A Cinematographic Analysis of the Upper Extremity Movements of World Class Players Executing Two Basic Badminton Strokes.

James Richard Poole

Louisiana State University and Agricultural & Mechanical College

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A CINEMATOGRAPHIC ANALYSIS OF THE UPPER EXTREMITY MOVEMENTS OF WORLD CLASS PLAYERS EXECUTING TWO BASIC BADMINTON STROKES

A Dissertation

Submitted to the Graduate Faculty of the Louisiana State University and Agricultural and Mechanical College in partial fulfillment of the requirements for the degree of Doctor of Education in

The Department of Health, Physical, and Recreation Education

by

James Richard Poole
B.A., San Diego State College, 1955
M.A., San Diego State College, 1965
August, 1970
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ABSTRACT

The purpose of this study was to analyze the upper extremity movements of four world class badminton players executing the two basic strokes of the forehand smash and the backhand clear. The four players, each of whom was currently ranked as the number one player in his respective country, were photographed with a Paillard-Bolex 16mm movie camera at sixty frames per second while executing the two strokes of forehand smash and backhand clear. Calibrations for camera speed were undertaken prior to and at the conclusion of the filming.

The films were taken in one of the men's gymnasia at Northwestern Louisiana State College, Natchitoches, Louisiana. The subjects were filmed over a two day period because of their schedules of participation in the Sixteenth United States Open National Championships.

Two views were taken of each subject. These were: (1) side view of ninety degrees; and (2) front view. The camera lens was placed thirty-six feet from the subject to avoid perspective error and also to ensure that the entire field of activity would be photographed.

At least five filmings were made of each subject from both front and side positions of each stroke. Because of subject or camera operator errors, the number of filmings varied between a minimum of five and a maximum of seven.

Both horizontal and vertical lines were placed on the wall
behind the subject to facilitate accurate measurements. Two lines twenty-four inches apart located on the floor beneath the subject served as reference points for determining accurate distances.

The film was processed on a Versamat Kodak Processing machine and analyzed by use of the Eastman Kodak Recordak Film Reader. Tracings were made on transparent paper from the projections by the recordak.

Two types of measurements were employed to analyze the two strokes. These were: (1) measurement of the angles between the segments of the upper extremity to calculate angular velocities; and (2) conversion of the angular velocities into linear velocities. The strokes were then analyzed to determine the most important movements for each stroke.

The findings of this study were as follows:

1. All four subjects' data indicated that the wrist action was the most important contributor to the force of a forehand smash.

2. Only one subject depended on the elbow movement to get any appreciable final velocity in the forehand smash. This subject had the lowest final velocity on the smash.

3. The subject who attained the highest velocity on the racket head movement waited until .017 seconds before contact to apply the largest increase in velocity on the forehand smash.

4. All four subjects' data indicated that the wrist action was
the most important contributor to the force of a backhand clear.

5. Only one subject had an elbow movement velocity of at least ten feet per second at contact on the backhand clear.

6. Three of the four subjects' rackets were accelerating as contact was made with the shuttle on the backhand clear.

The following conclusions were drawn within the limitations of this study:

1. The most important contributor to the force of the forehand smash and the backhand clear was the wrist action.

2. The highest velocity on the forehand smash was achieved by the subject who delayed his greatest movement until .017 seconds before contact with the shuttle.

3. The highest final velocities on the backhand clear were achieved by the subjects whose velocities were increasing during the .017 seconds before contact with the shuttle.

4. All the subjects extended their arm and elbow above the head as these two strokes were executed but only one subject used the arm to achieve any significant contribution to the velocity of his stroke.
CHAPTER I

INTRODUCTION

I. BACKGROUND

The game of badminton is relatively new in the United States. It first reached popularity in the 1930's, dropped off during the years of World War II due, perhaps, to lack of facilities and has gained again in the 1950's and 1960's. Today it is taught in a large number of high schools and colleges throughout the country and in YMCA's and recreation centers.

Badminton is a game that involves striking techniques, but these techniques can vary greatly from a slow tempo to one which is quick and involves deception. This difference in tempo can be attributed to the equipment used. The lighter, smaller badminton racket does not have the potential force of the larger mass of the tennis racket. To compensate for this, the velocity of the racket is increased.

Leggett\(^1\) states that the shuttle, also lighter than other projected objects, does not follow the laws of a free falling body but is dependent upon air resistance. The resistance offered by the feathers slows the shuttle and causes it to drop sooner and more

abruptly than a ball of similar weight which starts on a similar path.

The stroke production of overhead forehand shots in badminton can be compared to throwing a baseball. It can also be compared to striking a tennis serve as much of the body balance and footwork is similar.

Scott\(^2\) stated that the force in badminton is obtained by arm swing, wrist snap and to some extent by transfer of weight and trunk extension, but there is usually less trunk rotation than occurs in most striking activities.

Broer\(^3\) indicated that the wrist snap at impact moves the racket through a long distance very rapidly. Both the lighter racket and the lighter object to be contacted makes the use of the wrist muscles possible without loss of control. She believed that wrist flexion followed by extension, which occurs in all strokes just before the bird is contacted, is responsible for most of the speed imparted to the bird.

The physical education teacher needs to know exactly what does happen in the badminton swing so that proper mechanics can be taught. The area of kinesiology concerning analysis of motion can play an important role in teaching. If skills are to be taught and poor performance corrected, the teacher must be able to break the activity down into parts and know the physical laws governing each of these


parts. At the present time many books are unclear as to the arm movements in overhead badminton strokes.

In analyzing badminton strokes, photography, or specifically cinematography, can be of benefit. Cinematography has been defined by Cureton as "an analysis of motion through the use of photography. A sequence of pictures is used to observe the various phases of the movements being studied."

Cooper and Glassow state that Eadweard Muybridge (1831-1904) contributed much to kinesiological investigation with his skill in photography. Muybridge achieved much of his fame when he successfully filmed a race horse with all four feet off the ground to help the then governor of California, Leland Stanford, win a bet. By using twenty-four fixed cameras and two portable batteries of twelve cameras each, he was able to take pictures of animals and people in action. By the use of a zoopraxiscope, he could move the pictures fast enough that actual movement was simulated.

Palmer related how the influence of motion pictures on children and youth has been the subject of extensive investigation by the Payne Fund Committee on Educational Research in Motion Pictures. This

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research was under the direction of Dr. W. W. Charters of Ohio State University and conducted from 1928-1933.

Cureton\(^7\) wrote an article in 1939 which explained how to analyze film, how to judge speed of movement, and what errors to avoid. He stated at that time that there had been a marked increase in the number of research studies which attempted to analyze athletic performances. Cureton felt that analysis of athletic performances was for the following purposes: (1) to estimate the major factors which govern performance and their relative importance; (2) to derive the scientific principles of coaching, including an understanding of the physical mechanics of the skill; and (3) to lay the basis for a philosophical interpretation of athletic performance based upon relatively accurate theoretical considerations subject to some degree of verification. Cureton felt that analytical work on film promised to contribute much to technical knowledge of athletic action.

The use of cinematography since 1940 has been extensive in physical education, particularly in the area of coaching and athletics. Many research articles have been completed in this area and some of the more pertinent studies will be discussed in the chapter on related literature.

Although there have been many articles on cinematography, very few studies have investigated what actually happens in a badminton

\(^7\)Cureton, loc. cit.
stroke. Barth did an analysis on the backhand drive shot using two different grips. Tetreault did an analysis of the short and deep serves in badminton. However, no study has been found that used expert players in analyzing the arm movements of the overhead smash and backhand clear strokes. This study was concerned with this problem.

II. THE PROBLEM

Statement of the Problem

The study was directed toward the following problem: what are the desirable upper extremity movements in executing the two badminton strokes of forehand smash and backhand clear? Are there differences in the upper extremity movements among expert players?

Purpose of the Study

The purpose of this study was to analyze the upper extremity movements, including the determination of angular and linear velocities, of four world class badminton players executing the two basic badminton strokes of the forehand smash and the backhand clear.

III. DEFINITION OF TERMS

Acceleration. Acceleration is the rate of change in velocity;


it may or may not be uniform and may be positive or negative.¹⁰

**Body angles.** Body angles were the angles drawn for each player which connected the various segments such as the racket, the forearm, and the arm.¹¹

**Cinematography.** Cinematography was the use of motion pictures to study athletic performance. A sequence of pictures is used to observe the various phases of movements being studied.¹²

**Elbow movement.** Elbow movement was the movement at the shoulder which caused the linear velocity of the elbow.

**Expert players.** Expert players were the four male players, each of whom was currently ranked number one in his respective country in men's singles.

**Linear motion.** Linear motion consists of motion in a straight line, from one point directly to another.¹³

**Overhead backhand clear.** This term referred to a stroke hit above the head on the backhand side of the body. The shuttle should fly high over the net and fall near the opponent's baseline.

**Overhead forehand smash.** This term referred to a stroke hit above the head on the forehand side of the body. The shuttle is hit as

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¹² Cureton, *loc. cit.*

¹³ Bunn, *op. cit.*, p. 5.
hard as possible so that the shuttle will fly low over the net on a
downward trajectory to land about 1/2 to 2/3 the way back in the
opponent's court.

Racket movement. Racket movement was the movement at the wrist
which caused the linear velocity of the racket head.

Rotary motion. Rotary motion is motion in which all points
describe circular arcs about a line or axis.14

Upper extremity segments. This term was defined as the three
segments of the arm, the forearm, and a combination of the wrist and
racket.

Velocity. Velocity is the rate of change of position in a
given direction.15

Wrist action of the clear. This term was defined as the
supination and extension of the wrist while executing a backhand clear.

Wrist action of the smash. This term was defined as the
pronation and flexion of the wrist while executing a forehand smash.

Wrist movement. Wrist movement was the movement at the elbow
which caused the linear velocity of the wrist.

Wrist snap. Wrist snap was the movement of the hand and wrist
from a hyperextended position to a position of full extension.

14 Williams and Lissner, op. cit., p. 147.
15 Bunn, op. cit., p. 22.
IV. DELIMITATIONS OF THE STUDY

The delimitations of this study were: (1) this study was limited to the analysis of four expert players, each of whom was currently ranked number one in his respective country in men's singles for the 1968-69 season; (2) the filming was done at Northwestern Louisiana State during the week of the Sixteenth United States Open National Badminton Tournament at Natchitoches, Louisiana, April 2 through 5, 1969; (3) the study was limited to two basic strokes and the analysis of these strokes was through photographic means; and (4) the motion pictures were taken during trial performances and not during actual play.

