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Cinematographical and Mechanical Analysis of the Golf Swing of Female Golfers.

Linda L. Parchman
Louisiana State University and Agricultural & Mechanical College

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OF THE GOLF SWING OF FEMALE GOLFERS

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
Linda L. Parchman
B.S., University of Arkansas, 1958
M.S., University of Illinois, 1961
August, 1970
Dedicated to those who cared
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The investigator would like to express her appreciation to the four women who served as subjects for this study for their cooperation and travel at their own expense to the filming site.

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ABSTRACT

The purpose of this study was to analyze the movement and timing of selected body segments during the execution of the golf drive by female golfers. Cinematography was the method used to analyze the mechanics of the action of body segments during the golf swing.

The filming for the study occurred on November 15th, 1969, at Centenary College Gymnasium, Shreveport, Louisiana. Four women golfers of amateur status, who were former state and regional champions, served as subjects for the study.

The subjects were filmed from the side, front and overhead, by three sixteen millimeter movie cameras set at sixty-four frames per second.

The movement and timing of the body segments were analyzed while the film was projected by a microfilm reader. Tracings were drawn from selected frames of pertinent views of the body during the swing.

A descriptive analysis of the movement that occurred in all three views and linear velocity contributions of the body segments to the clubhead were computed. The percentage contribution of the linear velocity of each body segment was determined.

The findings of this study were:

xix
1. The clubshaft, hands, and arms not only failed to form a straight line at address, but there was an observed change in the wrist angle for all four subjects before the hands had passed the right knee.

2. For three subjects the right knee failed to maintain the same position throughout the backswing.

3. For two subjects the initial movement in the downswing was a lateral hip movement to the left, and for two it was a rotation around an axis.

4. For all four subjects the wrists had begun to "uncock" in the downswing by the time the left arm was horizontal to the floor.

5. The linear velocity contributions of the acting joints were not comparable to those stated in the hypothesis which were 70 percent wrist, 20 percent shoulder, 5 percent hip and 5 percent spine.

Within the limitations of this study, the following conclusions were reached:

1. The results of this study failed to show a consistency relative to the swing patterns between subjects concerning:
a. The movement of the clubhead away from the ball.
b. The angle of the wrist at the address position.
c. The amount of wrist angle occurring throughout the swing.
d. The right knee position during the phase from the address to the top of the backswing.
e. The movement of the hips when initiating the downswing.
f. The linear velocity contributions of the acting joints.

2. Subject one most nearly achieved the description for the swing by leading authorities.

3. Current literature may be inaccurate in the descriptive analysis of the golf swing.

4. The execution of the golf drive in which the linear velocity of the body segments was greatest was that of subject one for whom there was a definite lateral hip movement, the hip and spine had made major contributions prior to contact, both knee joints flexed toward the target early in the downswing, and the wrist angle did
not increase on the downswing.

5. The wrist lever was the major contributor to the linear velocity of the clubhead for all four subjects.

6. The percentage contribution of the body segments to linear velocity for skilled performance as indicated in the hypothesis may be incorrect for women.
CHAPTER I

INTRODUCTION

The year, 1969, was expected to see an addition of 400 golf courses to the 9,615 already listed. Spending on golf equipment will have topped one billion dollars through that year, more than was spent on any other sport. It has been estimated that there are now twelve million golfers in this country alone.

... In twenty years that number will triple to thirty-six million. Whereas women now make up about twenty per cent of the golfing population, by then they may well make up nearly fifty per cent. Women are just finding the game, and in twenty years they are going to have more leisure time and probably will be more concerned about physical fitness than men. Everyone will want to be associated with the game, and people will say they play even if they don't.

The interest and dedication of those who play golf are unexcelled. The golf swing is perhaps discussed more than any of the other skills involved in the game. Hundreds of books have been written by professional golfers and physical educators in which the swing has been described.

---


Arnold Palmer has remarked:

The temptation to talk and write oracles has been almost irresistible, and those who have succumbed to it (including me) were only being human. Unfortunately, we have done golf a great disservice. We have made the game sound so difficult and so contrary to the body's natural instincts that we have surely scared away thousands of people who might otherwise have tried golf and enjoyed it.3

The various publications available to the physical educator which include a description of the golf swing are often confusing. Reese stated, "The full swing in golf has been described in such minute detail and in so many different ways that a beginning golfer who reads the material cannot help but be confused."4 Broer has supported this in stating the following:

Perhaps it is because so many people have written about golf and all have had their own devices for correcting their own individual errors that this sport has become so enmeshed in detail--detail which often hinders rather than aids learning because of the tension which it produces.5

In some cases physical educators have written texts in which they have described the golf swing in terms of what other sources have said or from what they, themselves, have experienced. It has been shown that not even professional


golfers were able to correctly diagnose their own form. While it is generally agreed that golf swings will vary due to individual differences in body build and concept, it would seem that a clear understanding of the mechanics of the golf swing is vital for those who teach as well as play the game. A cinematographical analysis of the golf swing of excellent players could provide a solid basis on which to formulate desirable execution of the skill.

Glassow remarked:

Pictures of motion taken at high speeds are as essential for the physical educator as is the microscope for the biologist. Most descriptions of sports skills and locomotor skills are based on what the eye can see or on what the performer thinks he does. Both have been shown to be erroneous.

While there have been a number of cinematographical studies of sports skills, the literature appears to be limited in studies of the golf swing. In particular there is a lack of an analysis of the golf swing of the female, although several investigations have been conducted with male golfers in which the primary purpose was an electromyographic analysis of the muscles used during the execution of the swing.

---


I. PURPOSE OF THE STUDY

The purpose of this study was to analyze the movement and timing of selected body segments during the execution of the golf drive by female golfers. The following hypotheses were formulated:

1. The clubhead moved in a straight line away from the ball on the backswing.

2. The clubshaft, hands, and arms maintained a straight line in the backswing until the hands passed the right knee.

3. The hands during the backswing began to cock at approximately hip level.

4. The right elbow pointed to the ground when the club shaft reached the top of the backswing.

5. The left arm remained straight throughout the backswing.

6. The right knee remained braced in relatively the same position throughout the backswing while the left knee flexed toward the mid-line of the body.

7. The initial movement in the downswing was a lateral hip turn to the left.

8. The wrists during the downswing delayed uncocking until the hands reached a point where they were approximately hip level.

9. At contact the hands, club shaft, and arms formed a straight line.
10. At contact the left knee was firm though slightly flexed.

11. The linear velocity contributions of acting joints were approximately 70 percent for the wrist, 20 percent for the shoulder, 5 percent for the hip, and 5 percent for the spine.\(^8\)

12. The downswings were three times faster than the backswings.\(^9\)

II. NEED FOR THE STUDY

Kinesiology texts and those dealing with the techniques of a certain skill frequently explain only the beginning and ending actions, for they are the slower phases and can be seen.

The force-producing phases, the most important, are for the most part neglected. These are the portions of a skillful act in which the movement is rapid, too fast for the human eye to observe. The range, sequence, and speed of joint action cannot be determined without the aid of some device which records and preserves them for future study.\(^{10}\)


\(^9\)Ibid., p. 116.

\(^{10}\)Ibid., p. 6.
The minute movements of the golf swing cannot be seen by the naked eye, and what has appeared to be obvious may not be the case.

While it is not necessary to explain every detail of a skill to a student, a physical educator should be knowledgeable concerning the mechanics.

It has been my experience that athletes are best left without a precise knowledge of the nature of their skill, and need only sufficient detail to correct faults, satisfy curiosity and inspire confidence. Because they learn their skills through their kinesthetic sensations and differ widely in intelligence, education and interests, more descriptive (if mechanically inaccurate) language in coaching is to be preferred to the jargon of Mechanics. But with physical education teachers and sports coaches, a knowledge of Mechanics can provide an essential tool with which to distinguish between important and unimportant, correct and incorrect, cause and effect, possible and impossible, for human motion must obey the laws of all motion, and athletic skill at the highest level applies these same principles to full advantage.  

A scientific undertaking of this caliber is a need in physical education and is overdue, especially in golf. The continued growth in numbers and influences of the female golfer indicates the need for skilled teachers of the game. It would seem, therefore, that a cinematographical and mechanical analysis of the golf swings of successful

female golfers could aid in understanding, and perhaps establish, desirable skill execution.

