level), and the high average

group r=-.975 (.05 level). McCord (32) advocated a 120 degree angle, much smaller than any angles of the subjects of this investigation. This correlation shows agreement with the beliefs of Breen (23), Bunn (3), and Hay (8), who all advocate a straightening tendency of the lead elbow. The correlation can be further interpreted in light of the mean angles for the lead elbow. The investigator believes that the mean angles and correlations relative to the literature indicate a tendency for an angle to range between 120 and 180 degrees.

Some of the correlations indicate tendencies toward logical expectations of results. Because of the anatomical construction of joints and the fact that the hip, knee, and ankle joints work in conjunction with one another, explanations can be given.

A correlation of r=.738 (.05 level) was determined between the angle of trail knee with the tee and the perpendicular distance of the trail knee from the tee for all subjects. As the angle of the trail knee increased, or approached 180 degrees, the perpendicular distance of the trail knee to the tee increased because of the logical anatomical sequence. Without moving the foot, extension of the knee necessitates an increase in distance from the tee.

When the perpendicular distance of the hip from the tee increased, the perpendicular distance of the knee from the tee also increased. Significant correlations of r=.946 (.01 level) for all subjects and r=.951 (.05 level) for low

average batters were found. A correlation of r=.942 was calculated for high average batters. These correlations were the result of the anatomical sequence of hip and knee and of the batting sequence of striding. Without striding, the batter could increase the perpendicular hip distance and decrease the perpendicular knee distance by increasing knee flexion and lowering the trail hip toward the trail ankle. This sequence would probably cause a negative effect on the swing by pulling some of the force away from the ball as the batter leans back at contact. As the perpendicular distance of the hip increased, the perpendicular distance of the ankle from the tee increased significantly relative to the all subject group and the low average batter group. These correlations were r=.898 (.01 level) and r=.930, approaching significance at the .05 level, respectively. This relationship was related to the anatomical sequence of the three joints of the leg and the batting sequence. To continue the sequence, significant correlations were recorded between perpendicular distance of the knee to the tee and perpendicular distance of the ankle to the tee. The correlations were r=.980 (.01 level) for the all subject group and r=.941, approaching significance at the .05 level for the low average group. These correlations indicated that as the distance from the knee to the tee increased, the distance from the ankle to the tee increased. With the trail leg, the hip rotation is inward and extension of the knee joint

requires dorsal flexion at the ankle (lowering of the heel toward the ground).

An increase in the angle of the lead elbow with the tee caused a significant decrease in the distance between the elbows with the tee. The correlation was r=-.757 (.05 level) for the all subject group. This correlation, to a point, can be explained by the nature of the bat swing. As the lead elbow extension increases, it necessitates an increase in the extension of the trail elbow. Without the reciprocal extension of the elbows, the batter would be required to greatly adduct the trail shoulder in order to swing, and the end of the bat could not be brought through the ball with anything but wrist power from the trail arm. Two other correlations were recorded in conjunction with elbow extension. A correlation of r=-.780 (.05 level) for the all subject group indicated that as the angle of the trail elbow with the tee increased, the distance between the elbows with the tee decreased. The correlation of r=-.939, approaching significance at .05 level for low average batters, indicated that an increase in the angle of the trail elbow with the tee related to a decrease in the distance between the elbows without the tee. This result is upheld by the above explanation, and that if the distance between the elbows did not decrease, the power behind the bat would decrease as the batter would be at a probable mechanical disadvantage.

For the all subject group, a correlation of r=.705, approaching significance at the .05 level, was found between the angle of the trail knee with the tee and the perpendicular distance of the ankle from the tee. Anatomical considerations explained this correlation. When the batter extends the trail knee, the lower extremity is lengthened relative to linear distances. The lengthening of the lower extremity requires a decrease in the distance of the trail heel from the floor and thusly would increase the perpendicular distance of the ankle to the tee. Without lowering the heel, the batter would be forced to elevate the hip to compensate for the angular change at the knee. This anatomical sequence also explained a correlation of r=.911 approaching significance at the .05 level for low average batters. As the angle of the trail ankle with the tee increased, the perpendicular distance of the trail hip to the tee increased. A correlation of r=-.981 (.05 level) for the high average batting group indicated that an increase in the angle of the trail elbow with the tee caused a decrease in the perpendicular distance of the trail knee to the tee. As the batter extends the arms to reach the ball, she must also make adjustments through the other body parts. A necessary adjustment in this respect was seen in a decrease in the perpendicular distance of the trail knee to the tee. The batters have adjusted their lower body to allow for effective use of the decrease in the elbow angle.

An increase in the angle of the lead elbow with the tee caused a decrease in the angle of the trail ankle with the tee. This was shown by a correlation for high average batters of r=-.916, approaching significance at the .05 level. This occurrence was explained by the sequence of adjustments mentioned above. The grip of the hands on the bat causes the elbows to be related in movement when swinging.

Two further correlations from the high average batter group were related to the trail elbow. A correlation of r=-.945, approaching significance at .05 level, was calculated between the trail elbow with the tee and the perpendicular distance of the trail hip to the tee. A correlation of r=-.938, approaching significance at .05 level, was found between the angle of the trail elbow with the tee and the perpendicular distance of the trail ankle from the tee. Both correlations were interpreted as an increase in the angle of the trail elbow causing a decrease in the other measure, mainly the perpendicular distance of the trail hip and the perpendicular distance of the trail ankle to the tee. These correlations were explained by examination of the batting sequence. An increase in the angle of the trail elbow resulted from the batter reaching to contact the ball and completely swinging through the ball. In order to make this reach effective, the batter also adjusted the angle of the knee and hence caused a decrease in the perpendicular distance of the trail ankle and trail hip. Swimley (40) stated that in order for batters to increase their hitting power,

they had to extend the lead leg and trail elbow at impact. His statement agrees with the results found in this investigation. An extension of the lead leg and trail elbow necessitates an adjustment in the degree of flexion of the trail leg.

A correlation of r=-.930, approaching significance at .05 level, for high average batters was determined between the linear distance between the wrists with the tee and the length of the stride with the tee. A possible explanation for this correlation relates to the utilization of pronation and supination of the wrists through contact. This correlation suggested that an increase in the distance between the wrists was related to a decrease in the stride. A batter who uses a short stride will contact the ball more off the midline of the body and hence will be forced to reach further ahead to contact the ball initially, and a decrease in the pronation and supination of the wrists and thus a decrease in the distance between the wrists will be evident.

A correlation of r=-.987 (.05 level) with the tee and was calculated for the low average batter group relative to batting average and the angle of the trail knee. The possible explanation for batting average increasing, while the angle of the trail knee decreased, stems from Swimley's (40) study. He stated that extension of the lead leg was necessary to increase hitting power. An extension of the lead leg would probably cause the batter to lower the heel

of the trail leg and cause extension of the trail knee, or an increase in the angle of the trail knee.

Further significant correlations were determined, but, because of the two separate filming situations, the meaning is doubtful.