V. LIMITATIONS OF THE STUDY

The limitations of this study were: (1) the quality of the pictures did not allow the markings on the upper extremity segments of the subjects to be utilized; (2) five filmings may not have been sufficient for the subjects to demonstrate average performance; and (3) the accuracy of the measurements was limited by the framing rate (.017) and the shutter speed (1/304 sec.) of the camera.

VI. BASIC ASSUMPTIONS

For purposes of this study it was assumed that: (1) the four players were motivated sufficiently to produce their best results as all were volunteers; and (2) that at the time of the experiment the
players were approaching their peak condition and performance.

VII. NEED FOR STUDY

Motor skill depends upon the effective use of body levers. Instructors who attempt to help players improve their badminton stroke techniques must be familiar with the proper joint actions used in an effective stroke. They must know the mechanical principles involved and be able to apply these specific principles to the learning of the specific stroke.

A review of existing literature by this investigator indicated that the badminton instructor would have difficulty finding material which gives a scientific analysis of the upper extremity movements for the clear and smash strokes. It was believed that a comparative analysis of expert players would be of value in determining whether differences existed among the players in the way they executed the strokes.

It was hoped that the results of this dissertation would aid badminton players and teachers in improving performance and the teaching of basic badminton strokes.
CHAPTER II

REVIEW OF THE LITERATURE

The review of related literature was presented under three main headings: (1) books on badminton and analysis of motion; (2) studies related to research in the areas of throwing, striking, and hitting objects; and (3) studies related to research in the area of badminton.

I. BOOKS ON BADMINTON AND BOOKS ON ANALYSIS OF MOTION

Authors of books on badminton stress different key points and concepts when describing the badminton swing. Several have emphasized the "wrist snap" as the most important factor in the stroke. Jackson and Swan\(^1\) emphasized that the beginner could never hope to become even a mediocre player without a correct grip and adequate wrist-flexibility. They visualized this "flick" as an arm and wrist movement similar to that used by the whip artist. In describing the overhead stroke, it was emphasized that the wrist must maintain a lead in front of the racket. As the wrist passed overhead, it was "snapped" to bring the racket face quickly ahead of the wrist. This "added a movement" to that of the swing itself. In the wrist snap, the racket

face would suddenly come forward and downward faster if the "flick" was introduced (that is, if the wrist was suddenly withdrawn) just before contact.

Miller and Ley\(^2\) stated that wrist action was extremely important in all badminton strokes as it was used for power, control, and deception. The wrist was bent or cocked backward during the backswing and was kept cocked until just before the shuttle was hit. Then, the wrist was snapped forward to throw the racket head into the shuttle. They emphasized making the wrist action similar to that of snapping a whip or a towel, swatting a fly, or fly casting.

Devlin and Lardner\(^3\) emphasized that the racket was brought forward in a kind of throwing motion with the wrist remaining cocked. As the weight was transferred from the rear to the front foot, the elbow would straighten, and just before the bird was hit, the wrist would uncock, lending power to the stroke. It was further stated that the thumb should largely control the racket head speed on the backhand overhead clear.

Davidson and Smith\(^4\) stated that the wrist should lead the move-
ment in all badminton strokes. The elbow and arm were straightened upward toward the spot where you wanted to hit the bird. The wrist was bent back as this straightening occurred. As the hand came up overhead, the wrist would straighten quickly which brought the racket head up from behind rapidly. This important movement should be so timed that the action of the elbow and wrist would straighten the arm and racket just as the bird was hit. They also emphasized that the wrist flick was a very important part of every swing in badminton.

Davis\(^5\) used the analogy of "waving goodbye" to emphasize the wrist movement. He felt that the very strong bending of the wrist, or the "cocking" and "uncocking" of the wrist as it is usually called, imparted the real length and speed to the shots. It was further stated that the wrist should be uncocked only in the last two or three feet before the racket strikes the shuttle. The fact that the wrist was brought into play only at the very last part of the swing was stressed as being a vital factor in deception, as well as being able to change the shuttle's direction by simultaneously rotating the wrist.

Varner\(^6\) felt that the wrist was a very important factor in deciding whether an overhead shot was to be a clear, a dropshot or a smash. It was stated that the speed of the wrist, the degree of wrist action used, and the angle of the face of the racket at the moment of


contact determined the stroke (i.e., clear, drop or smash) being employed. It was further emphasized that wrist power alone was not sufficient to propel the shuttle from one end of the court to the other; it necessitated arm and shoulder power in addition to exact timing of the wrist snap.

Friedrich and Rutledge\(^7\) stated that a tense, rigid wrist was an obvious deterrent to proper wrist action in hitting a shuttlecock. Arm and shoulder strength alone, without proper wrist action, would never provide sufficient power to propel the shuttlecock the desired distance on the court. Because of this, they suggested that many beginning players, although strong, are unable to make effective shots. They stated that the racket head made a definite, high pitched "swishing" sound when the player was using the wrist snap to good advantage.

Davidson and Gustavson\(^8\) emphasized that the forearm must rotate as part of the badminton swing. This rotation of the forearm was said to be necessary to get the face of the racket into a flat hitting position. Unless the forearm rotated, the player would hit with the edge of the racket. The authors maintained that if a player's power strokes lack snap and speed, this indicates that he has not rotated his forearm and wrist far enough. They felt that the last three feet of the racket's forward motion to strike the shuttle held the final


determining factor over hitting power, speed, control, and deception.

Authors of books on kinesiology and human movement have emphasized the need for proper techniques in teaching the analysis of motion. Each author has stressed different factors in teaching these techniques.

Rasch and Burke stated that it is very important that the coach not emphasize the contraction of specific muscles guiding athletes. Too much emphasis on kinesiology by many coaches has completely disorganized an athlete's performance by injudicious emphasis on specific muscle actions. It was also felt that the coach could err in the opposite direction and be too general in his instructions. For example, the tennis teacher's order to "hit the ball harder" may be quite ambiguous to a novice who is already stroking as hard as he can. It becomes meaningful to the learner when the coach is precise in his instructions and calls attention to the need for a longer preliminary backswing or a definite "step into the ball".

Scott felt that the development of motor performance, through acquisition of skills, is a unique contribution of physical education. She lists six purposes of kinesiology in physical education: (1) kinesiology should organize and make application of the facts and principles learned in the other basic sciences of anatomy, physics,

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and physiology. (2) Kinesiology should make an analysis and evaluation of activities by breaking it down into parts and comparing it with others. (3) This analysis of activities should make for better and easier teaching as the teacher emphasises certain parts for one student and other parts for another student. (4) The teacher should become more sensitive to poise and grace (or the lack of them) in other individuals so as to better understand the problems of efficiency and economy of movement. (5) Kinesiology should give a better understanding of posture. (6) The analysis of movement and understanding of standards should make the teacher more aware of irregular and unusual performance, and of abnormal structure.

Broer\(^\text{11}\) felt that the terms "good form" and "poor form" were frequently used in the execution of a motor skill. She was concerned with the fact that there is disagreement on what is good form for a particular skill. Historically, good form has been determined by analyzing the performance of an individual, or individuals, who have been usually successful in a particular activity. The concept of good form has changed from time to time because an individual who looked different from the accepted model demonstrated even greater success. There has been a failure to consider the possibility that an individual may be having success in spite of incorrect mechanics by compensation and extra expenditure of energy, or that an individual who uses his

body well mechanically may have certain mannerisms which, while they do not necessarily detract from his success, are not the reasons for it. Broer also stated that athletic performers and teachers "need to recognize that many somewhat different movements may be efficient and correct for a given purpose, depending upon the individual doing the performing." 

In summarizing the books on badminton and books on analysis of motion, the investigator found that all the authors indicated that wrist action of some degree was important. Some authors used the term "wrist snap" while others used the term "wrist flick". Seven authors of books on badminton stressed the wrist snap while only one author discussed rotation of the forearm along with use of the wrist. As this study was concerned with the relationship of wrist snap and forearm rotation to the success of a good stroke, it was noted that the authors have not agreed on how much wrist is used nor at what point it is employed. The books on analysis of motion have emphasized the importance of stressing the proper technique in teaching badminton, but the authors have not clearly specified the way to teach proper wrist action in the badminton strokes.

II. STUDIES RELATED TO RESEARCH IN THE AREAS OF THROWING, STRIKING, AND HITTING OBJECTS

Various researchers have conducted studies in the areas of

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12 Ibid.
(1) throwing a baseball, (2) hitting the baseball, and (3) striking a tennis ball. Because of the similarities of overhead badminton strokes to throwing a baseball or hitting a tennis serve, these studies have been included.

Collins¹³ compared the body mechanics of two different throws, overarm and sidearm. In the overarm throw the subjects made a conscious effort to keep the elbow at 90 degrees of flexion. She marked the subjects with special markings on the spinal and pelvic areas, and the arm and wrist area. She measured the range of angular movement, the contributions of each of the acting joints to the total velocity applied to the ball, and also compared the relationship of the joint summation of velocities to the measured velocity of the ball.

Lyon¹⁴ attempted to determine whether there was a definite pattern of joint movement which enabled one pitcher to throw with a greater velocity than another. He also wished to demonstrate the use of cinematography as a coaching aid. Markings were placed on the throwing shoulder and on the throwing arm of each subject. Angles were drawn and measured of the following areas: (1) hip flexion, (2) spinal abduction, (3) elbow extension, (4) rotation of humerus, (5) wrist flexion, (6) ankle extension, (7) knee extension, (8) shoulder abduction, (9) shoulder flexion, and (10) spinal rotation.


Quandt\textsuperscript{15} compared the pattern of joint movement in a fast ball with that of a change of pace pitch (palm ball). He used only one subject, Warren Spahn. He found certain anatomical landmarks on the film tracings and placed lines on the subject which joined these landmarks. A protractor was used to determine the angle of each joint action. The joint actions measured were: (1) left ankle extension, (2) left knee extension, (3) hip flexion, (4) angle of spine with horizontal, (5) spinal-clavicular angle, (6) shoulder abduction, (7) rotation of humerus, and (8) wrist flexion. Quant also measured the initial velocity for each pitch at moment of release.