III. DELIMITATIONS OF THE STUDY

This study was limited to only four successful women golfers, all of whom were former amateur champions of state or regional golf tournaments. The filming was conducted on the afternoon of November 15, 1969, in the Centenary College Gymnasium at Shreveport, Louisiana. Three sixteen millimeter movie cameras were used to film each subject from three views, side, front, and top, as she executed the golf swing with her driver. After the processing of the film the swings from the three views of each subject were analyzed in terms of the movement and timing of selected body segments.

IV. LIMITATIONS OF THE STUDY

The golf swings of the four female golfers were analyzed from films especially photographed for measurement, and the execution of the skill could possibly vary under a competitive situation. The effects, if any, of the hip and spinal belts on the performance of the swing could not be determined.
Due to inadequate lighting, the front view of the subjects was particularly dark as that camera opened only to F 2.5. The flash of the strobotac occasionally flashed between frames and was not discernible on every flash. Although the variable shutter was set at the fastest shutter speed of 1/400 of a second, some blurring of the club shaft occurred prior to contact.

For one subject all three photographic sequences failed to yield an actual contact frame or proximity, thereof, in the front view; contact occurred between frames, and this made the computation of the linear velocity difficult.

V. BASIC ASSUMPTIONS

It was assumed that motivation to perform well was present in all subjects. The fact that the subjects hit hard rubber indoor golf balls rather than regulation golf balls was assumed to make no difference in the performance of the swing. It was further assumed that the subjects had excellent swings since their performances in the past had led to championships.

VI. DEFINITION OF TERMS

Flexion. This was the act of two adjacent segments approaching one another.
Extension. This was the action away from flexion.

Hyperextension. This occurred when a segment extended beyond its normal starting position in extension.

Adduction. This was movement which occurred toward the midline of the body.

Abduction. This was movement in the frontal plane away from the midline of the body.

Moment Arm. This was the perpendicular distance from the axis of rotation to the point of contact.

Shoulder Moment Arm. The length of the moment arm was that of a line from the proximal end of the humerus to the point of impact. This line was perpendicular to the axis and to the line of the applied force.

Hip Moment Arm. At impact the length of the moment arm was the perpendicular distance from the axis, which was a vertical line passing through the center of the hip joint, to the point of impact.

Spinal Moment Arm. The length of the moment arm was the perpendicular distance from the axis, which was a line that passed through the upper spine, to the point of impact.
Wrist Moment Arm. This was the perpendicular line drawn from the axis of rotation at the wrist joint to the point of contact.

Square Stance. The feet were parallel to, and equally distant from, the imaginary line of flight of the ball.

Closed Stance. The right foot was drawn back from the line of flight.

Open Stance. The left foot was drawn back from the imaginary line of flight of the ball.

Address. This was the position prior to beginning the backswing of the drive.

Flattened Plane. The plane of the path of the club-shaft was more horizontal than vertical.

Upright Plane. The plane of the path of the club-shaft was more vertical than horizontal.

Wrist Cock. This was the action of radical flexion and extension of the left wrist and radial flexion and hyperextension of the right wrist.

Wrist Uncock. This was ulnar flexion and extension at the wrists.
CHAPTER II

REVIEW OF RELATED LITERATURE

The purpose of the present study was to analyze the movement and timing of selected body segments during the execution of the golf drive by female golfers. The reviewed literature was divided into two categories: (1) cinemagraphical studies of striking activities and (2) description of the golf drive by recognized authorities.

I. CINEMATOGRAPHICAL STUDIES OF STRIKING ACTIVITIES

The studies presented in this section were those which were conducted with skills involving projections of objects with an implement.

Race\textsuperscript{1} filmed 17 male professional baseball hitters during the batting practice of the 1959 baseball season in which he stationed a 16 millimeter camera fifteen feet directly in front of the anterior side of the batter. He found that, with the exception of one measurement for one hitter, there was no full forward knee extension at the

moment of contact with the ball. In addition the rotary motion initiated by dramatic hip rotation and culminated by quick and powerful wrist action was paramount in the hitters. There was a sharply increasing rate of velocity of the bat as it approached the ball.

In another study of baseball, Kitzman\textsuperscript{2} conducted an electromyographic analysis of the muscles used in the swing. He recorded the swings on film with a camera set at 24 frames per second. While his main concern was a muscle analysis, the findings have relevance to several studies which have been conducted with the same muscles in the golf swing. Four men, two skilled and two unskilled, were included in the study in which the functions of the right and left pectoralis major muscles, the right and left triceps brachii, and the right and left latissimus dorsi were studied during the batting swing. The conclusion was that right-handed baseball batters could increase the force of the swing by strengthening the left triceps brachii muscle.

In an effort to determine the methods used by two highly skilled male tennis players to direct the ball to the right and left sides of the court, Blievernicht\textsuperscript{3} analyzed


films taken from an overhead view in which each subject hit forty consecutive forehand drives. The results of the study indicated that racquet angle, position of the ball in relation to the body, and the left foot were factors in directing the tennis ball to the left or right. While step direction was a factor for one subject, it was not for the other. There was no one wrist angle that could be associated with drive direction.

Parchman analyzed the tennis serve of a highly skilled female player in order to determine the body lever actions contributing to the force in the serve. The results showed that the subject's wrist action and shoulder rotation contributed almost 80 percent of the linear velocity of the serve. It was of interest to the investigator to observe continued pronation of the wrist after contact, even though the subject appeared to have performed a flat service.

Barth determined the linear velocity of the badminton backhand stroke in the thumb-up and the standard grip of four well-skilled women. In addition the spatial and time relationships of the contributing arm levers to the

\[ \text{Reference 4} \]
Linda L. Parchman, "Film Analysis of the Body Lever Actions Contributing to the Force in a Tennis Serve for a Right-handed Player" (unpublished kinesiology paper, University of Arkansas, 1968).

\[ \text{Reference 5} \]
whole pattern of arm movement were calculated. The results of the study showed that there was a general pattern of flexion in both techniques of all subjects with shoulder flexion being greatest, wrist flexion second, and elbow flexion third. In addition the subject with the greatest average hand and racquet velocity had the higher total racquet velocity. In the majority of sequences the hand and racquet lever made the greatest contribution to racquet velocity, the forearm lever was second, and the upper arm lever was third. The velocity of the racquet was greater than the summation of the velocities.

Wrigglesworth analyzed the chip shot as performed by five experienced male golfers. The subjects were filmed from a front and a side view, simultaneously, with two sixteen millimeter cameras set at sixty-four frames per second. The purpose of the study was to investigate and identify the factors that give accuracy to the chip shot. In general the results were in accord with the descriptions reviewed in the literature. While some of the subjects differed on ball positioning and stance as well as wrist break, various authorities also differed. There was agreement on the use of a low numbered club in this particular length chip shot.

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Further results showed that the subjects had more wrist break than each had thought and more than each desired.

Using two eight millimeter cameras recording at 16 frames per second, Kraska analyzed the sand trap shot of three professional golfers. All of the golfers had the heel of the left hand at, but not over, the end of the shaft. The club face was open at address and contacted the sand approximately one inch behind the ball; the stance was open with the left toe seventeen inches and the right toe twelve inches from the line of flight. Kraska was of the opinion that one could improve in this skill if attention were directed to the above factors.

Clemence compared clubhead momentum before and after impact and also the impulse given to the ball by weighted and non-weighted clubs as related to the skill of thirty right-handed male golfers. A high speed, sixteen millimeter camera with recordings at 128 frames per second was used. The results indicated that in all measures of momentum, a higher level of skill insured significantly more momentum. With the addition of one-half ounce of weight to the wood and to the iron, there was a significant increase

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in momentum before and after contact. The impulse given to the ball was not affected by weight increase nor was there interaction between skill level of the golfer and addition of one-half ounce of weight to each club.

In analyzing the swing of one amateur and twelve professional men golfers from 2,500 stroboscopic pictures, Rehling\(^9\) was able to show that the movement of the skilled golfers was contrary to what they had thought as indicated by their answers on a checklist. In addition his study showed that the velocities of the clubheads averaged 200.26 feet per second. Velocity was not related to the size of the golfer.

Plagenhoef\(^10\) has stated that cinematographic equipment is better than stroboscopic equipment in terms of recording desired motion. Stroboscopic equipment not only produces an overlapping image, but it cannot be used under competitive conditions. He further stated that cameras which record at about sixty frames per second should be used for fast body motions, and one which will take in excess of 600 frames per second is needed to determine impact forces.