Bat Paths

The mean upward angle of swing for the low average batters was five degrees with the tee and 3.5 degrees without the tee. The standard deviation was 2.49 degrees and 8.13 degrees, respectively. The upward angle of swing for the high average batters was greater. The mean and standard deviation were 8.25 degrees and 3.31 with the tee; and 11.5 degrees and two without the tee, respectively. Williams (48) suggested that the batter should flatten the bat path to reduce the height of the ball in the air, and that a slight upswing would produce a long ball. The author failed to define his interpretation of a "slight" upswing. The lower average batters of this investigation have lowered the bat path through the ball and the high average batters of this investigation have a higher mean upward angle of swing. The resultant trajectory of the ball was unknown from this investigation, but the data of this study appeared to refute William's (48) statements.

The mean width of the high average bat paths with and without the tee was smaller than that of the low average batters. The mean and standard deviation of the high average bat path widths were 75.76 inches and 1.06 with the tee;

and 76 inches and 4.15 without the tee, respectively. The low average bat path widths mean and standard deviation were 83.48 inches and 5.41 with the tee and 84.04 inches and 9.74 without the tee, respectively. Vaughn (41), in his study, found that a short swing with wrist action was the most conducive to hitting for a high batting average. These results uphold the conclusions made by Vaughn (41).

The mean height of the bat paths of the high average batters was similar to the mean height of the low average batters. The high average group paths were slightly higher with the tee and slightly lower without the tee. The mean and standard deviation were 29.68 inches and 5.03 with the tee and 30.76 inches and 6.95 without the tee for the low average group respectively; and 30.96 inches and 3.34 with the tee and 27.48 inches and 4.26 without the tee for the high average group, respectively. No literature was found to refute or agree with this investigation's data. The lack of previous studies lead the investigator to believe that the vertical distance traveled by the bat (height) had little bearing on the success of the hitters in this study.

The followthroughs of subjects five and six, (both high average batters) without the tee, and subject five with the tee were the only bat paths that finished behind the backs of the subjects. This data agreed with the statements of Hay (8) and Watkins (45). Hay (8) advocated the use of a complete followthrough to reduce injury risk and to prevent interference with the force application to the ball.

Watkins (45) advocated a followthrough to behind the head of the batter. All other subjects of this investigation completed the followthroughs in front of the body.

Analysis of Variance

An ANOVA, calculated for the angle of the lead elbow at contact, yielded an F value of 5.83 (.05 level). This F value indicated that there was a significant difference for the angle of the lead elbow between the high average and low average batter groups without regard to the batting tee. The investigator believes that the lead arm has great bearing on the success of a batter as the significant result tends to uphold the importance of the lead arm. The small mean difference (6.44 degrees) in the size of this angle between the batting groups in this investigation tends to indicate an optimum range of the angle of the lead elbow for increased batting average.

ANOVA calculations for the bat path measures yielded two significant F values. Relative to the horizontal distance traveled by the bat (width of the swing), an F value of 9.25 (.05 level) was determined. This value indicated that there was a significant difference between the high average batter group and the low average batter group regardless of the presence of the batting tee. An F value of 7.71 (.05 level) was found relative to the angle of upward trajectory of the bat through ball contact. This value indicated a significant difference between the high and low average batting groups, regardless of the presence of the

batting tee. Lopiano (53) and Vaughn (41) stated that a more compact swing or a shorter swing with wrist action was most conducive to high average batting. The significant ANOVA results for the width of swings further suggests the shorter, more compact swing lead to more success in hitting, and higher batting averages.

Williams (48) stated that a slight upward swing was conducive to long ball hitting. He did not define "slight," and the result of this investigation tends to indicate that, for the subjects involved, the greater upward angle was more conducive to the high batting average. The investigator believes that this result also indicates an optimum range for the upward angle of swing for the greatest success.

Summary

Discussion has been presented in this chapter relative to the findings of this investigation. In Chapter 6, conclusions will be drawn based on these results and implications for further research will be presented.

Chapter 6

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

This chapter summarizes this investigation, drawing conclusions from the results and proposing recommendations for further study.

Summary

The purpose of this investigation was to conduct a kinematic analysis of selected phases of softball batting form of eight female softball players. The subjects of this study (N=8) were randomly selected high school varsity softball players chosen from squad lists submitted by coaches of the selected participant schools.

The film sequence took place in a high school gymnasium and involved a softball bat, batting tee, and softballs. The subjects dressed in dark shirts, shorts and knee socks and had marks placed on them with tape to facilitate analysis.

Filming involved the use of a Bolex 16 mm. movie camera and a homemade beam splitter. A grid, 8 feet by 8 feet, divided into six inch squares was superimposed on the subject by means of a beam splitter. The film was Kodak Tri-X Reversal film and was run at the 64 frames per second setting on the camera. The camera calibration showed camera

speed to be 58.02 frames per second. The camera was fully wound for each subject's trial to minimize film speed changes.

The eight female subjects were divided into two groups for analysis. The groups were based on batting average for the 1975 season. A batting average of .420 or better was considered high average batting. The batting averages were calculated from the batting profile sheets that had been submitted for each subject.

The first part of the testing situation involved each subject taking two trials at hitting a softball off a batting tee while being filmed. The second part of the test involved two trials swinging at an imaginary pitched ball while being filmed. These four trials for each subject were analyzed to obtain angular and linear measurements for comparison of swings in the batting average groups with and without the batting tee.

Analysis was done using the angular and linear measurements at ball contact, and plotting bat paths for each subject. Analysis included calculation of the mean and standard deviation for each demographic, contact and bat path variable, formation of a correlation matrix for each category of the analysis, and ANOVA for individual contact measures and bat path measures to test for differences.

The more prominent significant relationships (.05 level) for demographic data included height and at bats for

the high average batter group and batting average and age for the low average batter group.

A variety of significant correlations were found relative to the linear and angular measurements at contact. Most of these correlations were explained by means of logical anatomical sequences. These correlations included an increase in the angle of the lead and trail elbows with and without the tee causing a decrease in the distance between the elbows at contact; changes in the angle of the trail knee and trail ankle causing changes in the perpendicular distances of the trail hip, trail knee, and trail ankle. Consistency between trials with the tee and trials without the tee was found for the angle of the trail knee, distance between the elbows, and length of the stride for the all subject group. The high average batter group was consistent relative to stride length.

The high average batter group was significantly different (.05 level) from the low average group on three variables. The high average batter group recorded smaller angles of the lead elbow, greater angle of upward swing of the bat through contact, and less horizontal distance of the bat swing than the low average batter group, with no regard for the presence or absence of the batting tee.

Conclusions

Within the realm of this investigation, the following conclusions are warranted:

1. High average batter group use a shorter, more compact swing than low average batter group with and without the batting tee.

2. High average batter group use a greater upward angle of swing of the bat through ball contact than low average batter group both with and without the batting tee.

3. The angle of the lead elbow in the high average batter group was smaller than the angle of the lead elbow in the low average batter group both with and without the batting tee.

Recommendations for Further Study

In view of the findings of this investigation, certain recommendations are presented with regard to further study.

1. The problem at hand needs to be filmed in additional views of the subject. There is a need for an overhead as well as a side view to facilitate analysis of velocities, accelerations and the degree of body lean at various points in the batting sequence.

2. Apparatus should be employed to measure the change of weight distribution on the feet of the subjects through the batting sequence.

3. A study should be designed to investigate the amount of hip rotation, the change in level of the head and shoulders, and the angle of projection of the ball after contact.

4. A study needs to be performed at a higher frame per second film speed to obtain clearer pictures of the batting sequence and establishment of the exact point of contact and the area of the ball that was contacted.