Bowne\textsuperscript{16} used cinematography to determine the relationship between selected measures of body levers contributing to throwing and the velocities achieved with balls in both overhand and underhand throws using a softball and baseball. The lever variables selected for study included structure length measures and moment-arm measures of the selected acting body length. Acting levers included those for trunk rotation, for medial rotation of arm, for flexion of arm and for flexion of wrist. Moment-arm and throwing velocity data were obtained from motion picture films, tracings and measuring procedures. Structure length data were obtained by use of standard anthropometric


measurement techniques. She concluded that a study of the table of sums of moment-arm measures by groups indicated that at moment of release of ball a position of body segments which permitted the longest trunk lever moment-arm and the shortest arm lever moment-arm for medial rotation favored the achievement of better overhand throwing velocity with these subjects.

In analyzing hitting in baseball, several studies have been completed using either professional or college batters as subjects. Race\textsuperscript{17} studied seventeen proficient professional hitters of the Eastern League. Each hitter was analyzed only in the portions of the film showing the movements involved in effective hitting. That is, each was analyzed hitting a baseball for a very considerable distance or very sharply with a relatively flat trajectory that carried the ball beyond the limits of the infielders in their normal positions. The emphasis of the mechanical analysis was on the phases of the batting movements toward the path of the baseball and terminating at the instant the hitter's bat contacted the baseball. The findings of this study indicated that the rotary motion initiated by rather dramatic hip rotation and culminated by quick and powerful wrist action is paramount among the movements employed by professional hitters while engaged in effective hitting.

\textsuperscript{17}Donald Race, "A Cinematographic and Mechanical Analysis of the External Movement Involved in Hitting a Baseball Effectively," \textit{Research Quarterly} (October, 1961), pp. 394-404.
Watkins\textsuperscript{18} studied the effectiveness of motion pictures as an instructional aid in the correcting of batting faults in baseball. Twenty subjects from the varsity squad at the University of Iowa served as subjects and were divided into a control group and an experimental group. The findings would appear to warrant the conclusion that baseball batters who view motion pictures of their batting can significantly decrease the number of their batting faults as compared to baseball players who do not view motion pictures of their batting.

Nieman\textsuperscript{19} investigated whether successful college varsity batters utilized the basic fundamentals of hitting more frequently than unsuccessful college varsity batters. Six batters, classified as successful and unsuccessful by previous year's batting average, were filmed. Each batter took ten swings at selected pitches. Nine fundamentals were analyzed with 540 possible points in the sixty swings. It was considered an error if each point was not properly executed, with analysis being done on a subjective basis. Nieman concluded that successful hitters did not necessarily utilize correct batting fundamentals.

In the area of striking a tennis ball, two studies have been

\textsuperscript{18}\footnote{David Watkins, "Motion Pictures as an Aid in Correcting Baseball Batting Faults," \textit{Research Quarterly} (May, 1963), pp. 228-233.}

completed using cinematography. Johnson analyzed the tennis serve of advanced women players and listed four purposes. These were: (1) to determine the relationship between speed and accuracy of the slice service of advanced women players; (2) to analyze and compare the serving movements of these players; (3) to compare the serves, measured in terms of speed and accuracy, with the movements used in serving; and (4) to propose a practice serving target for advanced women players.

Each of the ten subjects hit twenty trial serves of their best slice first service. Measurements of service grip, placement of serve in court and time lapse from moment of impact to moment of contact with the court were obtained. Velocity and accuracy were calculated from the recordings of time and placement for each serve. The analysis of the serving movements used by these subjects was then compared with the rankings based on the evaluations of their serves. Johnson reported the following conclusions: (1) there was no relationship between speed and accuracy of the slice serves hit by these advanced women players; (2) in general, the fundamental gross movements used in serving were similar for all subjects; (3) differences which were observed in the various parts of the serving movements used by those subjects appeared to be significantly related to success in serving as follows: a) all of the subjects who used the continental grip were ranked above those subjects who used eastern forehand grip; b) degree of body rotation and

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backward bend was positively related to success in serving; and c) importance of arm extension at impact was emphasized, since the only subject who used a bent arm during the forward swing was ranked last.

Gelner conducted a study to determine the methods used to achieve horizontal (right-to-left) accuracy in the tennis forehand drive. Overhead and side views were taken of two skilled players using forehand drives to hit balls to line targets on right and left sides of the court. Twenty-five drives (thirteen right and twelve left) for which ball-racket contact was shown on the overhead view were analyzed. The following measures were identified by Gelner: (1) departing ball direction, ball distance from target, angle of incidence and angle of rebound, ball-body relationships, foot (left) direction, step direction, wrist angle-wrist movement, forearm line, elbow angle, humerus line, shoulder angle, shoulder line (inclination) spinal line, shoulder protraction, pelvic line, spinal rotation, and stroke path. It was concluded that a skilled player repeats a pattern of movement when hitting in the same direction and that there was little difference between the two skilled players in patterns of movement.

In summarizing the area of studies on throwing, striking, and hitting objects, the investigator found that four studies were done on throwing: one compared the overarm to sidearm throws; another investigated velocity of the ball; a third compared the pattern of movement

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in two different pitches; and the last compared the overhand and underhand throws. In the area of hitting a baseball, three studies were completed: one analyzed movements of "effective" professionals; another used motion pictures for instruction; and the last investigated to see if basic fundamentals were necessary for successful hitters. In the area of hitting a tennis ball, two studies were completed: one investigated the serve of advanced women players looking for a relationship between speed and accuracy on the slice service while the other study compared the body changes for a skilled player to hit straight or cross-court forehand drives.

As very little research has been completed in analyzing badminton strokes, the above studies show how activities similar to badminton such as throwing and striking can be utilized to better understand what probably occurs in a badminton swing.

III. STUDIES RELATED TO RESEARCH IN THE AREA OF BADMINTON

Several studies have been conducted in the area of badminton. Jones\textsuperscript{22} conducted a study to determine what value motion pictures taken of each student would be as an instructional device in learning to perform two badminton serves. The serves chosen were the long and short service, because control and experimental groups could conveniently be

\textsuperscript{22}Margaret Lois Jones, "The Use of an Experimental Study in Motion Pictures of Individuals Device in Teaching Badminton Techniques," (microcarded Master's thesis, Smith College, 1947).
The performances could be measured objectively and fairly acceptable reliability could be attained. She concluded that the range of ability was too great for groups to give evidence of a truly significant gain. One hundred percent of the students felt that the movies aided them in learning these two skills.

Gray\textsuperscript{23} investigated the effect of daylight projection of film loops on learning of badminton. He divided his subjects into four groups, two experimental and two control. The experimental classes were shown home-produced film loops of seven badminton strokes. On the basis of the results of a battery of skill tests, the following conclusions were drawn: (1) the film-loop group gained significantly in the first six week period over the controls; (2) both groups improved significantly at end of instruction period, based on results of battery of three skill tests; (3) at the end of the course, the experimental and control groups were similar; and (4) students believed that film loops were valuable.

Karsner\textsuperscript{24} compared the effectiveness of the lecture-demonstration method of instruction in the basic strokes used in badminton without motion-picture loops with the effectiveness of instruction with motion-picture loops. It was concluded that there were no significant

\begin{flushright}
\textsuperscript{24}Milo Gist Karsner, "An Evaluation of Motion-Picture Loops in Group Instruction in Badminton," (microcarded Doctoral dissertation, State University of Iowa, 1953).
\end{flushright}
differences between the groups at the end of the course although the
subjects felt that the use of motion-picture loops were valuable.

Mikesell\textsuperscript{25} compared the effectiveness of two teaching approaches
for beginning badminton. The control group was taught with the tradi-
tional method, but the experimental group had an emphasis on the
understanding of mechanical principles and their application to each
phase of instruction. The following conclusions were drawn after ten
weeks of instruction: (1) the experimental and control groups did not
differ significantly in learning achievement; and (2) the time spent on
an emphasis of understanding and applying the mechanical principles did
not deter from the final achievement of the experimental group.

Miller\textsuperscript{26} compared the effectiveness of high school badminton
instruction when given in two short units with one continuous unit
involving the same total time. Thirty girls were given six weeks of
continuous instruction in badminton, and were then compared with an
equal number of girls who had received two three-week periods of
instruction with fourteen weeks between periods of instruction. It was
concluded that the differences between the two groups were not
statistically significant.

\textsuperscript{25}Deloris Joan Mikesell, "The Effect of Mechanical Principle
Centered Instruction on the Acquisition of Badminton Skills,"

\textsuperscript{26}Susan Elizabeth Miller, "The Relative Effectiveness of High
School Badminton Instruction When Given in Two Short Units and One
Continuous Unit Involving the Same Total Time," (microcarded Master's
Thorpe investigated the relationship of intelligence and skill to success achieved by college women in badminton and tennis singles competition. The subjects were given either two badminton or two tennis skills tests and also the Otis Mental Ability Test. Round robin tournaments were played according to the skill test results and these results were correlated with skill and intelligence. Success in the tournament correlated .65 with skill in badminton and .60 with skill in tennis but correlations of skill and success with intelligence were practically zero. Success of the group with higher skill was significantly greater in each sport than for the lower skill group with intelligence held constant, but the success of the more intelligent group was not significantly greater in either sport with skill held constant.

Francis conducted a study to determine certain time, motion, and time-motion factors in eight athletic sports of which one was badminton. Six time factors, fifteen motion factors, and four time-motion factors were studied in thirty-six games of badminton. These were studied in six types of play, namely, men's and women's singles, men's and women's doubles, and mixed doubles. An example of time, motion,


and time-motion factors found in analyzing average players in men's singles was that in one game the man traveled on the average over a half mile at high speed and .05 of a mile at low speed, made 141 acute turns, propelled his weight in a vertical direction off the floor over 17 times, and hit the shuttle over 181 times, using at least six different types of strokes. All this he did in slightly over eight minutes and three seconds. While doing this, he executed his acute turns at a rate of 17.51 times a minute, and his hits at a rate of 22.5 times a minute. During his performance, he propelled his body off the floor approximately once every thirty seconds or 2.01 times per minute.

Smith$^{29}$ investigated whether badminton or tennis players disclosed their intentions through unconscious motor movements discernible by their opponents. Questionnaires were sent to top amateur and professional tennis and badminton players, and replies were received from twenty-seven tennis players and seven badminton players. From this questionnaire it was concluded that those "experts" felt their opponents did display "intention-displaying movements" by bodily movements.