Kerr\textsuperscript{11} analyzed his own swing from three views through the use of sixteen millimeter cameras set at sixty-four frames per second. Results showed that wrist flexion contributed almost 70 percent to the total linear velocity of the body segments. Clubhead velocity was found to be 130.72 feet per second prior to contact, and it decreased to 120.08 feet per second one frame after contact. These were approximations due to blurring of the contact frame. Kerr did not consider himself to be a good golfer, and the results "cannot be considered typical for all golfers.\textsuperscript{12}

Parchman\textsuperscript{13} analyzed the golf swings of a male golfer and a female golfer who were considered above average golfers. Three views were recorded simultaneously via sixteen millimeter cameras set at sixty-four frames per second. The total linear velocity of the body levers used in the swing of the female golfer was 120.20 feet per second, while that of the male golfer was 154.78 feet per second. Although the two subjects differed in total linear velocity, the percentages of the contributing segments of the body were


\textsuperscript{12}Ibid., p. 1.

\textsuperscript{13}Linda L. Parchman, "Cinematographical Analysis of the Golf Swing of Selected Subjects" (unpublished research paper, Louisiana State University, 1969).
practically the same between the two golfers. Wrist flexion and shoulder abduction accounted for almost 72 percent of the total linear velocity for both golfers.

Garrison\textsuperscript{14} studied and recorded electromyographically and cinematographically the golf swings of four "very good" male golfers. His primary concern was with the function of ten muscles of the arm and shoulder on the right and left sides of the body during the swing using a wood and an iron. He used analysis of variance to establish differences, if any, between the two clubs. Slater-Hammel\textsuperscript{15} also had used the electromyographic technique but not cinematography to analyze the golf swing and the function of the following muscles on both the left and right sides of the body: lateral head of the triceps brachii, short head of the biceps brachii and long head of biceps brachii; anterior, medial, and posterior deltoids; latissimus dorsi; and the pectoralis major. Of the four male subjects who were rated "good" performers, "none showed contractions of the left latissimus dorsi during the drive."\textsuperscript{16} In addition to the

\textsuperscript{14}Levon E. Garrison, "Electromyographic-Cinematographic Study of Muscular Activity During the Golf Swing" (microcarded Doctoral dissertation, Florida State University, 1963), 140 p.


\textsuperscript{16}Ibid., p. 171.
muscles analyzed by Slater-Hammel, Garrison also analyzed the internal and external oblique muscles of the abdomen and the pronator teres. The results showed that the muscular pattern was extremely reproducible for each of the subjects, and that while no patterns of activity were exactly alike, there were more similarities than differences in the various muscle activities during the swing. There was a significant difference in the average number of frames used in the entire swing between subjects; however, there was no significant difference between the time consumed by the wood and the time consumed by the iron during the swings of each subject. The latter suggested that the wood traveled faster than the iron to accomplish a greater distance in the same amount of time, even though the subjects tended to have a longer backswing and follow-through when using the wood. The same activity was recorded for both iron and wood, but there was a greater amplitude of muscle activity recorded for the wood swing. Garrison's investigation showed moderate activity of the right latissimus dorsi during the initial part of the backswing while Slater-Hammel found it to be limited to the first half or two-thirds of the downswing.

In a study by Karr\(^\text{17}\) of the swings of one good

Two fair golfers, and one poor golfer, all of whom were men, results similar to those of Garrison were obtained. Both Garrison and Karr recorded action in the left latissimus dorsi, and Garrison suggested that the discrepancies might have resulted from the lack of minimal activity recording in the study by Slater-Hammel.

Brennan analyzed and compared the joint actions in the golf drive and the seven iron shot performed by five women golfers with individual handicaps of 4, 5, 7, 9, and 12. It was her purpose to determine: (1) if there were a difference between the range of pelvic rotation and the range of spinal rotation between the drive and seven iron shot, (2) if there were a difference between the angular change of the wrist joints and inclination of the club shaft in the two skills, (3) if there were a difference between the linear velocities of the ball for the two skills, and (4) if there were a difference between selected body positions for the two skills. An overhead, a side, and a rear view were filmed, simultaneously, using sixteen millimeter cameras set at sixty-four frames per second with shutter speeds of 1/400 of a second. The t-test was used to test the significance of the difference between the means.

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Brennan found in the following items similarities between the two skills: (1) pelvic rotation in the backswing, (2) spinal rotation in the backswing and downswing, (3) action of the wrist joints, (4) angular change in the inclination of the club shaft, (5) inclination of the trunk in the stance, and (6) the width of the stance and position of the ball relative to the feet. She found in the following items differences between the two skills: (1) range and angular change of pelvic rotation on the downswing, (2) linear velocity of the clubhead prior to contact, (3) position of the hips at contact and (4) the clubhead inclination in the stance. She concluded that the differences were related directly to the different club lengths.

As a result of the longer lever, the linear velocity of the clubhead, the moment of inertia in the golf drive and the inclination of the club in the stance to the horizontal were greater in the golf drive. To overcome the greater moment of inertia in the golf drive, the range and rate of pelvic rotation increased in the backswing.19

II. DESCRIPTION OF THE GOLF DRIVE
BY RECOGNIZED AUTHORITIES

The following review of literature concerned the golf swing during the drive as described by authorities, both professional players as well as teachers. The review was categorized under the following parts of the total swing: (1) address and stance, (2) backswing and top of

19 Ibid., p. 118.
the backswing, (3) downswing and contact, and (4) follow-through.

Address and Stance

Berg and Dypwick\(^2^0\) emphasized that the address is the very basis of the swing and should not be slighted. They advocated a fairly erect posture with slight flexion in the knees. The ball, the authors explained, is addressed in line with the left heel. They further stated that one should avoid reaching for the ball, even though, as a rule, women stand relatively further from the ball than do men.

Wright\(^2^1\) preferred a slightly closed stance with the weight balanced from the ball of the feet back towards the heels.

Suggs\(^2^2\) presented a similar view, allowing a square to slightly closed stance for the drive.

Bruce and Davies\(^2^3\) stated that usually a closed stance is used when driving from the tee. Further, the


right elbow is slightly bent while the left arm is extended. Although the waist is bent slightly, a straight line is desirable from the hips to the head. The weight of the body is "pulled toward the inside of the ankles, slightly forward on the balls of the feet."\(^{24}\)

Each of the foregoing authorities advocated a "waggle" of the clubhead and a "forward press" with the hands and right knee.

Fossum and Dagraedt\(^{25}\) explained that the feet should be turned outward slightly and placed about shoulder width apart. They recommended an inward squeeze of the knees so that one feels as if he were standing "knock-kneed."

Nicklaus\(^{26}\) felt that this weight is evenly distributed between both feet and also between the heel and ball of each foot. His stance is square with his left toe open slightly toward the line of flight.

Hogan\(^{27}\) stressed that the right foot points straight ahead while the left toe points out slightly; the knees are slightly flexed while the back is straight.

\(^{24}\)Ibid., p. 18.


Backswing and Top of the Backswing

Berg and Dypwick explained that on the backswing the left hand and left side move the clubhead away in a straight line from the ball. They emphasize that the wrists begin to break just before hip level. At the top of the backswing, the wrists are fully cocked, with the clubhead dipping just below the horizontal.

Suggs has said that the left hand pushes the club back away from the ball. The left knee flexes in toward the midline of the body; the right leg is braced but not rigid so that it can bear the body weight as it is transferred to the right side. She also explained that the wrists begin to "cock" at hip level. Further, the hips and shoulders continue to turn while the left arm remains straight but not tense. While the left arm remains straight throughout the swing, the right elbow remains fairly close to the body. Suggs underlined that the head turns but does not move.28

Wright stated that the clubhead is swept back very low with the clubhead, arms, shoulders, and hips turning together in a one-piece move. She felt that the weight shifts to inside the right foot, right leg and right knee; at the top of the backswing, the right elbow points toward

28Suggs, loc. cit.
the ground and a line from the right armpit to the elbow is parallel to the ground. "There is a 45 degree hip turn, weight on the inside of the right foot, leg, knee, right knee still bent or flexed as at the address position."²⁹

It is of interest to note here that Cooper and Glassow stated: "At the height of the backswing, it will be seen that hip action has rotated the pelvis almost 90 degrees and that spinal rotation has turned the upper torso more."³⁰

Bruce and Davies stated that the clubhead is swept back in a straight line from the ball until the hands are in front of the right knee, at which point, the weight is shifted slowly to the right leg allowing the left knee to move in and down toward the ball. This action causes the left heel to raise from the ground several inches. "The right leg, with the knee relaxed, maintains a straight, balanced position."³¹ The authors further stated that as the hands pass the right leg, the clubhead is lifted by gradually cocking the wrists. At the top of the backswing, the right elbow points toward the ground. They stress that the club shaft should not drop below a line parallel with the ground.