5. The problem of proper batting technique requires a study employing more subjects of a wider range of batting averages than this investigation used.

APPENDIX A

March 18, 1975

Dear Sir:

Your school has been selected, along with five other Finger Lakes Schools, in a random drawing to participate in my graduate thesis project. The participation I ask will require three (3) girls from your interscholastic softball team to meet in Newark for one Saturday morning to be filmed hitting softballs. I will also ask your girls' coach to fill out a batting profile sheet on each girl for the 1975 season.

The time needed from the girls and from the coach is minimal, but of extreme importance. The girls to participate will be drawn randomly after the squad lists have been received.

Because time is of the essence, please notify me if your school would rather not participate so I may contact an alternate. I assure you that names and results will be strictly confidential.

Sincerely,

Karen E. Hegeman
Newark Central School
Newark, NY 14513

KEH/ee

APPENDIX B

Dear Coach,

The following girls have been chosen from your squad to be subjects in a study on high school girl's softball batting. Please keep the enclosed record on each girl and return it to me after your season is complete.

GIRLS _____

_____

_____

RETURN TO: Karen E. Hegeman
Newark Central School
Newark, NY 14513

Sincerely,

APPENDIX C

NAME_____AGE_____YEARS EXPERIENCE_____

Inning	1	2	3	4	5	6	7	8	9	10
Game 1										
Game 2										
Game 3										
Game 4										
Game 5										
Game 6										
Game 7										
Game 8										
Game 9										
Game 10										

Key
1B--Single
2B--Double
3B--Triple
HR--Homerun
E--Error allowed hitter to get on
BB--Walk
K--Strike out
O--Out at Base
FO--Fly out, pop out, line out
BT--Bunt

Directions:
1. Fill in one box per time at bat each game
2. Use only symbols in key
3. Error constituted by ball easily getting by or being touched and baubled by a fielder

APPENDIX D

Dear _____,

You have been chosen, along with two other members of your girls' varsity softball team to participate in a film study of high school girl's softball batting. This project is for a graduate thesis being completed for Ithaca College and includes eighteen players from six schools in the Finger Lakes League.

All I ask of you is to be at the Newark Senior High School, 625 Peirson Avenue, Newark, New York on Saturday _____, at _____. Come dressed in a long sleeve, dark top and dark shorts and knee socks. It will take approximately two hours for the group to complete the hitting. Your actual time will be about 5 minutes.

It is extremely important that I know if you will be there or not. To complete this project, all 18 subjects must come at the same time. Please return the attached portion of this letter to me by _____.

Please show this letter to your parents and assure them no names will be used, and none but myself will see the films. Thank you.

Sincerely,

Karen E. Hegeman
Grad. Student, I. C.
Newark Central School

APPENDIX E

RETURN THIS SHEET TO:

Miss Karen E. Hegeman
Newark Central School
Newark, NY 14513

Name_____

Age_____

School_____

I am interested in being in the study.

I am not interested, please contact an alternate.

I, _____ give my daughter _____ permission to take part in the graduate thesis study filming at Newark Central School on _____. I fully understand that her name will be kept confidential, and that the films will not be made public.

Signature _____

Date Signed_____

APPENDIX F

RAW DATA

At Contact

Subj/ Hit	Lead Elbow	Trail Elbow	Trail Knee	Trail Ankle	Perpendicular distance to tee: Hip	Knee	Ankle	Distance between: Hands	Elbows
1-1	177	163	157	159	2.5	1.25	3.1	.5	1.6
1-2	162	115	132	124	1.75	1.6	3.2	.55	1.55
1-3	170	121	137	119	--	--	--	.65	1.55
1-4	174	123	140	119	--	--	--	.50	1.55
2-1	169	154	143	113	1.0	1.2	2.8	.9	1.45
2-3	152	152	148	120	0.7	0.9	2.2	.8	1.6
2-4	174	102	154	142	--	--	--	.4	1.5
2-5	176	131	147	136	--	--	--	.55	1.5
3-1	142	117	162	141	1.9	2.4	3.8	1.00	2.3
3-2	162	132	158	127	1.65	2.1	3.75	1.05	2.05
3-3	180	100	161	124	--	--	--	.75	2.10
3-4	171	104	162	133	--	--	--	.80	1.05
4-2	170	118	151	--	2.8	3.0	4.25	.70	1.70
4-3	164	108	144	81	2.2	2.5	4.1	.85	1.85
4-4	173	115	155	156	--	--	--	.75	1.7
4-5	168	111	141	135	--	--	--	.80	1.8
5-1	145	129	150	--	2.0	2.0	3.2	.70	1.9
5-2	134	120	148	148	2.2	2.3	3.7	.75	2.10
5-3	161	120	145	143	--	--	--	.50	1.7
5-4	158	141	139	124	--	--	--	.60	1.8

Subj/ Hit	Lead Elbow	Trail Elbow	Trail Knee	Trail Ankle	Perpendicular distance to tee: Hip	Knee	Ankle	Distance between: Hands	Elbows
6-1	166	131	142	104	1.4	1.8	3.5	.90	1.8
6-2	161	133	139	124	1.1	1.4	3.1	1.0	1.9
6-3	174	141	153	167	--	--	--	1.0	1.8
6-4	171	139	137	126	--	--	--	1.0	1.75
7-1	169	105	143	161	2.35	2.1	3.5	.90	2.15
7-2	136	115	147	--	2.5	2.4	3.8	1.05	2.3
7-3	169	113	151	--	--	--	--	.80	1.7
7-4	170	108	145	153	--	--	--	.85	1.8
8-1	175	146	172	--	2.8	3.3	4.5	.60	1.4
8-2	180	137	169	160	2.75	3.45	4.8	.80	1.5
8-3	178	123	161	155	--	--	--	.80	1.70
8-4	172	140	164	--	--	--	--	.70	1.6

LINEAR MEASUREMENTS AT CONTACT

Subject	Distance Between Hands (cm)	Aver. Dist. (cm)	Converted* to Inches	Distance Between Elbows (cm)	Aver. Dist. (cm)	Converted* to Inches (Multiplier 16x and divider 2.54)
1-1-L**	.50	.52	3.28	1.6	1.58	9.95
1-2	.55			1.55		
1-3	.65	.58	3.65	1.55	1.55	9.76
1-4	.50			1.55		
2-1	.9	.85	5.35	1.45	1.52	9.57
2-3	.8			1.60		
2-4	.4	.48	3.02	1.50	1.55	9.76
2-5	.55			1.50		
3-1-H**	1.0	1.02	6.42	2.30	2.18	13.73
3-2	1.05			2.05		
3-3	.75	.78	4.91	2.10	1.98	12.47
3-4	.80			1.85		
4-2	.70	.78	4.91	1.70	1.78	11.21
4-3	.85			1.85		
4-4	.75	.78	4.91	1.70	1.75	11.02
4-5	.80			1.80		

*Conversion factor to change film measurements to actual size measurements.