Tergersen$^{30}$ investigated the relationship of selected measures of wrist strength, vision, and general motor ability to badminton playing ability. Subjects who had just finished a semester of badminton playing ability.

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were given the French Short Serve and Clear Tests and the Miller Wall Volley Test. Motor ability was measured by the Scott Test, palmar and dorsal flexion by a tensiometer, temporal vision by a perimeter, and depth perception by the Howard-Dolman apparatus. It was found that total badminton playing ability correlated significantly with general motor ability, depth perception, and peripheral vision. The wall volley correlated significantly with motor ability and depth perception. The better and poorer six players differed significantly in motor ability, depth perception, and peripheral vision but not in total wrist strength.

Ikeda\textsuperscript{31} attempted to determine the relationship of selected measures of wrist flexibility, kinesthesis, and agility to badminton playing ability. During the last two weeks of an eight week badminton unit, a series of tests which included wrist flexibility, a shuttle race, and various measures of kinesthesis, such as arm forward, wrist extension, wrist flexion, target finger spread, supination-pronation and grip pressure, were administered to 72 women students. These test scores were compared to the results on the volley and clear badminton tests. There was no significant relationship between wrist flexibility, kinesthesis, or agility and badminton playing ability.

Lucey conducted a study to examine critically wrist action as it is related to the acquisition of skill in learning the game of badminton. Angular velocity and range of movement in the flexion and deviation planes of motion of the wrist were measured by the WSL Dynamic Wrist Tester developed by the author. To measure part-game learning a high serve test was devised. A round robin tournament and a badminton rating scale were also used to measure total game performance. Lucey concluded: (1) the WSL Dynamic Wrist Testor was a reliable instrument of measurement of angular velocity and range of motion of the wrist; and (2) the badminton high serve test and badminton rating scale were more reliable and valid as measuring instruments for proficiency in badminton than any existing published test of the same kind.

Tetreault conducted a study of three expert badminton players performing the deep serve normally used in singles and the short-low serve used predominantly in doubles. The author took 16mm films from two camera positions and analyzed the film to determine: (1) length of supporting base at start of swing; (2) use of backswing; (3) continuity of motion from backswing to forward swing; (4) portion of stroke during release of shuttle; (5) angle through which stroking arm rotated during forward swing; (6) degree of elbow flexion during forward swing, degree

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of wrist extension one frame prior to contact with shuttle; (7) degree of knee flexion and extension throughout forward swing; (8) degree of increase in body lean during stroking; (9) amount of forward movement of shoulder throughout forward swing; (10) point at which contact was made with shuttle; (11) shuttle velocity after contact with racket; and (12) angle of trajectory of shuttle after contact.

Barth compared the standard with the thumb-up grip on the racket for badminton backhand strokes. The author tried to determine the relative position of the arm segments at the end of the full backswing, the linear velocity of the racket in the two techniques of the backhand drive from end of full backswing to the contact with the shuttle, and the spatial and time relationships of the contribution of hand and racket, forearm, and upper arm levers to the whole pattern of movement. Barth reported the following conclusions: (1) a general pattern was shown in relation to the amount of flexion of the joints at the end of full backswing with the shoulder having greatest flexion, the wrist second, and the elbow third; (2) hand and racket lever had the greatest range of movement, the forearm second, and the upper arm the least flexion in the majority of the sequences; (3) in general, there was a positive relationship between average hand and racket lever velocity and total average racket velocity; (4) the hand and racket lever made the greatest contribution to racket velocity with the

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forearm lever second and upper arm lever third; and (5) the velocity of the racket was greater than the "summation of velocities." The hand and racket, forearm, and upper arm levers contributed approximately fifty percent to the total racket velocity.

In summarizing the research in the area of badminton, the investigator found that three studies were done using film loops or motion pictures to aid in instruction. In all three studies, no significant differences were noted in the control and experimental groups at the end of the course although all the students felt that the film or film loops were valuable. Two studies were done to investigate different ways of teaching badminton. One study taught application of mechanical principles to the experimental group while the other compared two short units of instruction against a single continuous unit. No statistically significant differences were found between the two groups. Other studies investigated relationship between intelligence and skill, time-motion factors, and intention-displaying movements. Three studies dealt with wrist strength, wrist flexibility, and wrist action. Two studies specifically used cinematography for analytical purposes. One analyzed the deep and short serves and the other compared the standard with the thumb-up grips on the backhand drive strokes.
CHAPTER III

PROCEDURES FOR THE STUDY

I. OVERVIEW

Four world class badminton players from the countries of Denmark, Malaysia, Scotland, and the United States were photographed while executing the two badminton strokes of forehand smash and backhand clear. Calibrations for camera speed were undertaken prior to and at the conclusion of the filming. The following data were determined for each subject: (1) the angles between the various upper extremity segments were measured to calculate angular velocities; and (2) the angular velocities of the various upper extremity segments were converted into linear velocities. A detailed analysis of each subject's performance was then undertaken in an attempt to determine the various upper extremity movements involved in these two previously mentioned strokes.

II. SUBJECTS

The four male subjects analyzed were the number one ranked singles players in their respective countries in the year 1968-69. All were volunteers and were selected by this writer as the best representatives of four different badminton areas of the world. These subjects participated in the Sixteenth United States Open National Championships.
at Northwestern State College in Natchitoches, Louisiana.

**Erland Kops.** Erland Kops was the number one player from Denmark. He was thirty-two years old, five feet ten inches tall, and weighed 180 pounds.

**Tan Aik Huang.** Tan Aik Huang was the number one player from Malaysia. He was twenty-four years old, five feet eleven inches tall, and weighed 161 pounds.

**Robert McCoig.** Robert McCoig was the number one player from Scotland. He was twenty-nine years old, five feet nine inches tall, and weighed 144 pounds.

**Jim Poole.** Jim Poole was the number one player from the United States. He was thirty-seven years old, six feet tall, and weighed 200 pounds.

III. CINEMATOGRAPHIC METHOD

**Photographic Equipment**

A Paillard-Bolex H16 Reflex camera was used to photograph the various upper extremity movements as the subjects executed the smash and clear strokes. The camera's speed was set at 64 frames per second and it was run with a $\frac{1}{2}$ open shutter (1/304 sec.).

Cine-Kodak 4-X 7224 reversal type 16mm movie film (black and white) was used in the filming.

**Camera Speed.** Although the camera was set at 64 frames per second, it was found that 64 frames actually took 1.0688 seconds to be transported through the film gate.
Calibration of Camera Speed. The speed of the camera was calibrated against the force of gravity upon a falling body. This was accomplished by the method proposed by Cureton. An iron ball was released in the plane of movement and photographed in the same field of vision and at the point where the strokes were filmed. The ball was dropped and filmed prior to and at the conclusion of the filming of the subjects. The following formula was used to calculate falling bodies:

\[ S = \frac{1}{2}gt^2 \]
\[ t^2 = \frac{S}{g} \]

\[ t^2 = \frac{8}{16.1} = .49072 \text{ seconds} \]
\[ t = .49072 = .704 \text{ seconds} \]

The time required for the ball to drop eight feet was .704 seconds, during which time forty-two frames were exposed. The time required for exposing sixty-four frames was 1.0688 seconds.

Time Per Frame. The time in hundredths of a second for each frame was recorded as the actual time which elapsed for a particular frame as calculated from the camera speed. The time per frame was a constant .017 seconds.

Location and Conditions of Filming

The films were taken in one of the men's gymnasium of Northwestern Louisiana State College, Natchitoches, Louisiana. The subjects

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were filmed over a two day period because of their schedules of participation in the Sixteenth United States Open National Championships.

There were two views taken of each subject:

1. **Side view of 90°**. The camera lens was placed at a distance of thirty-six feet from the racket side of the subject.

2. **Front view**. The camera lens was placed directly in front of the subject at a distance of thirty-six feet from the subject.

To minimize perspective error, the camera lens was placed thirty-six feet from the subject with a telephoto lens being used, thus providing a sufficient field of vision from the beginning through the completion of the movement. The camera was started and run for at least one second in order to allow it to reach its optimum operating speed before the shuttle was hit to the subject. Prior to each filming, the camera was rewound to ensure maximum operating speed.

The camera was locked in place on a stationary tripod. Tape marks were placed on the floor which allowed the camera lens to be positioned exactly thirty-six feet from the subjects on all of the filming. The camera lens was placed $4\frac{1}{2}$ feet from the floor, a distance which was approximately half way from the floor to the top of the subject's extended racket during his swing, thus allowing the photographing of the entire field of activity. The subjects used wood frame with steel shaft badminton rackets and feather shuttles.

At least five filmings were made of each subject from both front and side positions of each stroke. If the subject felt he had not hit
the shuttle correctly, or the person operating the camera felt that the subject might have been out of the camera frame, another picture was made. For this reason, the number of filmings varied for each subject from a minimum of five to a maximum of seven for each stroke.

The shuttle was hit to the subject from a position approximately thirty feet away by one of the other subjects who then became the target of the hits to ensure proper direction of the stroke. Three warmup hits were taken by each subject prior to the five to simulate game conditions.

A recording board indicating the type of stroke being executed and the number of the hit was placed in the field of view of the camera. Two pieces of Scotch Lite brand reflective tape on the floor, placed parallel twenty-four inches apart running toward the camera and in the same general area as the subject's feet, were also in the field of view. On the wall behind the subjects, a line of Scotch Lite tape 4½ feet from the floor and parallel to the floor served as a reference point for the horizontal axis. A second line perpendicular to the floor acted as the reference point for the vertical axis.

Since a regulation net would have interfered with the filming from the frontal view, a simulated net was placed twenty-one feet from the subject in the direction of his hit at the regulation five feet height. The net was constructed of kite string strung between two regulation net posts with one foot long pieces of white tape placed at two foot intervals to provide the necessary depth perception.
The string was measured for correct height with a tape measure.

**Method of Projection**

The film was processed on a Versamat Kodak Processing Machine, and a positive print was returned. The film was analyzed by use of an Eastman Kodak Recordak Film Reader. The recordak made it possible to project an image of the subject directly on a flat surface for both viewing and tracing.

Tracings were made on thin, transparent paper from the images projected by the recordak. A 4-H pencil was used in an attempt to reduce any errors that might result from using a softer lead. Angular measurements were determined from these tracings of the three segments of the upper extremity.