²⁹Wright, loc. cit., p. 11.


³¹Bruce and Davies, loc. cit., p. 20.
Fossum and Dagraedt explained that the backswing is started with a push from the left side while keeping the clubhead low to the ground as far as possible. The left shoulder turns under the chin until the left hand is just past the right knee at which time the wrist begins to cock. At the top of the backswing the left arm is still extended with the arms close together and the right elbow pointing at the right hip; the club points approximately at the target.

Nicklaus felt that his left hand acts as a guide and assumes major control of the club in taking the club back. He explained that he moves the clubhead back in a straight line for as long as the hips and shoulders will allow, delaying any breaking or cocking of the wrists. "Sometimes the clubhead will be five feet away from the ball before there is any noticeable hinging in my wrists."\(^{32}\) At the top of his backswing, he stated that his weight is on the inside of his right foot with his right knee steady, as if it were locked into position similar to the address.

Hogan emphasized that the only hinge from the left shoulder to the clubhead occurs at the hands—the left arm stays firm throughout the backswing. The right elbow points to the ground when the club reaches the top of the backswing.

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\(^{32}\) Nicklaus, loc. cit., p. 32.
Snead stated that if the left arm is straight and the shoulders turn properly, "the clubhead stays low to the ground 18 to 24 inches before it starts rising appreciably." At the top of the backswing the left shoulder is directly beneath the chin. While Snead swings just below the horizontal at the top, he stressed that one should not swing so far that he would lose control of the club. Concerning the left heel, he recommended that it should leave the ground only slightly, if at all.

**Downswing and Contact**

Berg and Dypwick stressed that the left hand controls the downswing all the way through to the ball. They stated further that the left hand pulls the clubhead down to a point where the hands are about hip level. At that point, the power of the wrists which were held in a "cocked" position is unleashed at the ball. "If the wrists uncoil too soon, their power is wasted before reaching the ball, causing loss of distance, consistency and accuracy." At contact the authors stated that a straight line is formed by the left arm and club shaft.

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34 Snead, loc. cit., p. 38.

35 Berg and Dypwick, loc. cit., p. 16.
Suggs also stated that at the start of the downswing her sensation is that of pulling the clubhead with her left hand back to the ball in the same arc as that followed by the clubhead on the backswing. "The transfer of weight from my right to left side starts at the same moment my arms and hands begin their downward course." She further cautioned against rushing the turn of the hips and said that the turn should be part of a coordinated motion in which the hands, wrists, arms, shoulders, hips, legs and feet work together to get the clubhead back to the ball. She, as well as Berg and Dypwick, stated that the movement by the hips is a slide forward to the left and then a turn.

Wright explained that her first move in the downswing is a return of the weight toward the left foot with the left hip turning. The hands stay fully cocked and "are merely going along for the ride at this point." The right elbow moves down into the right side as the hands pull the shaft into the downswing.

Bruce and Davies described the action in the downswing as an uncoiling of the body. The weight is slowly shifted to the left leg, and the arms "bring the clubhead down through the same arc it followed on the backswing."

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36 Suggs, loc. cit., p. 31.

37 Wright, loc. cit., p. 11.

38 Bruce and Davies, loc. cit., p. 21.
The authors further explained that the entire action of the downswing is initiated by the left side of the body. When the ball is contacted, the wrists are firm. As the weight is transferred to the left leg, the left knee is relaxed, although a stable base is maintained.

Fossum and Dagraedt used the following description: "From the 'top' position, pull the club from the whole left side (left shoulder, arm, hand and hip), down and through the ball and at the target."\(^{39}\) The head is steady in its original position, behind the ball.

Nicklaus said that at the start of his downswing he feels his weight shift and his hips turn to the left with the clubhead lagging behind. Although Nicklaus tries to make the club return to the ball along the same path, he says, "I'm really not sure that the clubhead returns along its original path, but that is how it feels to me."\(^{40}\) His greatest power in his swing, he feels, comes from his legs, which turn his hips and body.

Hogan stated that he had noticed one thing that all good golfers do and that all bad golfers do not. That observation was that the good golfers have their left wrists leading at impact. "At impact the left wrist of a good


\(^{40}\) Nicklaus, loc. cit., p. 32.
golfer is slightly convex, while that of a poor golfer is generally concave."^41

Middlecoff^42 explained that if a smooth, unhurried and full backswing has been made, then the downswing should follow an orderly sequence of movements. He says that while these movements appear to be made at the same time, they are separated by fractions of seconds with the legs and hips moving first, then the shoulders, and finally the hands and arms, with the club and clubhead trailing behind. "Move your hands down first and you will lose timing—and distance."^43

Follow-through

Berg and Dypwick, Suggs, and Wright indicated that the right heel is off the ground at contact and through the follow-through. These three agree that the right wrist begins to roll after the impact of the clubhead and that the right shoulder passes underneath the chin. The head is back of the ball at contact, according to these authorities. In addition they concurred that the hands roll to well above the head, maintaining control of the club and that the weight is completely on the left foot with the body in a well-balanced position. Wright, Fossum and Dagraedt stated

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^41Hogan, loc. cit., p. 34.


^43Ibid., p. 28.
that the hips and upper body will be facing the target at the finish of the follow-through. Wright added that immediately after impact the eyes should still be looking at the spot where the ball was, but all agreed that the head and eyes eventually turn to follow the flight of the ball.

III. SUMMARY OF RELATED LITERATURE

Section I of this chapter was concerned with cinematographical studies of a striking nature. Of those studies reviewed other than golf, five analyzed joint actions and linear or ball velocities, and one was a muscle analysis in conjunction with the filming. The review of cinematographical golf studies included two that were concerned with joint action and techniques of a shortened form of the swing. Of the studies of the full-swing one compared changes in momentum with weighted and non-weighted clubs, one used stroboscopic equipment to analyze the swings, three analyzed joint actions and linear velocities, and three were primarily interested in a muscular

44 Race, Blievernicht, Kitzman, Parchman, and Barth, loc. cit.
45 Kitzman, loc. cit.
46 Wrigglesworth, Kraska, loc. cit.
47 Clemence, loc. cit.
48 Rehling, loc. cit.
49 Kerr, Parchman, Brennan, loc. cit.
analysis of the swing.\textsuperscript{50}

Section II of this chapter was devoted to a description of the golf drive by recognized authorities.

\textsuperscript{50} Garrison, Slater-Hammel, and Karr, loc. cit.
CHAPTER III

PROCEDURE FOR THE STUDY

I. OVERVIEW OF THE STUDY

The filming for this study was conducted on the afternoon of November 15, 1969, in the Centenary College Gymnasium at Shreveport, Louisiana. The purpose of this study was to analyze the movement and timing of selected body segments during the execution of the golf drive by successful amateur women golfers who had won championship titles in state or regional competition.

II. SELECTION OF SUBJECTS

This study was limited to four successful women golfers, who, because of their championship titles, were assumed to have better golf swings. They included: Mrs. Barbara Fay White Boddie and Mrs. Jeanie Butler Kalencki both of Shreveport, Louisiana, Mrs. Wanda Hendrix of Tyler, Texas, and Miss Anne Hollier of Opelousas, Louisiana.

Barbara Fay Boddie, 29, won the Western Amateur and Broadmoor Invitational in 1964, the Western Amateur and Louisiana State Women's Amateur Championships in 1965, the Southern Women's Amateur Championship in 1967, and she was
a member of the Curtis Cup and World Team in 1964 and 1966. She was sixty-seven inches in height and weighed 120 pounds. She had a scratch handicap, was rated nationally in the top ten women amateurs in 1965 in the United States, and averaged 220 yards on her drives from the tee. The length of her driver was 43-1/2 inches. She used a club that had a men's medium shaft, and the swingweight of the clubhead was D-2.