**"L"--Low Average Batters. "H"--High Average Batters.

Subject	Distance Between Hands (cm)	Aver. Dist. (cm)	Converted* to Inches	Distance Between Elbows (cm)	Aver. Dist. (cm)	Converted* to Inches (Multiplier 16x and divider 2.54)
5-1	.70	.72	4.54	1.90	2.0	12.60
5-2	.75			2.10		
5-3	.50	.55	3.46	1.70	1.75	11.02
5-4	.60			1.80		
6-1	.90	.95	5.98	1.80	1.85	11.65
6-2	1.0			1.90		
6-3	1.0	1.0	6.30	1.80	1.78	11.21
6-4	1.0			1.75		
7-1 -L**	.90	.98	6.17	2.15	2.22	13.98
7-2	1.05			2.30		
7-3	.80	.82	5.16	1.70	1.75	11.02
7-4	.85			1.80		
8-1	.6	.70	4.41	1.40	1.45	9.13
8-2	.8			1.50		
8-3	.7	.75	4.72	1.70	1.65	10.39
8-4	.7			1.60		

*Conversion factor to change film measurements to actual size measurements.

**"L"--Low Average Batters. "H"--High Average Batters.

STRIDE LENGTH

Subject	Stance (cm.)	Contact (cm.)	Difference (cm.)	Converted to Inches* (Multiplier 16x and ÷ by 2.54)	Mean (in.)
1-1	2.4	4.1	1.7	10.7	12.9
1-2	2.7	5.1	2.4	15.1	
1-3	2.6	5.7	3.1	19.5	18.2
1-4	2.8	5.5	2.7	17.0	
2-1	3.9	4.1	0.2	1.2	2.8
2-3	3.3	4.0	0.7	4.4	
2-4	3.6	4.1	0.5	3.1	4.4
2-5	3.4	4.3	0.9	5.7	
3-1	4.3	4.3	0	0	0
3-2	4.2	4.2	0	0	
3-3	3.9	4.4	0.5	3.1	1.8
3-4	4.6	4.7	0.1	.6	
4-2	3.3	4.6	1.3	8.2	5.4
4-3	3.9	4.3	0.4	2.5	
4-4	3.7	5.6	1.9	12.0	12.6
4-5	3.5	5.6	2.1	13.2	
5-1	3.1	5.1	2.0	12.6	12.3
5-2	3.6	5.5	1.9	12.0	
5-3	3.1	5.7	2.6	16.4	12.9
5-4	3.1	4.6	1.5	9.4	
6-1	4.5	4.5	0	0	1.9
6-2	4.3	4.9	.6	3.8	
6-3	4.6	5.3	.7	4.4	2.8
6-4	4.3	4.5	.2	1.2	
7-1	3.5	4.8	1.3	8.2	8.2
7-2	4.4	5.7	1.3	8.2	
7-3	4.1	5.5	1.4	8.8	9.4
7-4	4.1	5.7	1.6	10.1	
8-1	4.6	4.6	0	0	1.2
8-2	4.4	4.8	.4	2.5	
8-3	5.2	5.2	0	0	1.2
8-4	3.7	4.1	.4	2.5	