**Procedure for Analysis**

The film was placed in the recordak and prepared in the following manner: letters of the alphabet were scratched backwards (A, B, C, D, etc.) on one edge of the emulsion side of the film. The letter (A) was placed a few frames before the beginning of the forward phase of the upper extremity movements by the subject. This frame became Al. The next four frames were A2 through A5 and the fifth frame was labeled (8). This frame became B1. The next four frames were B2 through B5, etc.

In order to obtain the correct measurements of the projected
images on the screen a multiplier was used. This multiplier was obtained by using the two pieces of Scotch Lite brand reflecting tape, twenty-four inches apart, as reference points. These two lines served as a constant, making it possible to establish a multiplier. The linear measurements on the screen were multiplied by the constant, thus giving the actual size and distance. The following formula was used to obtain the multiplier:

\[
\frac{24 \text{ inches}}{x \text{ inches}} = \text{multiplier}
\]

\[
24 \text{ inches} = \text{actual distance between the two lines} \\
x \text{ inches} = \text{distance between lines on the screen} \\
\frac{24}{x} = Z \text{ inches} \\
Z = \text{multiplier}
\]

The multiplier was important in determining actual distances and was also used along with the horizontal and vertical lines to check the alignment of the transparent paper when tracing the reference points on the subjects.

IV. ANALYTICAL METHOD

Two types of measurements were employed to analyze the forehand smash and the backhand clear of the four world class badminton players. These were: (1) the measurement of the angles between the segments of the upper extremity to calculate angular velocities; and (2) conversion of these angular velocities into linear velocities by the use of

\[2^{nd} \text{Cureton, op. cit., p. 7-8.}\]
segment lengths.

Stick figures from the waist upward of the four players were used in determining the angular measurements. Reference points were plotted on the transparent paper and connected by straight lines. An article by Hubbard\(^3\) was helpful in determining the reference points. The reference points used were the following: (1) the center of the trunk at the waist; (2) the center of the trunk at the throat; (3) the center of the shoulder at the head of the humerus; (4) the center of the elbow; (5) the center of the wrist; and (6) the top of the racket head. See Appendix A for examples of the stick figures.

The following angles were measured and are shown in Figure 1:

1. the angle between the arm and a horizontal line (ABC);
2. the angle between the forearm and the arm (B'CD);
3. the angle between the racket and the forearm (C'DE).

These angle measurements were made for eight consecutive frames. The angular velocity was determined by dividing the differences in degrees between any two frames by the time per frame (.017). Tables II, IV, VI, in Chapter IV show the angular velocities for all four subjects on the forehand smash and Tables IX, XI, and XIII in Chapter IV show the angular velocities for the backhand clear. The linear velocity was then computed by utilizing the

Angle $ABC = \text{Upper arm with relation to a horizontal line.}$
Angle $B'CD = \text{Forearm with relation to upper arm.}$
Angle $C'DE = \text{Racket (wrist) with relation to forearm.}$

**FIGURE 1**

**AN ILLUSTRATION OF THE MANNER BY WHICH THE ANGLES WERE MEASURED FOR THE THREE SEGMENTS OF THE UPPER EXTREMITY**
following formula from Cooper and Glassow:

\[
\text{Linear Velocity} = \frac{\text{Angular Velocity}}{57.29} \times \text{Length of Segment}
\]

\[57.29 = \text{One radian}\]

Since one of the subjects had only one filming out of his five clear enough for analysis on the forehand smash, the writer used only one filming for each subject on both strokes. This one filming for the other three subjects was randomly selected from the best films which clearly showed the racket head and desirable angles for measurement. All tracings, measurement of angles, and computations were computed on three different occasions and the average of these values was used in the final data.

A detailed analysis of each subject's performance was then undertaken to show the similarities and differences in the strokes of the four players.

CHAPTER IV

PRESENTATION AND ANALYSIS OF DATA

The purpose of the study was to analyze the upper extremity movements of four world class badminton players executing the two basic badminton strokes of the forehand smash and the backhand clear. The analysis was done by the cinematographic technique.

Angular velocities were first determined for all three upper extremity segments and these velocities were then converted into linear velocities. Measurements were taken of the four subjects at the time of the filming and the lengths of the three segments used in determining the linear velocities is shown in Table I. After calculating the linear velocities, the two strokes were analyzed to determine the most important movements for each stroke.

I. ANALYSIS OF THE UPPER EXTREMITY MOVEMENTS ON THE FOREHAND SMASH

The material on the forehand smash was reviewed in the following manner: (1) the elbow movement of all four players was analyzed utilizing Table III on page 48; (2) the wrist movement of all four players was analyzed utilizing Table V on page 50; (3) the racket head movement of all four players was analyzed utilizing Table VII on page 52; (4) the total final velocity of all three segments was analyzed utilizing Table VIII on page 53; and (5) the percentages of total final velocity for the three segments was presented in Table IX on page 54.
### TABLE I

LENGTHS OF THE THREE SEGMENTS OF THE UPPER EXTREMITY WHICH WERE USED IN DETERMINING THE LINEAR VELOCITIES OF THE FOREHAND SMASH AND BACKHAND CLEAR STROKES OF FOUR BADMINTON PLAYERS

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Length of Arm in Inches</th>
<th>Length of Forearm in Inches</th>
<th>Distance from Wrist to Middle of Racket in Inches</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kops</td>
<td>12.2</td>
<td>10.8</td>
<td>22.0</td>
</tr>
<tr>
<td>Aik Huang</td>
<td>11.1</td>
<td>10.8</td>
<td>22.1</td>
</tr>
<tr>
<td>McCoig</td>
<td>12.2</td>
<td>10.2</td>
<td>22.0</td>
</tr>
<tr>
<td>Poole</td>
<td>12.6</td>
<td>11.8</td>
<td>22.2</td>
</tr>
</tbody>
</table>
In Tables II, IV, VI, X, XII, and XIV, the angular velocities were computed for the six consecutive frames before contact and the first frame after contact with the shuttle. Frames 1 through 6 were before contact and frame 7 was after contact with the shuttle. All angular velocities were derived from the degree differences between frames. For example, frame 1 of Kops had a degree measurement of 112°. Frame 2 had a degree measurement of 94°. The difference in degrees between frame 1 and 2 was 18°. This was calculated into an angular velocity of 1059° per second as shown in frames 1-2 in Table II on page 47. This angular velocity was converted into a linear velocity of 18.8 ft/sec. This number is shown under frames 1-2 for Kops in Table III.

As shown in the linear velocity in Table III, all four subjects initially used 18 to 29 ft/sec of elbow movement. By the time of contact, however, all subjects had lost most of their elbow velocities with Aik Huang dropping to zero (0) velocity. McCoig had the only velocity of any consequence. His elbow was moving 15.6 ft/sec at the time of contact. This indicated that he used more movement of his arm in the smash than did the other three subjects. The tracings of the eight consecutive frames which are located in Appendix A showed that all four subjects had the upper arm raised above the head at the point of contact with the shuttle.

Table V shows the linear velocity of the wrist movement for all four players. All four subjects showed increases, followed by decreases, and increases again before contact. There did not appear to
be any pattern in the subjects' velocities. It was noted that Kops, Aik Huang, and McCoig decreased between the last two velocities shown in the table, while Poole increased slightly.

Table VII presents the linear velocity of the racket head movement for all four players. As can be seen by comparing the feet per second for Tables III, V, and VII, the linear velocity of the racket head movement was considerably greater than the other two segment movements. As shown in Table VII, Kops attained his highest velocity at contact as did Aik Huang, although Kops had a 41 ft/sec higher velocity than did Aik Huang. Both McCoig and Poole decreased between the last two velocities with Poole still showing a 25 ft/sec higher velocity than McCoig.

In Table VIII, the total final velocities for each subject were computed by combining the three upper extremity movements of the elbow, wrist, and racket head. All four subjects' data indicated that the wrist action was the most important contributor to the force of a smash. This combination of pronation and flexion of the wrist was especially important for Kops and Poole as very little velocity was shown for these subjects on the other two segments. As shown in the table, Aik Huang realized zero (0) velocity from the elbow movement while achieving 13.8 ft/sec from the wrist movement. McCoig almost reversed this as he obtained less than one foot per second from the wrist movement while receiving 15.6 ft/sec from the elbow movement. There was a 69 feet per second difference between the highest total final velocity for Kops and the lowest final velocity for McCoig.
Table IX shows the percentages of total final velocity for the three segments. As shown, Kops received 92 percent of his final velocity from wrist action with McCoig receiving 76 percent. Both Aik Huang and Poole placed between these extremes with 86 and 89 percent respectively. Aik Huang received 14 percent from wrist movement while McCoig received 23 percent from elbow movement.
### TABLE II

**Angular Velocity of the Elbow for the Six Consecutive Frames Before Contact and the First Frame After Contact with the Shuttle of Four Badminton Players Executing a Forehand Smash**

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Frames 1-2 Deg/Sec</th>
<th>Frames 2-3 Deg/Sec</th>
<th>Frames 3-4 Deg/Sec</th>
<th>Frames 4-5 Deg/Sec</th>
<th>Frames 5-6 Deg/Sec</th>
<th>Frames 6-7 Deg/Sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kops</td>
<td>1059</td>
<td>823</td>
<td>529</td>
<td>588</td>
<td>529</td>
<td>471</td>
</tr>
<tr>
<td>Aik Huang</td>
<td>1412</td>
<td>588</td>
<td>1176</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>McCoig</td>
<td>1647</td>
<td>353</td>
<td>529</td>
<td>118</td>
<td>176</td>
<td>882</td>
</tr>
<tr>
<td>Poole</td>
<td>1118</td>
<td>1353</td>
<td>529</td>
<td>235</td>
<td>706</td>
<td>235</td>
</tr>
</tbody>
</table>

* Time in seconds before racket contacted shuttle.
TABLE III

LINEAR VELOCITY OF THE ELBOW FOR THE SIX CONSECUTIVE FRAMES BEFORE CONTACT AND THE FIRST FRAME AFTER CONTACT WITH THE SHUTTLE OF FOUR BADMINTON PLAYERS EXECUTING A FOREHAND SMASH