Wanda Hendrix, 31, won the Texas State Women's Public Links Championship in 1960 and again in 1961. She was runner-up in the Texas State Women's Amateur Championship in 1961 and again in 1965. She won both the Southern Women's Amateur Tournament and the Louisiana State Women's Amateur Tournament in 1963. She was sixty-five inches in height and weighed 117 pounds. Her golf handicap was three, and she averaged 200 yards on her drives from the tee. Her driver was 43-1/2 inches in length that had a men's flexible shaft, and the swingweight of the clubhead was D-0.

Jeanie Butler Kalencki, 23, won the Texas Women's State Amateur Championship in 1964 and also the International Four-ball Tournament in 1966. She was sixty-eight inches in height and weighed 135 pounds. Her golf handicap was two, and her drives averaged 210 yards from the tee. Her club was 43-1/2 inches with a men's regular shaft, and the swingweight of her clubhead was D-0.

Anne Hollier, 34, won the Louisiana State Women's Amateur Championship in 1968 and again in 1969. She was
sixty-six inches in height and weighed 130 pounds. Her golf handicap was four, and she averaged 200 yards on her drives from the tee. Her club was 43-1/2 inches in length with a men's regular shaft. Her clubhead's swingweight was D-2.

III. FILMING PROCEDURE AND PHOTOGRAPHIC SET-UP

Three H16 Bolex Reflex cameras with variable shutters and set at sixty-four frames per second were employed to film each subject from the front, side, and overhead, simultaneously, as each subject executed the golf swing with a driver. Cine-Kodak Tri-X, reversal film type 7278 was used. The aperture for the camera located directly in front of the anterior side of the subject was F 2.5. The side camera located at the right side of the subject or at the "take-a-way" side, was set at an F-stop of 2.0. The overhead camera had an automatic setting for the amount of light available. The floor cameras were located twenty-five feet from the subject, and the overhead camera was located on a platform which was thirty feet from the subject being photographed. Each camera was secured to a tripod. The shutter speed for all three cameras was set at 1/400 of a second by adjustment of the variable shutter. A plumb line was used for locating the center of the area to be photographed, and the overhead camera was placed so that the lens was directly over that point. The floor cameras were placed so that the
lens focused on the end of the plumb line which was at a point waist high with the subject. Each camera was independently operated on a signal from the investigator.

Each subject was allowed to warm up prior to being filmed. The subject was then filmed as she hit a hard rubber indoor golf ball from a plastic tee with her driver. A total of three drives was filmed for each subject. Following the third filmed swing, each subject was filmed from her left side as she hit a plastic ball toward a floor camera in order that moment arms could be computed.

IV. EQUIPMENT USED

The following equipment was placed in view of all three cameras: a strobotac, Type 1531-A, General Radio Company, Concord, Massachusetts; numbered boxes for recording the three filmed swings of each subject; and a twelve inch reference marker. A black back-drop was placed behind the subjects to aid in distinguishing body outlines in the films taken by the front camera. A white net was placed to the left of the subjects to receive the driven balls. Two pieces of astro-turf nailed to two sheets of heavy plywood, 48 inches by 32 inches each, were placed side by side to provide a platform from which the subjects drove the balls. In addition a white sheet was placed beneath the boards. Three floodlights were placed on the floor to give additional lighting.
A black water color marking pen was used for drawing lines down the length of the left arm from the top of the shoulder to the wrist of each subject. Lines were also drawn down the length of the right side of the leg and from mid-thigh to the knee. The left wrist was encircled with a black line. A black "X" was marked at the top of the left shoulder. White tape was used to place an "X" on top of each subject's hair.

To assist in the determination of spinal and hip rotations, the subjects wore belts of wide elastic and adjustable burlap at the back of which light aluminum rods, 26 inches in length, were inserted. The spinal belt was placed around the thorax just below the armpits; the pelvic belt was placed around the pelvic girdle at the crest of the ilium. The changes in degrees from frame to frame for spinal and hip rotations were determined by the angle formed from the lines drawn through the projections of the aluminum rods.

Each subject used her own driver. Each subject wore white bermuda shorts, a white sleeveless shirt, and golf spikes.

V. PROCEDURE FOR ANALYSIS

The film from each of the three cameras was processed, and an additional print of each of the films was made. After determining the best sequence in terms of photography
and a frame which showed as nearly as possible actual contact of the clubhead with the ball, the side, front, and top views for each subject were then cut and spliced together. The third "take" for three of the subjects and the second for the fourth one were selected. Each of the three views for that subject was labeled by scratching a letter of the alphabet (A, B, C, etc.) backwards on the edge of the emulsion side of the film. This was done to simplify the recording of the data for each frame. The first letter (A) was placed at the frame immediately before the takeaway of the golf club. After scratching "A-1, A-2, A-3, etc." through to "A-5," "B-1, etc." was then placed in order.

The strobotac set to flash every 1/20th of a second to determine the framing rate for each camera was used.

Tracings of the outline of the subject in each view were made with a 4-H pencil on thin tracing paper while the film was projected via the Recordak. The downswing was used for calculating the linear and angular velocities of the body levers. To determine the angle for the wrist lever, intersecting lines were drawn through the length of the shaft of the club and through the center of the forearm. To determine the angle for shoulder abduction, intersecting lines were drawn through the humerus, lengthwise, and from the top of both shoulders, horizontally. Pelvic rotation and spinal rotation were determined by measuring the changes in angle from the lines drawn through the lengths of the rods in the
elastic belts.

The joint actions contributing to the velocity of the golf swing were measured one frame before contact. The changes in degrees from one frame before contact to the contact frame were converted into degrees per second by dividing the degrees by the time for the frame. The quotient of degrees per second divided by 57.2957 degrees represented radians per second. The product of radians per second and the length of the moment arm represented the linear velocity in feet/second. Moment arms for the wrist, shoulder, spine, and hip were measured as the perpendicular distance from the axis of rotation to the point of contact. The following formula was used for computation of the linear velocity.

\[
\text{Linear velocity} = \frac{\text{Angular velocity} \times \text{Length of moment arm}}{57.29}
\]

In measuring the lengths of moment arms or linear distances, a conversion factor was needed which converted the film measure to actual measure. Reference markers of twelve inches were in view of all cameras. Measurement was made with a 50th of an inch ruler, and twelve inches divided by the number of fiftieths measured gave the length in inches equal to one-fiftieth of an inch. The actual lengths were then converted to feet.

The number of frames exposed per second by the camera was determined in the following manner:
\[
\frac{\text{Total no. of frames}}{\text{Total time}} = \text{frames per second}
\]

Angles of inclination were drawn showing body segment movement and club shaft movement. The time required for the selected body segments to complete the backswing and downswing was computed.
CHAPTER IV

PRESENTATION AND ANALYSIS OF THE DATA

The analysis of the data for this study was facilitated by analyzing sixteen millimeter motion picture films of the golf drive of four successful amateur female golfers. Three views of each subject were recorded by three cameras running simultaneously.

Body segment contributions to the linear velocity of the clubhead were computed for each subject using the formula:

\[
\text{Linear Velocity} = \frac{\text{Angular Velocity \times Moment}}{57.2957 \times \text{Arm}}
\]

In order to determine frame time, the strobotac was set to flash every .05 second. It was expected that the frames between flashes would be counted, and that a consecutive number of flashes would occur. However, consecutive flashes were recorded for the side and top views for only one subject, and consecutive flashes were recorded for the front view for another subject. In all other views of the subjects, consecutive flashes occurred no more than four times. Therefore, on the basis of the views in which at least nine consecutive flashes were recorded, the following frame times were established: side and top cameras, sixty-three frames
per second and front camera, sixty-two frames per second. The time per frame was .0159 seconds for the side and top cameras and .0161 for the front camera.

Linear distances in the films were converted to increments of fifty units per inch. For the top view thirty-two increments were equal to twelve inches, while the front view yielded thirty-five increments equal to twelve inches, and the side view distances of twelve inches were equal to forty increments.

I. BARBARA FAY BODDIE

Analysis of the Swing in the Front View

Barbara Fay Boddie is hereafter referred to as "subject one."

Figure 1 depicts four tracings of the subject from the front view. It may be seen that frame "E-5" is that of the subject as she addressed the ball, and it was one frame before the takeaway of the clubhead. Each tracing after frame "G-1" represents the position of the subject after every five frames. Each five frames represents a time span of .08 seconds.