*Conversion factor to change film size to actual size

APPENDIX G

DEVELOPMENT OF LINE OF BEST FIT

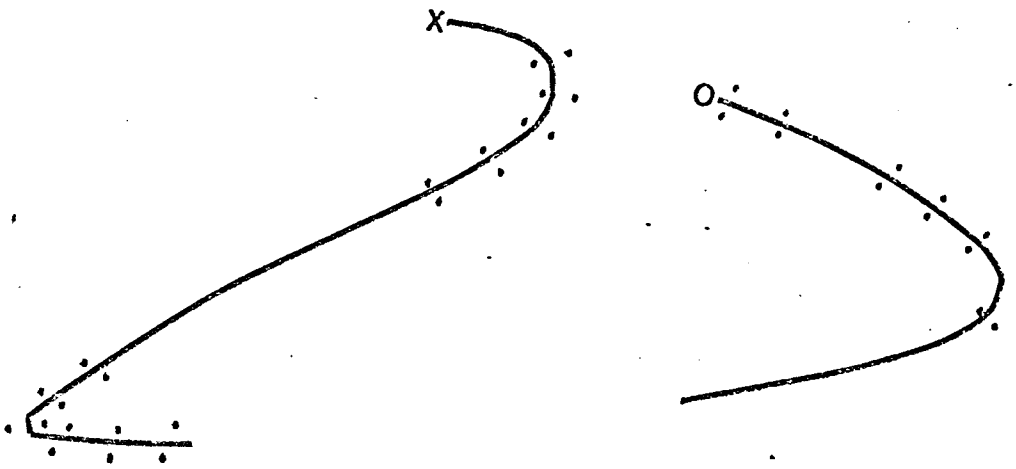
SUBJECT ONE WITH THE TEE

DEVELOPMENT OF LINE OF BEST FIT

SUBJECT ONE WITHOUT THE TEE

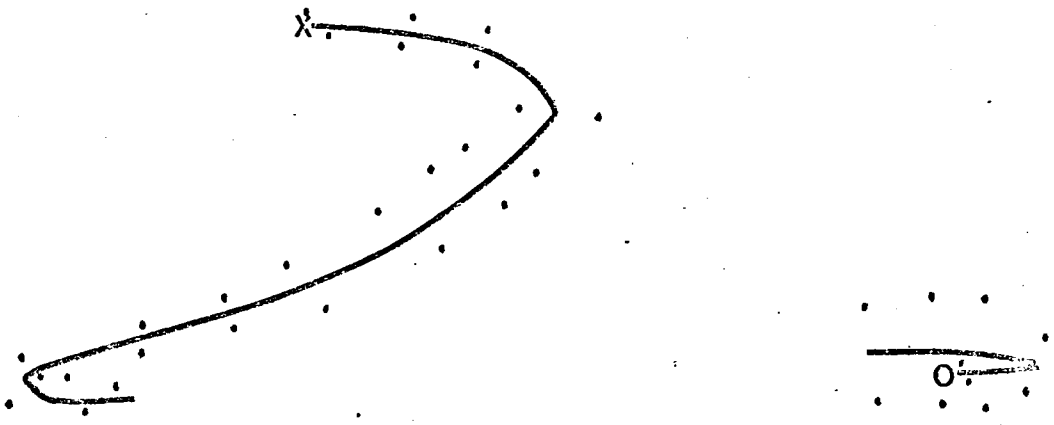
DEVELOPMENT OF LINE OF BEST FIT

SUBJECT TWO WITH THE TEE



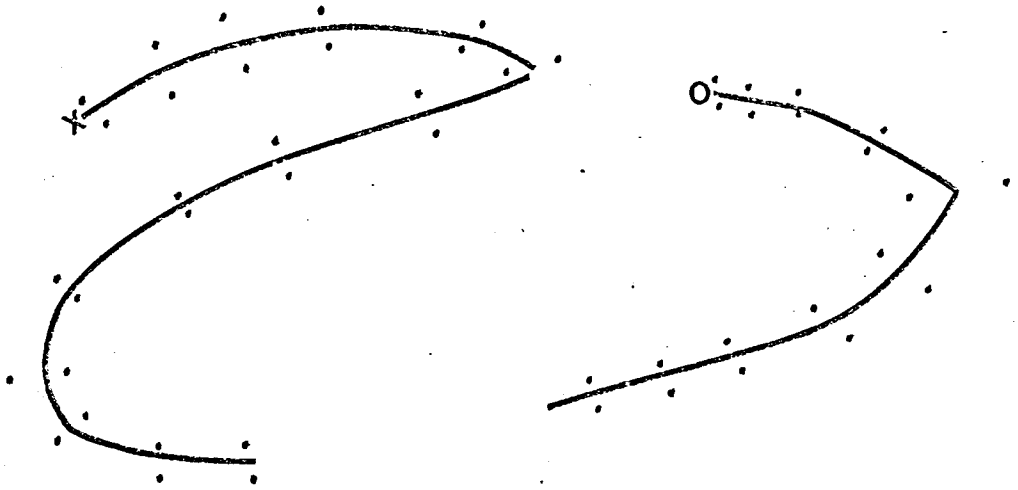
DEVELOPMENT OF LINE OF BEST FIT

SUBJECT TWO WITHOUT THE TEE



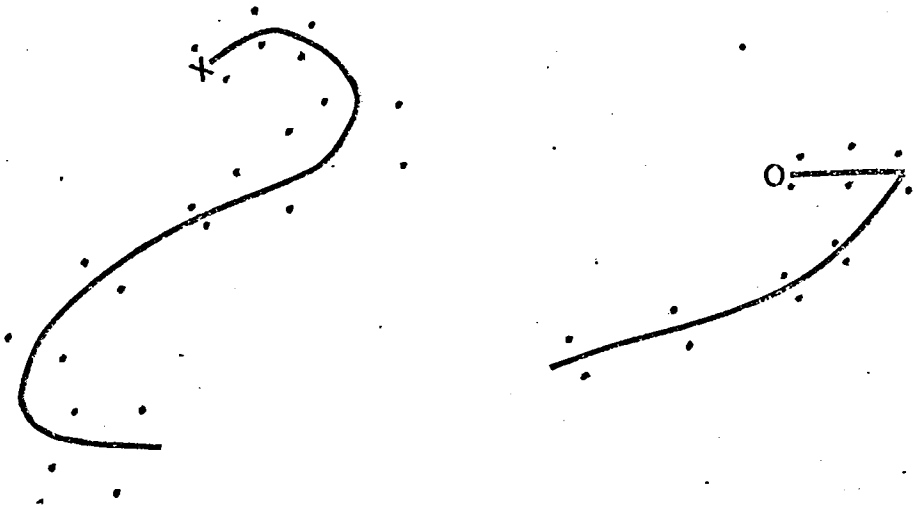