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Frames 1-2 (Ft/Sec)</th>
<th>Frames 2-3 (Ft/Sec)</th>
<th>Frames 3-4 (Ft/Sec)</th>
<th>Frames 4-5 (Ft/Sec)</th>
<th>Frames 5-6 (Ft/Sec)</th>
<th>Frames 6-7 (Ft/Sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kops</td>
<td>18.8</td>
<td>14.6</td>
<td>9.4</td>
<td>10.4</td>
<td>9.4</td>
<td>8.4</td>
</tr>
<tr>
<td>Aik Huang</td>
<td>22.8</td>
<td>9.5</td>
<td>18.9</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>McCoig</td>
<td>29.2</td>
<td>6.2</td>
<td>9.4</td>
<td>2.1</td>
<td>3.1</td>
<td>15.6</td>
</tr>
<tr>
<td>Poole</td>
<td>20.5</td>
<td>24.8</td>
<td>9.7</td>
<td>4.3</td>
<td>12.8</td>
<td>4.3</td>
</tr>
</tbody>
</table>
TABLE IV

ANGULAR VELOCITY OF THE WRIST FOR THE SIX CONSECUTIVE FRAMES BEFORE CONTACT AND THE FIRST FRAME AFTER CONTACT WITH THE SHUTTLE OF FOUR BADMINTON PLAYERS EXECUTING A FOREHAND SMASH

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Frames 1-2 (Deg/Sec)</th>
<th>Frames 2-3 (Deg/Sec)</th>
<th>Frames 3-4 (Deg/Sec)</th>
<th>Frames 4-5 (Deg/Sec)</th>
<th>Frames 5-6 (Deg/Sec)</th>
<th>Frames 6-7 (Deg/Sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kops</td>
<td>412</td>
<td>1294</td>
<td>765</td>
<td>1118</td>
<td>2353</td>
<td>235</td>
</tr>
<tr>
<td>Aik Huang</td>
<td>294</td>
<td>882</td>
<td>882</td>
<td>2235</td>
<td>941</td>
<td>882</td>
</tr>
<tr>
<td>McCoig</td>
<td>1353</td>
<td>529</td>
<td>1823</td>
<td>1470</td>
<td>1294</td>
<td>59</td>
</tr>
<tr>
<td>Poole</td>
<td>941</td>
<td>588</td>
<td>706</td>
<td>1941</td>
<td>176</td>
<td>294</td>
</tr>
</tbody>
</table>
TABLE V

LINEAR VELOCITY OF THE WRIST FOR THE SIX CONSECUTIVE FRAMES BEFORE CONTACT AND THE FIRST FRAME AFTER CONTACT WITH THE SHUTTLE OF FOUR BADMINTON PLAYERS EXECUTING A FOREHAND SMASH

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Frames 1-2 (Ft/Sec)</th>
<th>Frames 2-3 (Ft/Sec)</th>
<th>Frames 3-4 (Ft/Sec)</th>
<th>Frames 4-5 (Ft/Sec)</th>
<th>Frames 5-6 (Ft/Sec)</th>
<th>Frames 6-7 (Ft/Sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kops</td>
<td>6.5</td>
<td>20.3</td>
<td>12.0</td>
<td>17.5</td>
<td>36.9</td>
<td>3.7</td>
</tr>
<tr>
<td>Aik Huang</td>
<td>4.6</td>
<td>13.8</td>
<td>13.8</td>
<td>35.1</td>
<td>14.8</td>
<td>13.8</td>
</tr>
<tr>
<td>McCoig</td>
<td>20.0</td>
<td>7.8</td>
<td>27.0</td>
<td>21.8</td>
<td>19.2</td>
<td>.9</td>
</tr>
<tr>
<td>Poole</td>
<td>16.1</td>
<td>10.1</td>
<td>12.1</td>
<td>33.3</td>
<td>3.0</td>
<td>5.0</td>
</tr>
</tbody>
</table>
TABLE VI

ANGULAR VELOCITY OF THE RACKET HEAD FOR THE SIX CONSECUTIVE FRAMES BEFORE CONTACT AND THE FIRST FRAME AFTER CONTACT WITH THE SHUTTLE OF FOUR BADMINTON PLAYERS EXECUTING A FOREHAND SMASH

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Frames 1-2 (Deg/Sec)</th>
<th>Frames 2-3 (Deg/Sec)</th>
<th>Frames 3-4 (Deg/Sec)</th>
<th>Frames 4-5 (Deg/Sec)</th>
<th>Frames 5-6 (Deg/Sec)</th>
<th>Frames 6-7 (Deg/Sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kops</td>
<td>294</td>
<td>1765</td>
<td>118</td>
<td>412</td>
<td>588</td>
<td>3941</td>
</tr>
<tr>
<td>Aik Huang</td>
<td>588</td>
<td>529</td>
<td>412</td>
<td>2000</td>
<td>1941</td>
<td>2647</td>
</tr>
<tr>
<td>McCoig</td>
<td>235</td>
<td>59</td>
<td>647</td>
<td>412</td>
<td>2176</td>
<td>1647</td>
</tr>
<tr>
<td>Poole</td>
<td>471</td>
<td>647</td>
<td>706</td>
<td>235</td>
<td>3941</td>
<td>2412</td>
</tr>
</tbody>
</table>
### TABLE VII

**LINEAR VELOCITY OF THE RACKET HEAD FOR THE SIX CONSECUTIVE FRAMES BEFORE CONTACT AND THE FIRST FRAME AFTER CONTACT WITH THE SHUTTLE OF FOUR BADMINTON PLAYERS EXECUTING A FOREHAND SMASH**

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Frames 1-2 (.102) Ft/Sec</th>
<th>Frames 2-3 (.085) Ft/Sec</th>
<th>Frames 3-4 (.068) Ft/Sec</th>
<th>Frames 4-5 (.051) Ft/Sec</th>
<th>Frames 5-6 (.034) Ft/Sec</th>
<th>Frames 6-7 (.017) Ft/Sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kops</td>
<td>9.4</td>
<td>56.4</td>
<td>3.8</td>
<td>13.2</td>
<td>18.8</td>
<td>126.1</td>
</tr>
<tr>
<td>Aik Huang</td>
<td>18.9</td>
<td>17.0</td>
<td>13.2</td>
<td>64.3</td>
<td>62.4</td>
<td>85.0</td>
</tr>
<tr>
<td>McCoig</td>
<td>7.5</td>
<td>1.9</td>
<td>20.7</td>
<td>13.2</td>
<td>69.6</td>
<td>52.7</td>
</tr>
<tr>
<td>Poole</td>
<td>15.2</td>
<td>20.9</td>
<td>22.8</td>
<td>7.6</td>
<td>127.2</td>
<td>77.9</td>
</tr>
</tbody>
</table>
TABLE VIII

LINEAR VELOCITY OF THE THREE SEGMENTS OF THE UPPER EXTREMITY
AND TOTAL FINAL VELOCITY OF FOUR BADMINTON
PLAYERS EXECUTING A FOREHAND SMASH

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Velocity of Elbow Ft/Sec</th>
<th>Velocity of Wrist Ft/Sec</th>
<th>Velocity of Racket Head Ft/Sec</th>
<th>Total Final Velocity Ft/Sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kops</td>
<td>8.4</td>
<td>3.7</td>
<td>126.1</td>
<td>138.2</td>
</tr>
<tr>
<td>Aik Huang</td>
<td>0</td>
<td>13.8</td>
<td>85.0</td>
<td>98.8</td>
</tr>
<tr>
<td>McCoig</td>
<td>15.6</td>
<td>.9</td>
<td>52.7</td>
<td>69.2</td>
</tr>
<tr>
<td>Poole</td>
<td>4.3</td>
<td>5.0</td>
<td>77.9</td>
<td>87.2</td>
</tr>
</tbody>
</table>
TABLE IX

PERCENTAGES OF TOTAL FINAL VELOCITY FOR THE THREE SEGMENTS OF THE UPPER EXTREMITY OF FOUR BADMINTON PLAYERS EXECUTING A FOREHAND SMASH

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Percent of Total Final Velocity from Elbow Movement</th>
<th>Percent of Total Final Velocity from Wrist Movement</th>
<th>Percent of Total Final Velocity from Racket Head Movement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kops</td>
<td>6</td>
<td>2</td>
<td>92</td>
</tr>
<tr>
<td>Aik Huang</td>
<td>0</td>
<td>14</td>
<td>86</td>
</tr>
<tr>
<td>McCool</td>
<td>23</td>
<td>1</td>
<td>76</td>
</tr>
<tr>
<td>Poole</td>
<td>5</td>
<td>6</td>
<td>89</td>
</tr>
</tbody>
</table>
II. ANALYSIS OF THE UPPER EXTREMITY MOVEMENTS ON THE BACKHAND CLEAR

The material on the backhand clear was reviewed in the following manner: (1) the elbow movement of all four players was analyzed utilizing Table XI on page 59; (2) the wrist movement of all four players was analyzed utilizing Table XIII on page 61; (3) the racket head movement of all four players was analyzed utilizing Table XV on page 63; (4) the total final velocity of all three segments was analyzed utilizing Table XVI on page 64; and (5) the percentages of total final velocity for the three segments were presented in Table XVII on page 65.

As shown in Table XI, Kops and Aik Huang had zero (0) velocity of the elbow movement at time of contact with the shuttle. Poole had only 3.2 feet per second with McCoig having the largest elbow movement with 10.4 feet per second. The highest velocity by any subject during the seven frames measured was McCoig who had a velocity of 28.0 feet per second between the first two frames. All four subjects showed uneven velocities throughout the movement. Aik Huang was the only player whose elbow movement velocity did not move above five feet per second at any time during the stroke. The tracings in Appendix A show that all four subjects had the upper arm extended above the head as the shuttle was contacted. Kops had less arm extension than did the other three subjects.

Table XIII provides the velocities of the wrist movement for the four players on the backhand clear. As shown, all four subjects had a
larger velocity at the wrist than they did at the elbow. Kops, McCoig, and Poole increased between the last two frames shown before contact while Aik Huang decreased slightly. Kops, McCoig, and Poole had a similar wrist movement velocity pattern in that their velocities decreased, then increased, then decreased, and finally increased before contact. Aik Huang showed a different pattern in that his velocity decreased, then increased, and finally decreased before contact with the shuttle. Except for Aik Huang, the other three subjects showed velocities in the 20's at some time during the stroke. The highest velocity for Aik Huang was 14.8 feet per second which was slightly above his velocity of 10.1 feet per second at contact.