It may be observed in frame "E-5" of Figure one that the subject's lower left arm and clubshaft were not a straight extension and were hyperextended seven degrees. However, as the hands reached a point almost in the center of the body in frame "H-1," seven degrees of wrist flexion
FIGURE 1

TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF BARBARA FAY BOODIE WHILE EXECUTING GOLF DRIVE, FRONT VIEW
had occurred. An additional nine degrees occurred in "I-1," when the hands were in front of the right leg; ten additional degrees occurred in "J-1" (Fig. 2) when the hands were in front of the right hip; and an additional ten degrees occurred in "K-1," the point at which the clubshaft was horizontal to the floor and the hands were almost at a point level with the waist. From that point the subject's hands appeared to reach further back as spinal rotation occurred to allow the left shoulder to turn beneath the chin. The angle in the wrist increased sixty-three degrees in frame "L-1," at which time the left arm was almost horizontal to the floor. This increase was almost double that of the angle in "K-1." In frame "L-1" the subject's left knee began to adduct, or move in toward the midline of the body, and flex. It was observed that in "M-1," (Fig. 2) "N-1" and "O-1" (Fig. 3) that there was little change in the angle of the wrist joint; it was during these frames that the shoulder continued to rotate as the clubshaft reached the top of the backswing. Table I presents the change in the angle of the wrist joint during the backswing and the downswing of the clubshaft.

The hands have reached the top of the backswing in frame "O-1." The clubshaft dropped ten degrees below a position horizontal to the floor at that point. The hands were to the right of and above head level at that point in "O-1"; the left arm was straight but not hyperextended.
FIGURE 2

TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF BARBARA FAY BODDIE WHILE EXECUTING THE GOLF DRIVE, FRONT VIEW
FIGURE 3

TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF BARBARA
FAY BODDIE WHILE EXECUTING THE GOLF DRIVE, FRONT VIEW
TABLE I

CHANGES IN ANGLE OF WRIST JOINT DURING VARIOUS PHASES AS REPRESENTED BY FRAMES OF MOTION PICTURES DURING BACKSWING AND DOWNSWING OF GOLF DRIVE OF BARBARA FAY BODDIE

<table>
<thead>
<tr>
<th>Frame</th>
<th>Degree of Change</th>
<th>Frame</th>
<th>Degree of Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>E-5</td>
<td>-7</td>
<td>P-1</td>
<td>117</td>
</tr>
<tr>
<td>G-1</td>
<td>0</td>
<td>Q-1</td>
<td>120</td>
</tr>
<tr>
<td>H-1</td>
<td>7</td>
<td>R-1</td>
<td>96</td>
</tr>
<tr>
<td>I-1</td>
<td>16</td>
<td>R-3</td>
<td>68</td>
</tr>
<tr>
<td>J-1</td>
<td>26</td>
<td>R-5</td>
<td>44</td>
</tr>
<tr>
<td>K-1</td>
<td>36</td>
<td>S-1</td>
<td>33</td>
</tr>
<tr>
<td>L-1</td>
<td>63</td>
<td>S-2</td>
<td>28</td>
</tr>
<tr>
<td>M-1</td>
<td>116</td>
<td>S-3</td>
<td>0</td>
</tr>
<tr>
<td>N-1</td>
<td>118</td>
<td>S-4</td>
<td>-21</td>
</tr>
<tr>
<td>O-1</td>
<td>118</td>
<td>S-5</td>
<td>-38</td>
</tr>
</tbody>
</table>
Superimposed over frame "0-1" were the succeeding frames: "0-2," "0-3," "0-4," "0-5," and "P-2," and it was observed that the first movement in the downswing was a lateral shift of the left hip in the direction of the line of flight. The left thigh also began to abduct or move away from the midline of the body. There appeared to be little change in the position of the hands and the clubshaft through frame "0-4," however, in "0-5" the hands brought the clubshaft back to a horizontal position. Not until "P-2" did the hands move from the high position above the head. The hips move laterally through "P-2," and thereafter, appeared to rotate. As the subject pulled the clubshaft down in "P-2," it was noted that her left knee had returned to her address position, and the right knee had flexed and the right thigh had adducted. Little change occurred in the wrist lever until "Q-5" (Fig. 4) when the left arm had returned to a position horizontal to the floor. From "Q-5" to "R-1" the wrist angle decreased 19 degrees as the wrists "uncocked." Both knees had flexed. From Table I it may be seen that the angle in the wrist was decreasing through each frame throughout downswing.

One frame before the contact frame, the wrist angle was 28 degrees (see Figure 5). At contact, in frame "S-3" it was observed that the left knee appeared to be extended (see Figure 5). The left arm was extended, and the head was well behind the ball. The wrist angle continued to decrease after contact.
FIGURE 4

TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF BARBARA FAY BODDIE WHILE EXECUTING THE GOLF DRIVE, FRONT VIEW
FIGURE 5
TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF BARBARA FAY BODDIE WHILE EXECUTING THE GOLF DRIVE, FRONT VIEW
The subject's head remained well in position after contact. At the finish of her swing her hands were over seven inches above and slightly back of her head. Her weight appeared to be supported entirely on her left foot, as her right toe maintained contact with the turf.

Figure six shows the path of the clubshaft during the backswing from selected frames, and Figure seven is that of the downswing. The time in which the subject completed her backswing was fifty frames or .805 seconds. Her downswing was completed in or nineteen frames or in .3059 seconds. The downswing was over 2.6 times as fast as the backswing.

Analysis of the Swing in the Side View

The path of the clubshaft on the backswing and downswing are shown in Figure eight. The clubhead appeared to move away from the ball fairly straight from E-1 to "G-1." It can be seen, however, in "G-4" or fourteen frames after the takeaway, that the clubhead has left that path. The shaft and arm flattened somewhat as both reached back on the backswing. The downswing plane is more upright. The paths of the hands were not the same for the two planes.

During the backswing the right knee of the subject appeared to extend somewhat. The joint moved 1.4 inches from the address position to the top of the backswing (see Figure nine). There were twenty-one degrees of flexion at
FIGURE 6

OVERLAPPED TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF CLUBSHAFT DURING BACKSWING OF GOLF DRIVE OF BARBARA FAY BODDIE, FRONT VIEW
FIGURE 7
OVERLAPPED TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF CLUBSHAFT DURING DOWNSWING OF GOLF DRIVE OF BARBARA FAY BODDIE, FRONT VIEW
FIGURE 8
OVERLAPPED TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF CLUBSHAFT DURING BACKSWING AND DOWNSWING OF GOLF DRIVE OF BARBARA FAY BODDIE, SIDE VIEW
FIGURE 9

TRACINGS MADE FROM FRAMES OF MOTION PICTURES
OF ADDRESS POSITION AND TOP OF BACKSWING
POSITION OF GOLF DRIVE OF BARBARA
FAY BODDIE, SIDE VIEW
the right knee joint in "E-1" and seventeen degrees in frame "O-1." The right humerus is parallel to the ground, and the elbow does not point toward the ground. The top of the hands were four inches above a point level with the head. The left heel lifted slightly from the turf.

Figure ten illustrates the path of the ball in each succeeding frame as well as the path of the clubshaft on the follow-through. The subject appears to have hooked the ball. It can be seen that the clubshaft in "S-4" was approximately shoulder level.

Analysis of the Swing in the Top View

Figure 11 shows the view of the subject from the top camera during her address position. It appeared, in observing the hip and spinal markers, that the subject's left shoulder and left hip were slightly "open" toward the target. However, her stance was "closed." The right foot was abducted at eight degrees while the left foot was turned at approximately thirty degrees.

Figure 12 illustrates the change in hip rotation on the backswing and on the downswing. The hips rotated a total of seventy degrees on the backswing from B-1 to "K-1"; however, only fifty-five degrees occurred from a line parallel to the line of flight. Hip rotation on the backswing was completed in 46 frames. The hips moved laterally in "K-5" to initiate the downswing. Rotation of the hips
FIGURE 10
OVERLAPPED TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF BALL AND CLUBSHAFT AFTER CONTACT DURING GOLF DRIVE OF BARBARA FAY BODDIE, SIDE VIEW
FIGURE 11

TRACING MADE FROM FRAME OF MOTION PICTURES OF ADDRESS POSITION OF GOLF DRIVE OF BARBARA FAY BODDIE, TOP VIEW
FIGURE 12

OVERLAPPED TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF HIP ROTATION REPRESENTED BY ALUMINUM RODS DURING BACKSWING AND DOWNSWING OF GOLF DRIVE OF BARBARA FAY BODDIE, TOP VIEW
covered 113 degrees to "O-2," contact frame. The hips rotated three degrees one frame before contact.