DEVELOPMENT OF LINE OF BEST FIT

SUBJECT THREE WITH THE TEE



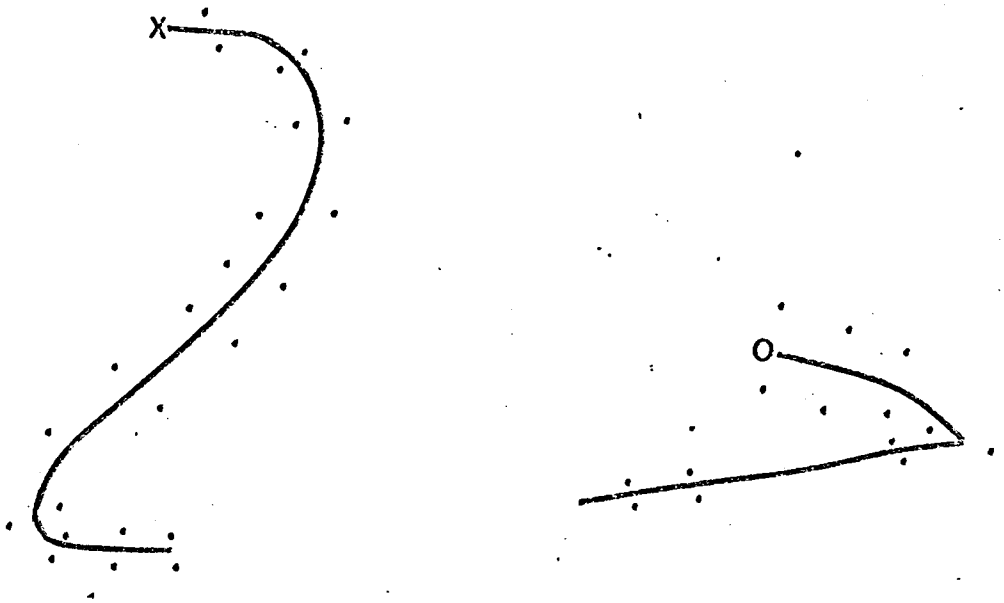
DEVELOPMENT OF LINE OF BEST FIT

SUBJECT THREE WITHOUT THE TEE



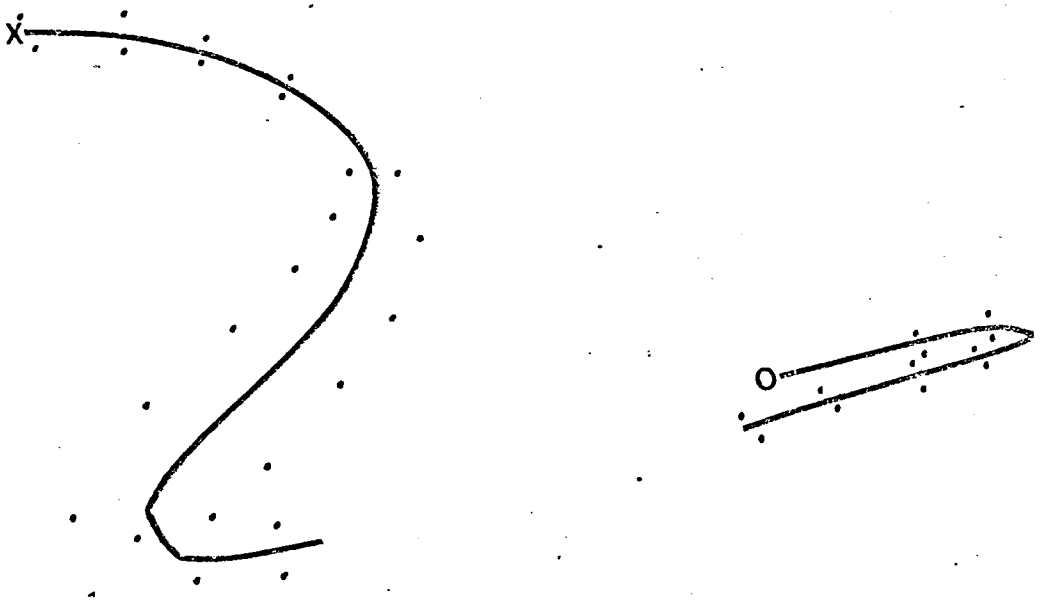
DEVELOPMENT OF LINE OF BEST FIT

SUBJECT FOUR WITH THE TEE



DEVELOPMENT OF LINE OF BEST FIT

SUBJECT FOUR WITHOUT THE TEE



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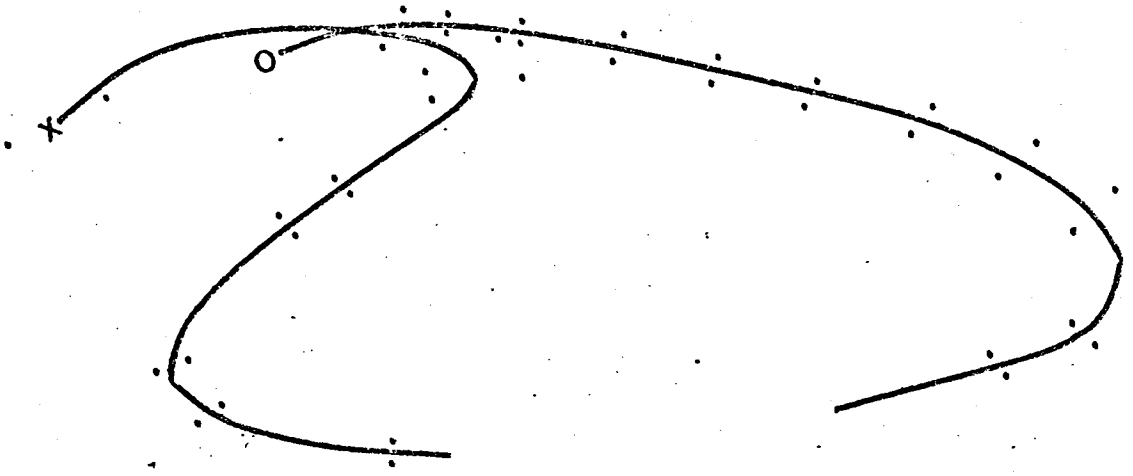
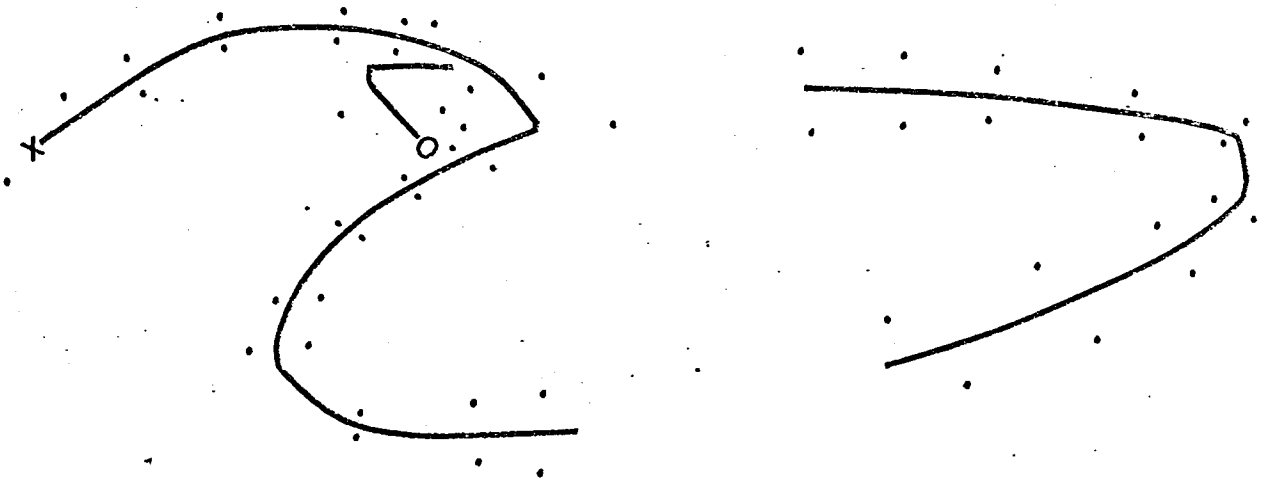