In Table XV, the velocities for the racket head are shown. The velocities of Kops, Aik Huang, and McCoig increased between the last two frames shown before contact while the velocity of the racket head of Poole markedly decreased from 64 feet per second to thirty feet per second. This would indicate that the racket was slowing up when contact was made with the shuttle. There was a 41 feet per second difference between the velocity of Aik Huang and the velocity of Poole at time of contact. A look at the overall pattern of the four subjects showed markedly different patterns. For example, it was seen that Kops kept his racket head velocity above thirty feet per second for the last five frames shown in the table; the velocities of Aik Huang remained at approximately two feet per second at frames 3-4 but increased rapidly in the last three frames; the velocities of McCoig increased rapidly in the last two frames; and the velocities of Poole
increased rapidly in frames 3-4 through 5-6, but decreased at the final frame.

Table XVI gives the final velocities for each subject by combining the last frames before contact of the elbow, wrist, and racket head movements. All four subjects' data indicated that wrist action was the most important contributor to the force of the backhand clear. As shown in the table, both Kops and Aik Huang received zero (0) velocity from the elbow movement, whereas McCoig received 10.4 feet per second from the elbow. Both McCoig and Poole received over twenty feet per second from the wrist movement. Aik Huang had the highest racket head velocity with 71.8 feet per second which was 28.5 feet per second higher than both Kops and McCoig who were the next highest. As shown in the table, Aik Huang also had the highest final velocity with 81.9 feet per second and Poole the lowest velocity with 55.8 feet per second.

Table XVII shows the percentages of total final velocity for the three segments. As shown, Aik Huang received 88 percent of his total velocity from wrist action (racket head movement) and Kops received 76 percent. Both McCoig and Poole received percentages in the 50's with 57 and 54 percent respectively. McCoig received thirteen percent from the arm movement which was considerably higher than the five percent of Poole who had the second highest percent. Both Kops and Aik Huang received zero (0) percentage of their final velocity from the elbow movement. Both McCoig and Poole received a large percent of their final velocity from the wrist movement getting thirty percent and forty percent respectively.
TABLE X

ANGULAR VELOCITY OF THE ELBOW FOR THE SIX CONSECUTIVE FRAMES BEFORE CONTACT AND THE FIRST FRAME AFTER CONTACT WITH THE SHUTTLE OF FOUR BADMINTON PLAYERS EXECUTING A BACKHAND CLEAR

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Frames 1-2 (Deg/Sec)</th>
<th>Frames 2-3 (Deg/Sec)</th>
<th>Frames 3-4 (Deg/Sec)</th>
<th>Frames 4-5 (Deg/Sec)</th>
<th>Frames 5-6 (Deg/Sec)</th>
<th>Frames 6-7 (Deg/Sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kops</td>
<td>1412</td>
<td>765</td>
<td>0</td>
<td>588</td>
<td>823</td>
<td>0</td>
</tr>
<tr>
<td>Aik Huang</td>
<td>59</td>
<td>118</td>
<td>0</td>
<td>294</td>
<td>118</td>
<td>0</td>
</tr>
<tr>
<td>McCoig</td>
<td>1588</td>
<td>294</td>
<td>471</td>
<td>353</td>
<td>176</td>
<td>588</td>
</tr>
<tr>
<td>Poole</td>
<td>823</td>
<td>647</td>
<td>1235</td>
<td>0</td>
<td>529</td>
<td>176</td>
</tr>
</tbody>
</table>
TABLE XI

LINEAR VELOCITY OF THE ELBOW FOR THE SIX CONSECUTIVE FRAMES BEFORE CONTACT AND THE FIRST FRAME AFTER CONTACT WITH THE SHUTTLE OF FOUR BADMINTON PLAYERS EXECUTING A BACKHAND CLEAR

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Frames 1-2 (.102) Ft/Sec</th>
<th>Frames 2-3 (.085) Ft/Sec</th>
<th>Frames 3-4 (.068) Ft/Sec</th>
<th>Frames 4-5 (.051) Ft/Sec</th>
<th>Frames 5-6 (.034) Ft/Sec</th>
<th>Frames 6-7 (.017) Ft/Sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kops</td>
<td>25.0</td>
<td>13.6</td>
<td>0</td>
<td>10.4</td>
<td>14.6</td>
<td>0</td>
</tr>
<tr>
<td>Aik Huang</td>
<td>.9</td>
<td>1.9</td>
<td>0</td>
<td>4.8</td>
<td>1.9</td>
<td>0</td>
</tr>
<tr>
<td>McCoig</td>
<td>28.0</td>
<td>5.2</td>
<td>8.4</td>
<td>6.3</td>
<td>3.0</td>
<td>10.4</td>
</tr>
<tr>
<td>Poole</td>
<td>15.0</td>
<td>11.9</td>
<td>22.6</td>
<td>0</td>
<td>9.7</td>
<td>3.2</td>
</tr>
</tbody>
</table>
**TABLE XII**

**ANGULAR VELOCITY OF THE WRIST FOR THE SIX CONSECUTIVE FRAMES BEFORE CONTACT AND THE FIRST FRAME AFTER CONTACT WITH THE SHUTTLE OF FOUR BADMINTON PLAYERS EXECUTING A BACKHAND CLEAR**

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Frames 1-2 (Deg/Sec)</th>
<th>Frames 2-3 (Deg/Sec)</th>
<th>Frames 3-4 (Deg/Sec)</th>
<th>Frames 4-5 (Deg/Sec)</th>
<th>Frames 5-6 (Deg/Sec)</th>
<th>Frames 6-7 (Deg/Sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kops</td>
<td>1353</td>
<td>176</td>
<td>647</td>
<td>412</td>
<td>412</td>
<td>882</td>
</tr>
<tr>
<td>Aik Huang</td>
<td>823</td>
<td>823</td>
<td>118</td>
<td>823</td>
<td>941</td>
<td>647</td>
</tr>
<tr>
<td>McCoig</td>
<td>882</td>
<td>882</td>
<td>588</td>
<td>1765</td>
<td>1470</td>
<td>1529</td>
</tr>
<tr>
<td>Poole</td>
<td>412</td>
<td>59</td>
<td>294</td>
<td>1529</td>
<td>941</td>
<td>1294</td>
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</table>
TABLE XIII

LINEAR VELOCITY OF THE WRIST FOR THE SIX CONSECUTIVE FRAMES BEFORE CONTACT AND THE FIRST FRAME AFTER CONTACT WITH THE SHUTTLE OF FOUR BADMINTON PLAYERS EXECUTING A BACKHAND CLEAR

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Frames 1-2 (Ft/Sec)</th>
<th>Frames 2-3 (Ft/Sec)</th>
<th>Frames 3-4 (Ft/Sec)</th>
<th>Frames 4-5 (Ft/Sec)</th>
<th>Frames 5-6 (Ft/Sec)</th>
<th>Frames 6-7 (Ft/Sec)</th>
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</thead>
<tbody>
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<td>21.3</td>
<td>2.8</td>
<td>10.1</td>
<td>6.5</td>
<td>6.5</td>
<td>13.9</td>
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<tr>
<td>Aik Huang</td>
<td>12.9</td>
<td>12.9</td>
<td>1.9</td>
<td>12.9</td>
<td>14.8</td>
<td>10.1</td>
</tr>
<tr>
<td>McCoig</td>
<td>13.0</td>
<td>13.0</td>
<td>8.7</td>
<td>26.2</td>
<td>21.8</td>
<td>22.7</td>
</tr>
<tr>
<td>Poole</td>
<td>7.1</td>
<td>1.0</td>
<td>5.0</td>
<td>26.2</td>
<td>16.1</td>
<td>22.2</td>
</tr>
<tr>
<td>Subjects</td>
<td>Frames 1-2 (Deg/Sec)</td>
<td>Frames 2-3 (Deg/Sec)</td>
<td>Frames 3-4 (Deg/Sec)</td>
<td>Frames 4-5 (Deg/Sec)</td>
<td>Frames 5-6 (Deg/Sec)</td>
<td>Frames 6-7 (Deg/Sec)</td>
</tr>
<tr>
<td>--------------</td>
<td>----------------------</td>
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</tr>
<tr>
<td>Kops</td>
<td>176</td>
<td>1235</td>
<td>1000</td>
<td>1000</td>
<td>1294</td>
<td>1353</td>
</tr>
<tr>
<td>Aik Huang</td>
<td>235</td>
<td>1000</td>
<td>59</td>
<td>1353</td>
<td>1882</td>
<td>2235</td>
</tr>
<tr>
<td>McCoig</td>
<td>59</td>
<td>294</td>
<td>588</td>
<td>412</td>
<td>1294</td>
<td>1353</td>
</tr>
<tr>
<td>Poole</td>
<td>235</td>
<td>0</td>
<td>706</td>
<td>882</td>
<td>2000</td>
<td>941</td>
</tr>
</tbody>
</table>
TABLE XV

LINEAR VELOCITY OF THE RACKET HEAD FOR THE SIX CONSEQUENTIAL FRAMES BEFORE CONTACT AND THE FIRST FRAME AFTER CONTACT WITH THE SHUTTLE OF FOUR BADMINTON PLAYERS EXECUTING A BACKHAND CLEAR

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Frames 1-2 (.102) Ft/Sec</th>
<th>Frames 2-3 (.085) Ft/Sec</th>
<th>Frames 3-4 (.068) Ft/Sec</th>
<th>Frames 4-5 (.051) Ft/Sec</th>
<th>Frames 5-6 (.034) Ft/Sec</th>
<th>Frames 6-7 (.017) Ft/Sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kops</td>
<td>5.6</td>
<td>39.5</td>
<td>32.0</td>
<td>32.0</td>
<td>41.4</td>
<td>43.3</td>
</tr>
<tr>
<td>Aik Huang</td>
<td>7.6</td>
<td>32.1</td>
<td>1.9</td>
<td>43.5</td>
<td>60.5</td>
<td>71.8</td>
</tr>
<tr>
<td>McCoig</td>
<td>1.9</td>
<td>9.4</td>
<td>18.8</td>
<td>13.2</td>
<td>41.4</td>
<td>43.3</td>
</tr>
<tr>
<td>Poole</td>
<td>7.6</td>
<td>0</td>
<td>22.8</td>
<td>28.5</td>
<td>64.6</td>
<td>30.4</td>
</tr>
</tbody>
</table>
TABLE XVI

LINEAR VELOCITY OF THE THREE SEGMENTS OF THE UPPER EXTREMITY
AND TOTAL FINAL VELOCITY OF FOUR BADMINTON
PLAYERS EXECUTING A BACKHAND CLEAR