Figure 13 represents the amount of spinal rotation on the backswing and downswing. From the address position the spine rotated a total of 111 degrees on the backswing; however, ninety-one degrees occurred from a line parallel to the line of flight. From "K-5" in which spinal rotation began in the downswing to "P-2," contact frame, a total of 124 degrees of rotation occurred. Four degrees of rotation occurred in the spine one frame before contact. It was noted that hip rotation ceased at contact, but spinal rotation continued after contact to a total of 250 degrees indicating spinal flexibility from the top of the backswing to the finish of the follow-through in "S-3."

Body Segment Contributions to Linear Velocity of the Clubhead

To determine the contributions of each segment to the linear velocity of the clubhead, it was necessary to determine the change in degrees of each acting joint one frame before contact. Joint angular activity contributing to the linear velocity included: wrist, twenty-eight degrees; shoulder, four degrees; hip, three degrees; and spine, four degrees.

The lengths of the moment arms were calculated and are illustrated by the broken lines from the axis of rotation to the point of contact in Figure 14. Each moment arm
FIGURE 13

OVERLAPPED TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF SPINAL ROTATION REPRESENTED BY ALUMINUM RODS DURING BACKSWING AND DOWNSWING OF GOLF DRIVE OF BARBARA FAY BODDIE, TOP VIEW
FIGURE 14

MOMENT ARM LENGTHS REPRESENTED BY DOTTED LINES OF WRIST, SHOULDER, SPINE, AND HIP OF BARBARA FAY BODDIE WHILE EXECUTING GOLF DRIVE
was the perpendicular distance from the axis. Moment arms for the following articulations were measured as: wrist, 125/50 units or 3.1 feet; shoulder, 190/50 units or 4.7 feet; hip, 120/50 units or 3.0 feet; and spine, 160/50 units, or 4.0 feet.

The degrees of change for each contributing segment of the body from one frame before contact to contact were determined and converted to linear velocity. Table II presents these results. In addition the percentage of contribution to the summed linear velocity is presented for each segment of the body.

The summed linear velocities of the body segments were approximately 141.9125 feet per second (see Table II). Of that total, the wrist was the major contributor at 66.31 percent, the shoulder was second at 14.36 percent, the spine was next at 12.37 percent, and the hip was least at 6.96 percent.

II. WANDA HENDRIX

Analysis of the Swing in the Front View

Figure 15 presents tracings of the outline of subject two from the front view.

It may be observed in frame "A-1" that the clubshaft and left arm during the address were not a straight extension and were hyperextended fourteen degrees. Ten frames later in "C-1" when the hands were in front of the body the
### TABLE II

**BODY SEGMENT CONTRIBUTIONS TO LINEAR VELOCITY OF CLUBHEAD DURING GOLF DRIVE AS EXECUTED BY BARBARA FAY BODDIE**

<table>
<thead>
<tr>
<th>Lever</th>
<th>Degrees</th>
<th>Degrees Per Second</th>
<th>Radians Per Second</th>
<th>Moment Arm (Ft.)</th>
<th>Linear Velocity (Ft./Sec.)</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hip</td>
<td>3</td>
<td>188.6792</td>
<td>3.293</td>
<td>3.0</td>
<td>9.879</td>
<td>6.96</td>
</tr>
<tr>
<td>Spine</td>
<td>4</td>
<td>251.5729</td>
<td>4.340</td>
<td>4.0</td>
<td>17.560</td>
<td>12.37</td>
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<tr>
<td>Wrist</td>
<td>28</td>
<td>1739.1310</td>
<td>30.353</td>
<td>3.1</td>
<td>94.0943</td>
<td>66.31</td>
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<td><strong>Total</strong></td>
<td></td>
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<td></td>
<td></td>
<td><strong>141.9125</strong></td>
<td><strong>100.00</strong></td>
</tr>
</tbody>
</table>


FIGURE 15

TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF WANDA HENDRIX WHILE EXECUTING GOLF DRIVE, FRONT VIEW
arm and shaft were extended. By the time that the hands reached a point at approximately hip level in frame "G-1" (Fig. 16) the wrist angle had increased to thirty-five degrees. At this point the left knee had begun to flex and the left thigh had begun to adduct. The hands reached back in "H-1," and the angle of the wrist increased to 100 degrees, almost three times that of the angle in "G-1." At that point the arm was in a position just below the horizontal.

Table III shows the change in angle of the wrist joint in the backswing and in the downswing of the clubshaft. Figure 17 shows additional tracings of the front view. As the subject continued to raise her hands on the backswing in "I-1," "J-1," and "K-1," the wrist angle decreased slightly as she raised her clubshaft vertically. At the top of the backswing in "K-1" the clubshaft had reached a point thirty degrees above the horizontal position. As she started her downswing in "K-3," her hands moved downward simultaneously as her left knee initiated the hip turn. It appeared that her hip movement was rotation and not a lateral movement. As her hands pulled the clubshaft downward, her wrist angle continued to increase through frame "M-2" (Fig. 18) to a total of 132 degrees. It can be seen in "M-2" that the left arm is at a position horizontal to the floor.

In frame "N-1" (Fig. 19) the wrist angle had decreased to ninety-six degrees and the right heel was well off of the turf. Both knees were flexed. The wrist angle decreased
FIGURE 16

TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF WANDA HENDRIX WHILE EXECUTING GOLF DRIVE, FRONT VIEW
TABLE III
CHANGES IN ANGLE OF WRIST JOINT DURING VARIOUS PHASES AS REPRESENTED BY FRAMES OF MOTION PICTURES DURING BACKSWING AND DOWNSWING OF GOLF DRIVE OF WANDA HENDRIX

<table>
<thead>
<tr>
<th>Frame</th>
<th>Degree of Change</th>
<th>Frame</th>
<th>Degree of Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-1</td>
<td>-14</td>
<td>K-3</td>
<td>98</td>
</tr>
<tr>
<td>B-1</td>
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<td>123</td>
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<tr>
<td>D-1</td>
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<tr>
<td>K-1</td>
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<td></td>
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<td>-21</td>
</tr>
<tr>
<td></td>
<td></td>
<td>O-4</td>
<td>-40</td>
</tr>
</tbody>
</table>
FIGURE 17

TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF WANDA HENDRIX WHILE EXECUTING GOLF DRIVE, FRONT VIEW
FIGURE 18

TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF WANDA HENDRIX WHILE EXECUTING GOLF DRIVE, FRONT VIEW
FIGURE 19

TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF WANDA HENDRIX WHILE EXECUTING GOLF DRIVE, FRONT VIEW
through each succeeding frame from that point. In frame "O-1" (Fig. 20) one frame before contact, the angle of the wrist joint was 29 degrees. At contact the left knee appeared to be flexed slightly and remained in that position well after contact. The left arm and clubshaft did not appear to be quite extended, but it was felt that frame "O-2" was a split instant before contact. The head was well behind the ball.

The angle of the wrist continued to decrease after contact. While the subject's head remained down after contact, she had moved to observe the ball before her arms reached a horizontal position.

Figures 21 and 22 present the path of the clubshaft during the backswing and the downswing from selected frames. The time in which the subject completed her backswing in fifty-one frames was .8211 seconds. Her downswing was completed in twenty frames or .322 seconds. Her downswing was 2.55 times that of the backswing.