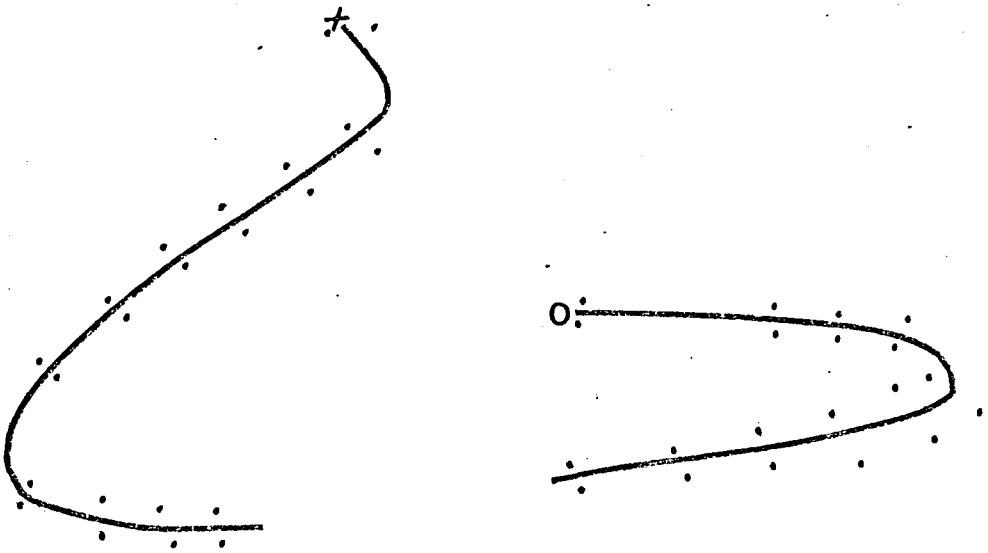
DEVELOPMENT OF LINE OF BEST FIT

SUBJECT FIVE WITHOUT THE TEE



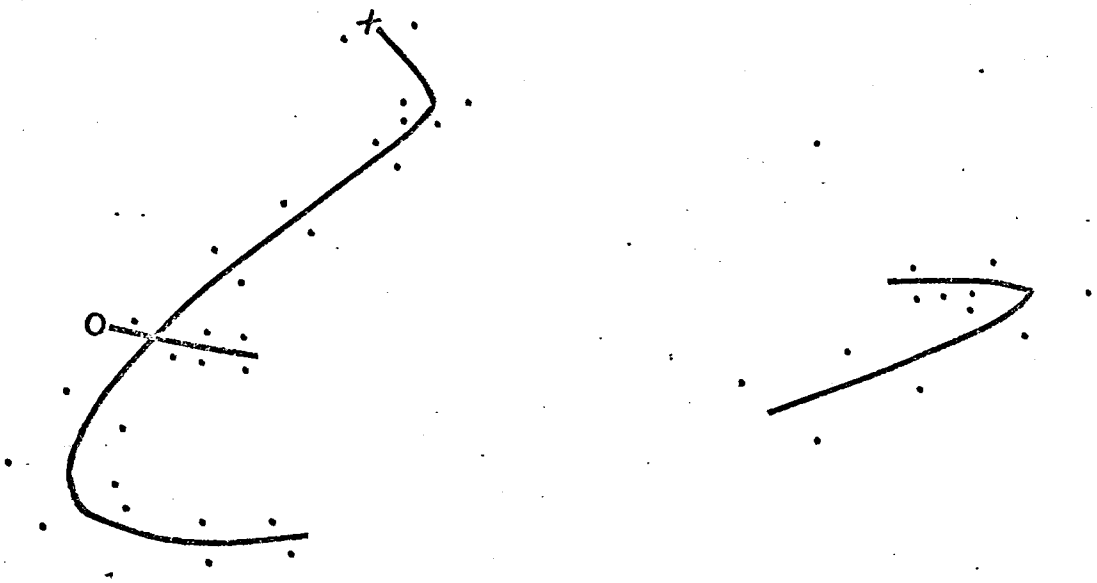
DEVELOPMENT OF LINE OF BEST FIT

SUBJECT SIX WITH THE TEE



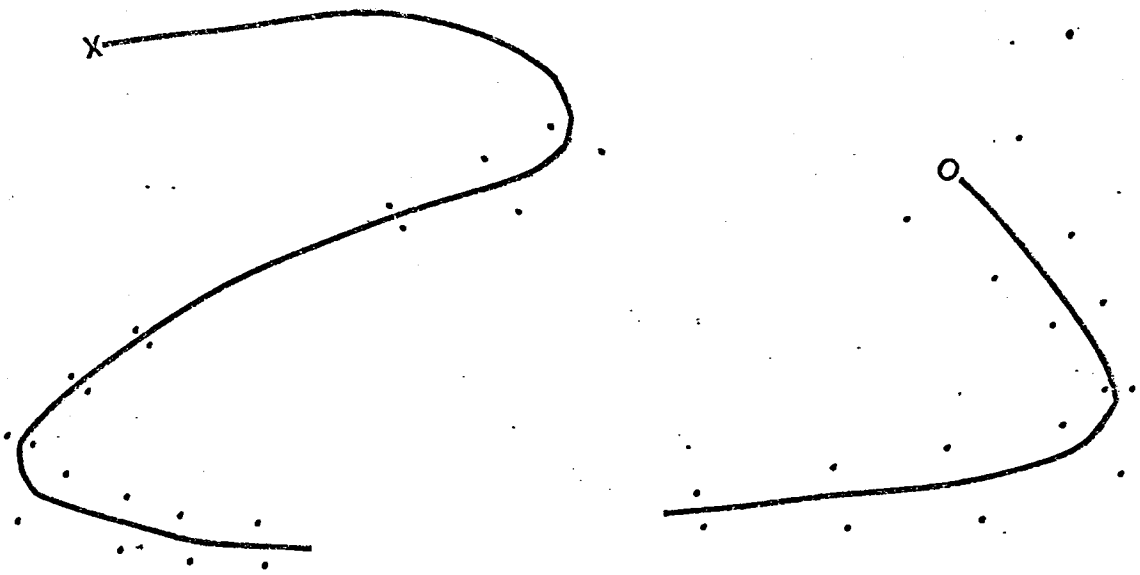
DEVELOPMENT OF LINE OF BEST FIT

SUBJECT SIX WITHOUT THE TEE



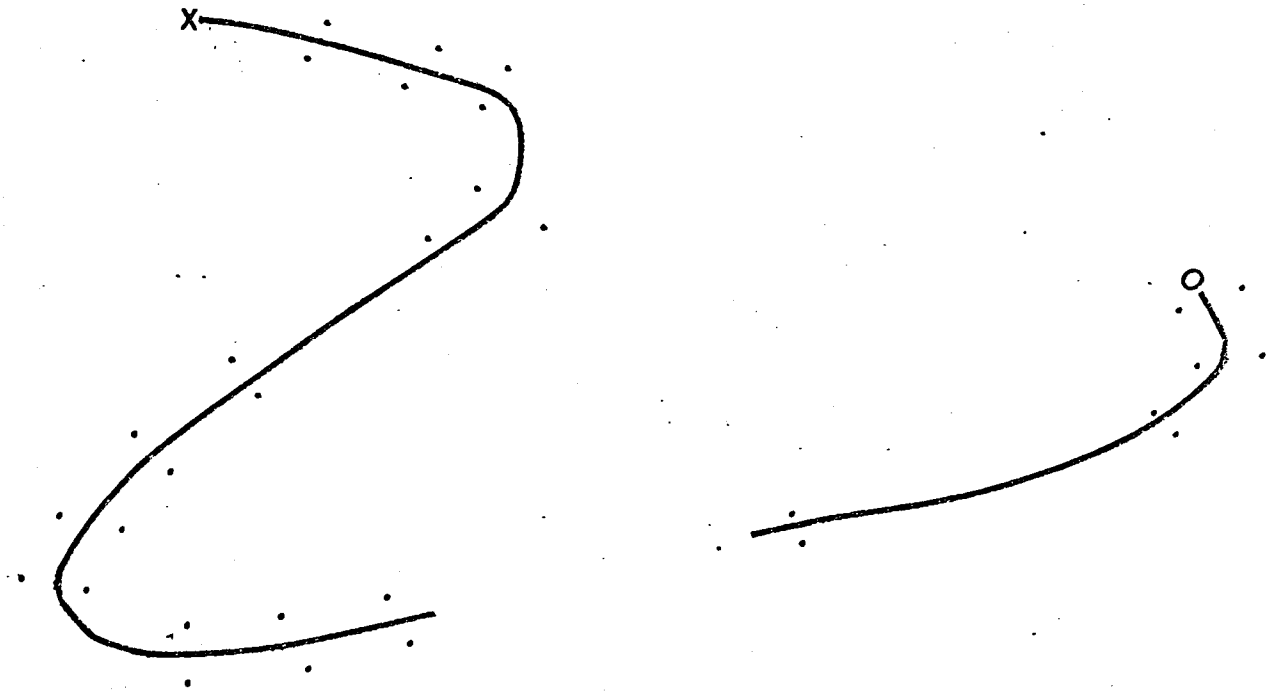
DEVELOPMENT OF LINE OF BEST FIT

SUBJECT SEVEN WITH THE TEE



DEVELOPMENT OF LINE OF BEST FIT

SUBJECT SEVEN WITHOUT THE TEE

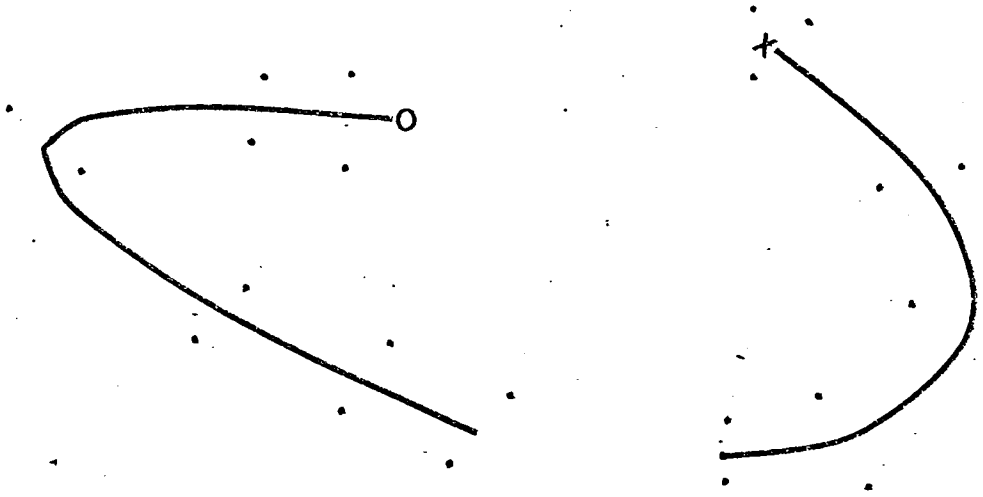


DEVELOPMENT OF LINE OF BEST FIT

SUBJECT EIGHT WITH THE TEE

DEVELOPMENT OF LINE OF BEST FIT

SUBJECT EIGHT WITHOUT THE TEE



APPENDIX H

MEAN SCORES OF ALL MEASURES AT CONTACT

Subject		Angle Lead Elbow	Angle Trail Elbow	Angle Trail Knee	Angle Trail Ankle	To Tee: Perpendicular Distance* Trail Hip	Trail Knee	Trail Ankle	Distance* Between Hands	Elbows
1-L**	With	169.5	139	144.5	141.5	7.09	8.98	19.84	3.28	9.95
	Without	172	122	138.5	119	--	--	--	3.65	9.76
2	With	160.5	153	145.5	116.5	5.35	6.61	15.75	5.35	9.57
	Without	175	116.5	150.5	139	--	--	--	3.02	9.76
3-H**	With	152	124.5	160	134	11.18	14.17	23.78	6.42	13.73
	Without	175.5	102	161.5	128.5	--	--	--	4.91	12.47
4	With	167	113	147.5	81	15.75	17.32	26.3	4.91	11.21
	Without	170.5	113	148	145.5	--	--	--	4.91	11.02
5	With	139.5	124.5	149	148	13.23	13.54	21.73	4.54	12.60
	Without	159.5	130.5	142	133.5	--	--	--	3.46	11.02
6	With	163.5	132	140.5	114	7.87	10.08	20.79	5.98	11.65
	Without	172.5	140	145	146.5	--	--	--	6.30	11.21
7-L**	With	152.5	110	145	161	15.28	14.17	22.99	6.17	13.98
	Without	169.5	110.5	148	153	--	--	--	5.16	11.02
8	With	177.5	141.5	170.5	160	17.48	21.26	29.29	4.41	9.13
	Without	175	131.5	162.5	155	--	--	--	4.72	10.39

*Converted from centimeters from the film to inches in actual size through investigation conversion of 16x.

**"L"--Low Average Batters. "H"--High Average Batters.

APPENDIX I

ALL ANGLES--ALL PAIRS

With Tee

Subject 1		Subject 2		Subject 4		Subject 3	
119	125	142	138	117	124	145	143
134	130	137	140	128	134	144	141
132	129	131	143	131	138	147	148
152	162	129	146	137	139	136	142
153	158	130	134	144	148	139	142
159	161	140	140	152	148	139	140
141	150	145	141	147	152	135	141
131	132	147	145	145	155	136	137
158	143	148	155	141	139	125	144
135	132	149	155	154	131	123	142
154	138	148	155	156	118	122	148
171	164	154	159	111	108	139	147
165	165	155	149	138	125	139	150
164	164	149	146	153	151	150	154
164	162	149	159	154	150	150	156
180	172	145	149	155	155	153	156
176	171	124	147	147	151	150	155
154	160	136	123	147	146	149	156
156	144	148	129	152	142	130	136
152	137	159	132	170	170	125	138
162	138	161	139	149	143	133	154
165	136	155	138	154	148	137	159
159	135	153	138	145	153	137	166
146	125	150	130	152	151	150	170
136	123	148	127	152	157	172	170
132	122	142	116			159	174
		140	114			161	155
		180	167			162	155
		143	145			156	151
		143	145			160	152
		150	150			165	153
		154	144			162	150
		151	144			160	156
		149	148			162	156
		153	146			158	155
		150	143			141	129
		111	119				
		111	121				
		116	114				

(continued)

With Tee

Subject 5		Subject 6		Subject 7		Subject 8	
140	139	149	149	151	147	144	136
140	137	153	156	142	146	142	141
141	138	149	152	146	144	144	140
139	142	150	153	144	144	138	143