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Velocity of Elbow Ft/Sec</th>
<th>Velocity of Wrist Ft/Sec</th>
<th>Velocity of Racket Head Ft/Sec</th>
<th>Total Final Velocity Ft/Sec</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kops</td>
<td>0</td>
<td>13.9</td>
<td>43.3</td>
<td>57.2</td>
</tr>
<tr>
<td>Aik Huang</td>
<td>0</td>
<td>10.1</td>
<td>71.8</td>
<td>81.9</td>
</tr>
<tr>
<td>McCoig</td>
<td>10.4</td>
<td>22.7</td>
<td>43.3</td>
<td>76.4</td>
</tr>
<tr>
<td>Poole</td>
<td>3.2</td>
<td>22.2</td>
<td>30.4</td>
<td>55.8</td>
</tr>
</tbody>
</table>
TABLE XVII

PERCENTAGES OF TOTAL FINAL VELOCITY FOR THE THREE SEGMENTS
OF THE UPPER EXTREMITY OF FOUR BADMINTON
PLAYERS EXECUTING A BACKHAND CLEAR

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Percent of Total Final Velocity from Elbow Movement</th>
<th>Percent of Total Final Velocity from Wrist Movement</th>
<th>Percent of Total Final Velocity from Racket Head Movement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kops</td>
<td>0</td>
<td>24</td>
<td>76</td>
</tr>
<tr>
<td>Aik Huang</td>
<td>0</td>
<td>12</td>
<td>88</td>
</tr>
<tr>
<td>McCoig</td>
<td>13</td>
<td>30</td>
<td>57</td>
</tr>
<tr>
<td>Poole</td>
<td>6</td>
<td>40</td>
<td>54</td>
</tr>
</tbody>
</table>
CHAPTER V

SUMMARY, FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

I. SUMMARY

The purpose of this study was to analyze the upper extremity movements of four world class badminton players executing the two basic strokes of the forehand smash and the backhand clear. The four players, each of whom was currently ranked as the number one player in his respective country, were photographed with a Paillard-Bolex 16mm movie camera at sixty-four frames per 1.0688 seconds (sixty frames per second) while executing the two strokes of forehand smash and backhand clear. Calibrations for camera speed were undertaken prior to and at the conclusion of the filming.

The films were taken in one of the men's gymnasiums of Northwestern Louisiana State College, Natchitoches, Louisiana. The subjects were filmed over a two day period because of their schedules of participation in the Sixteenth United States Open National Championships.

Two views were taken of each subject. These were: (1) side view of ninety degrees; and (2) front view. The camera lens was placed thirty-six feet from the subject to avoid perspective error and also to ensure that the entire field of activity would be photographed.

At least five filmings were made of each subject from both front and side positions of each stroke. Because of subject or camera operator errors, the number of filmings varied between a minimum of five and a
Both horizontal and vertical lines were placed on the wall behind
the subject to facilitate accurate measurements. Two lines twenty-four
inches apart located on the floor beneath the subject served as
reference points for determining accurate distances.

The film was processed on a Versamat Kodak Processing machine,
and a positive print was returned. The film was analyzed by use of the
Eastman Kodak Recordak Film Reader. Tracings were made on transparent
paper from the projections by the recordak.

Two types of measurements were employed to analyze the two
strokes. These were: (1) measurement of the angles between the segments
of the upper extremity to calculate angular velocities; and (2) conver­
sion of the angular velocities into linear velocities. The strokes were
then analyzed to determine the most important movements for each stroke.

II. FINDINGS

The findings of this study were as follows:

1. All four subjects' data indicated that the wrist action was
   the most important contributor to the force of a forehand
   smash.

2. Only one subject depended on the elbow movement to get any
   appreciable final velocity in the forehand smash. This
   subject had the lowest final velocity on the smash.

3. The subject who attained the highest velocity on the racket
   head movement waited until .017 seconds before contact to
apply the largest increase in velocity on the forehand smash.

4. All four subjects' data indicated that the wrist action was the most important contributor to the force of a backhand clear.

5. Only one subject had an elbow movement velocity of at least ten feet per second at contact on the backhand clear.

6. Three of the four subjects' rackets were accelerating as contact was made with the shuttle on the backhand clear.

Discussion of Findings

The findings of this study were generally in agreement with the most recent books on badminton and analysis of motion. Generally, these books state that the wrist action contributes the most to the racket and shuttle velocity. In this study, the subject with the highest final velocity received 92 percent from the wrist action and the subject with the lowest final velocity still received 76 percent of his final velocity from the wrist.

It should be emphasized that the term "wrist action" for the forehand smash includes not only extension and flexion of the wrist but also pronation of the hand, wrist, and forearm. All four subjects used pronation to attain more power in their smash but it is vital also for deception as a quick wrist movement keeps the opponent off balance and unsure of the direction of the impending stroke.

The one subject who used any elbow movement of any consequence (15 feet per second) had the lowest final velocity on the forehand
smash. This indicated that the use of the arm is not advantageous in developing a strong smash.

The findings on the backhand clear also confirmed the statements in books on badminton and analysis of motion. All four subjects' data in this study indicated that the wrist action was the most important contributor to the force of the clear. One of the subjects received 88 percent of his total velocity from the wrist while the subject with the least velocity received 54 percent of his total velocity from the wrist.

The term "wrist action" for the backhand clear includes not only extension and flexion of the wrist but, more importantly, the supination of the hand, wrist, and forearm. Supination was apparent in the strokes of all four subjects and is used for deception as well as power. Supination in the badminton stroke is the foremost distinguishing characteristic that separates the sweeping tennis type of backhand from the quick badminton flick type of backhand.

Another finding that has important implications for the badminton teacher is that the subject with the lowest final velocity on the backhand clear was also the only subject whose racket head velocity decreased just before the final frame. This indicated that he had started his swing too soon and it had lost its largest velocity before reaching the area of contact with the shuttle.
III. CONCLUSIONS

The following conclusions were drawn within the limitations of this study:

1. The most important contributor to the force of the forehand smash and the backhand clear was the wrist action.
2. The highest velocity on the forehand smash was achieved by the subject who delayed his greatest movement until .017 seconds before contact with the shuttle.
3. The highest final velocities on the backhand clear were achieved by the subjects whose velocities were increasing during the .017 seconds before contact with the shuttle.
4. All the subjects extended their arm and elbow above the head as these two strokes were executed but only one subject used the arm to achieve any significant contribution to the velocity of his stroke.

IV. RECOMMENDATIONS

Following the analysis of the four expert players demonstrating the two basic badminton strokes of forehand clear and backhand smash, the following recommendations seemed warranted:

1. A cinematographic analysis of the forehand smash and backhand clear which utilizes performers at various levels of skill is needed. This would allow comparisons to be made between experts and other subjects of lesser skill.
2. A cinematographic study of the flight pattern of the shuttle utilizing a short shutter speed and high framing rate should be made to see if it spins when hit at a high velocity and to determine if it oscillates in flight. There were indications in this study that the shuttle may not travel in a consistent pattern.

3. A cinematographic study of the flight patterns of shuttles made of various types of materials should be made to determine the consistency of their flight patterns.
SELECTED BIBLIOGRAPHY
SELECTED BIBLIOGRAPHY

A. BOOKS


**B. PERIODICALS**


**C. UNPUBLISHED MATERIALS**


APPENDIX A
STICK FIGURES OF KOPS AS HE EXECUTES A FOREHAND SMASH. DEGREE MEASUREMENTS WERE TAKEN OF THESE EIGHT CONSECUTIVE FRAMES AND CONVERTED TO LINEAR VELOCITIES.
Stick figures of Aik Huang as he executes a forehand smash. Degree measurements were taken of these eight consecutive frames and converted to linear velocities.
STICK FIGURES OF McCoig as he executes a forehand smash. Degree measurements were taken of these eight consecutive frames and converted to linear velocities.
Stick figures of Poole as he executes a forehand smash. Degree measurements were taken of these eight consecutive frames and converted to linear velocities.
STICK FIGURES OF KOPS AS HE EXECUTES A BACKHAND CLEAR. DEGREE MEASUREMENTS WERE TAKEN OF THESE EIGHT CONSECUTIVE FRAMES AND CONVERTED TO LINEAR VELOCITIES.
STICK FIGURES OF AIK HUANG AS HE EXECUTES A BACKHAND CLEAR. DEGREE MEASUREMENTS WERE TAKEN OF THESE EIGHT CONSECUTIVE FRAMES AND CONVERTED TO LINEAR VELOCITIES.
STICK FIGURES OF McCOIG AS HE EXECUTES A BACKHAND CLEAR. DEGREE MEASUREMENTS WERE TAKEN OF THESE EIGHT CONSECUTIVE FRAMES AND CONVERTED TO LINEAR VELOCITIES.
STICK FIGURES OF POOLE AS HE EXECUTES A BACKHAND CLEAR. DEGREE MEASUREMENTS WERE TAKEN OF THESE EIGHT CONSECUTIVE FRAMES AND CONVERTED TO LINEAR VELOCITIES.
VITA

The writer was born in Nashville, Tennessee on February 6, 1932 and attended elementary school in Nashville. He graduated from Point Loma High School in San Diego, California in 1950.

In 1955, San Diego State College awarded the writer the Bachelor of Arts degree with a major in physical education and a minor in history. From 1955 to 1957, he served in the United States Air Force as a Second Lieutenant. Following his release in 1957, he returned to San Diego State College and completed his teaching credential in 1958.

The writer taught and coached on the secondary school level serving as physical education instructor, history teacher, and basketball coach in the San Diego City School System from 1958 to 1966. He received his Master of Arts degree in physical education from San Diego State College in 1965.

In September, 1966 the writer was employed by Tulane University as a physical education instructor. With the exception of 1968 when he served as a graduate assistant at Louisiana State University, he has been employed by Tulane University of New Orleans.

The writer entered Louisiana State University in June, 1967 to work toward the Doctor of Education degree with a major in physical education and a minor in education administration. The degree was awarded at the summer commencement, 1970.
EXAMINATION AND THESIS REPORT

Candidate: James Richard Poole

Major Field: Physical Education

Title of Thesis: A Cinematographic Analysis of the Upper Extremity Movements of World Class Players Executing Two Basic Badminton Strokes

Approved:

Major Professor and Chairman

Dean of the Graduate School

EXAMINING COMMITTEE:

Ralph E. Stiker

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Date of Examination:

July 20, 1970