137	134	143	158	145	142	143	144
132	138	122	151	142	142	169	136
136	133	148	129	145	143	159	145
133	137	121	115	143	145	169	168
133	134	146	143	136	133	167	168
130	136	109	130	143	145	168	169
124	131	136	132	147	147	168	169
133	130	155	157	158	152	171	173
137	125	155	160	148	149	173	172
134	115	156	160	142	134	165	167
135	121	159	161	147	126	168	169
140	131	159	156	146	113		
166	147	157	157	100	134		
166	160	163	162				
164	164	140	141				
156	149	145	143				
132	128	147	143				
112	96	149	147				
84	111	149	142				
54	53	149	148				
167	169	151	146				
175	164	146	145				
149	153	142	143				
148	148	112	128				
151	155	122	132				
145	157	116	133				
107	130	114	134				
		109	124				
		105	115				
		103	117				
		102	113				
		102	115				

ALL ANGLES--ALL PAIRS

Without Tee

Subject 1		Subject 2		Subject 3		Subject 4	
131	135	125	131	130	155	123	119
136	140	131	130	133	150	126	123
141	140	131	130	138	136	127	125
142	144	133	129	137	149	128	125
145	148	133	135	138	144	132	130
146	150	133	135	145	147	121	129
149	148	136	129	143	146	129	138
153	158	130	130	144	141	149	142
152	163	130	125	147	148	152	149
156	165	121	129	138	147	150	154
156	161	125	129	144	144	126	148
157	152	169	161	137	153	131	143
143	162	154	157	140	155	129	165
150	146	152	162	144	161	165	162
127	132	155	164	146	160	41	47
134	139	169	118	150	160	97	91
147	149	144	97	154	159	152	144
171	165	124	150	140	131	119	108
170	161	139	141	146	143	141	141
174	170	148	149	160	158	169	170
164	168	153	150	159	160	161	161
137	143	155	152	147	157	164	163
145	152	152	153	161	161	155	154
150	153	151	151	160	164	146	132
155	148	153	156	160	164	120	68
154	158	161	156	166	165	155	138
120	121	156	170	170	165	159	133
134	132	167	151	168	168	161	134
130	143	162	145	142	138	165	146
		161	137	146	137	165	157
		146	136				
		121	131				
		151	162				
		164	164				
		166	161				
		161	155				
		158	146				
		48	174				
		34	112				

(continued)

Without Tee

Subject 5		Subject 5 continued		Subject 6		Subject 7		Subject 8	
139	144	164	158	149	152	149	144	129	139
142	146	154	159	154	155	143	141	131	138
143	139	152	155	155	155	147	145	130	137
140	136	151	157	148	154	141	144	138	133
138	134	153	159	151	153	138	141	133	130
137	130	144	120	123	155	142	145	125	128
135	123	159	138	110	158	140	136	133	135
139	118	148	159	150	121	139	136	139	145
129	120	131	142	148	118	138	141	169	169
132	131	120	136	152	141	136	134	152	136
133	131	121	130	153	136	144	141	155	165
135	134	124	127	151	135	145	146	162	167
134	139	126	117	145	126	150	160	156	161
131	132	123	118	147	143	156	156	156	151
119	118	136	130	165	162	160	150	157	150
112	117	135	136	167	170	156	131	172	178
120	141	138	142	162	164	146	125	160	162
89	121			162	160	105	102	162	165
153	145			160	143	106	159	159	164
156	128			168	168	125	127	163	168
138	148			151	139	143	143	164	165
158	166			149	146	161	160	163	170
165	163			156	154	162	162	165	173
157	158			156	155	163	164	166	169
149	147			153	147	164	166	161	166
136	120			153	146	165	162	144	147
98	100			133	137	158	156		
49	141			124	122	171	176		
175	159			120	138	173	175		
168	172			115	109	174	174		
143	140					172	176		
151	146								
154	150								
160	156								
162	156								
160	162								
161	162								

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