Analysis of the Swing in the Side View

Figures 23, 24, 25, and 26 are tracings from selected frames of the side view of the subject. The takeaway of the clubhead was observed as moving away from the ball from "B-1" to "C-1." It appeared that the clubhead did not move away in a straight line. The arms had moved closer to the body as early as "B-1." In "D-1," the trunk had inclined forward
FIGURE 20
TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF WANDA HENDRIX WHILE EXECUTING GOLF DRIVE, FRONT VIEW
FIGURE 21

TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF CLUBSHAFT DURING BACKSWING OF GOLF DRIVE OF WANDA HENDRIX, FRONT VIEW
FIGURE 22

TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF CLUBSHAFT DURING DOWNSWING OF GOLF DRIVE OF WANDA HENDRIX, FRONT VIEW
FIGURE 23
TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF WANDA HENDRIX WHILE EXECUTING GOLF DRIVE, SIDE VIEW
FIGURE 24

TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF 
WANDA HENDRIX WHILE EXECUTING GOLF DRIVE, 
SIDE VIEW
FIGURE 25

TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF WANDA HENDRIX WHILE EXECUTING GOLF DRIVE, SIDE VIEW
FIGURE 26

TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF WANDA HENDRIX WHILE EXECUTING GOLF DRIVE, SIDE VIEW
three degrees and by "E-1" ten degrees of forward inclination had occurred. It was observed that the left heel was approximately three inches off of the floor in frame "I-1." However, the subject lowered the heel a bit in "I-3" of Figure 25, but her downswing did not begin until "J-3." At the top of her swing in "J-1," the right elbow appeared to point toward the floor. Her hands were at a point approximately level with her head. In "N-1" (Fig. 26) at contact the trunk had inclined forward by twelve degrees from that of the trunk inclination at address. At contact the left knee appeared to be flexed. This was noticeable from the front tracings as well.

The subject's right knee decreased from thirty-four degrees of flexion at address to twenty-five degrees of flexion by the time that the clubshaft reached the top of the backswing. In addition the right knee moved backward from its position at address 2.1 inches.

Figures 27 and 28 illustrate overlapped tracings of the path of the clubshaft on the backswing and the downswing. Again it can be seen that the clubhead was swept back in a circular motion rather than in a straight line. Both the backswing and downswing would be described as somewhat "flattened" in their paths.

In Figure 29 the path of the ball and the clubshaft on the follow-through may be observed. The ball appeared to have been hit slightly out to the right. The follow-through
FIGURE 27

OVERLAPPED TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF CLUBSHAFT DURING BACKSWING OF GOLF DRIVE OF WANDA HENDRIX, SIDE VIEW
FIGURE 28
OVERLAPPED TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF CLUBSHAFT DURING DOWNSWING OF GOLF DRIVE OF WANDA HENDRIX, SIDE VIEW
FIGURE 29

OVERLAPPED TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF BALL AND CLUBSHAFT AFTER CONTACT DURING GOLF DRIVE OF WANDA HENDRIX, SIDE VIEW
may be seen as being more horizontal than vertical; the inclination of the shaft of frame "0-2" was thirty-seven degrees to the horizontal.

Analysis of the Swing in the Top View

Figure 30 shows the view of the subject from the top camera during the address position. The stance was a "closed" one, and her left toe was abducted at nineteen degrees while the left toe was turned at approximately thirty degrees. Both hip and spine were "open" slightly toward the target.

Figure 31 illustrates the change in hip rotation on the backswing and on the downswing. The hips rotated sixty degrees from "A-1" to "J-1," the top of the backswing; however, only fifty degrees of rotation occurred from a line parallel to the line of flight. The rotation in the downswing covered 100 degrees from the top of the swing to contact. The hips rotated four degrees one frame before contact. The hips also rotated an additional four degrees one frame after contact.

Figure 32 represents the amount of spinal rotation on the backswing and downswing. From the address position to the top of the backswing, the spine rotated 105 degrees; however, ninety-three degrees occurred from a line parallel to the line of flight.

From "J-4" to contact "N-2," the spine rotated 124 degrees. Seven degrees of rotation occurred one frame
TRACING MADE FROM FRAME OF MOTION PICTURES OF ADDRESS POSITION OF GOLF DRIVE OF WANDA HENDRIX, TOP VIEW
FIGURE 31

OVERLAPPED TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF HIP ROTATION REPRESENTED BY ALUMINUM RODS DURING BACKSWING AND DOWNSWING OF GOLF DRIVE OF WANDA HENDRIX, TOP VIEW
FIGURE 32
OVERLAPPED TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF SPINAL ROTATION REPRESENTED BY ALUMINUM RODS DURING BACKSWING AND DOWNSWING OF GOLF DRIVE OF WANDA HENDRIX, TOP VIEW
before contact.

**Body Segment Contributions**

**Linear Velocity of the Clubhead**

Joint angular activity contributions to the linear velocity of the clubhead included: wrist, twenty-nine degrees; shoulder, zero degrees; hip, four degrees; and spine, seven degrees.

The lengths of the moment arms measured in moments of fiftieths of an inch were: wrist, 103/50 units or 2.57 feet; shoulder, 178/50 units or 4.45 feet; hip, 120/50 units or 3.0 feet; and spine, 162/50 units or 4.0 feet. The conversion factor was 40/50 units equal to twelve inches (see Figure 33).

The degrees of change for each contributing segment of the body from one frame before contact to contact were determined and converted to linear velocity. Table IV presents these results. In addition the percentage of contribution to the summed linear velocity is presented for each segment of the body.

The summed linear velocities of the body segments were approximately 124.7019 feet per second. Of that total, the wrist was the major contributor at 64.79 percent, the spine was second at 24.65 percent, and the hip was third at 10.56 percent. There was no shoulder action one frame before contact.
FIGURE 33

MOMENT ARM LENGTHS REPRESENTED BY DOTTED LINES OF WRIST, SHOULDER, SPINE, AND HIP OF WANDA HENDRIX WHILE EXECUTING GOLF DRIVE
TABLE IV

BODY SEGMENT CONTRIBUTIONS TO LINEAR VELOCITY OF CLUBHEAD DURING GOLF DRIVE AS EXECUTED BY WANDA HENDRIX

<table>
<thead>
<tr>
<th>Lever</th>
<th>Range</th>
<th>Degrees Per Second</th>
<th>Radians Per Second</th>
<th>Moment Arm (Ft.)</th>
<th>Linear Velocity (Ft./Sec.)</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spine</td>
<td>7</td>
<td>440.2515</td>
<td>7.6838</td>
<td>4.0</td>
<td>30.7352</td>
<td>24.65</td>
</tr>
<tr>
<td>Hip</td>
<td>4</td>
<td>251.5729</td>
<td>4.3907</td>
<td>3.0</td>
<td>13.1721</td>
<td>10.56</td>
</tr>
<tr>
<td>Wrist</td>
<td>29</td>
<td>1801.242</td>
<td>31.4376</td>
<td>2.57</td>
<td>80.7946</td>
<td>64.79</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Total</td>
<td>124.7019</td>
<td>100.00</td>
</tr>
</tbody>
</table>
Analysis of the Swing in the Front View

Figure 34 represents tracings of subject three from the front view. It may be observed that the wrist is hyper-extended four degrees in the address position in frame "B-3" prior to the takeaway. Five frames later the shaft and lower arm were extended, but by "D-3" there were six degrees of radial flexion of the left wrist and this increased to twenty-one degrees in "E-3" (Fig. 35) when the hands were centered in front of the body. The left hand pronated during those five frames, and the angle increased only gradually from that point until the hands reached hip level in "H-1" (Fig. 36). The greatest angle increase occurred from that frame to "I-1," when the hands moved from hip to waist level.

Table V depicts the change in angle of the wrist joint in the backswing and downswing of the clubshaft. The clubshaft reached the top of the backswing in frame "M-3" (Fig. 38) when the hands were approximately head level. The clubshaft reached a position twelve degrees above the horizontal. As early as "L-3" (Fig. 37) the left knee had begun to abduct toward the target, although the shaft continued to backswing toward the horizontal through "M-2." In "M-3" the hips moved laterally as the hands pulled the clubshaft into the downswing. It may be observed in the table that the angle increased to 127 degrees in frame "M-4" and by as much
FIGURE 34
TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF JEANIE BUTLER KALENCKI WHILE EXECUTING THE GOLF DRIVE, FRONT VIEW
FIGURE 35

TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF JEANIE BUTLER KALENCKI WHILE EXECUTING THE GOLF DRIVE, FRONT VIEW
FIGURE 36

TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF JEANIE BUTLER KALENCKI WHILE EXECUTING THE GOLF DRIVE, FRONT VIEW
TABLE V

CHANGES IN ANGLE OF WRIST JOINT DURING VARIOUS PHASES AS REPRESENTED BY FRAMES OF MOTION PICTURES DURING BACKSWING AND DOWNSWING OF GOLF DRIVE OF JEANIE BUTLER KALENCKI

<table>
<thead>
<tr>
<th></th>
<th>Backswing</th>
<th></th>
<th>Downswing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frame</td>
<td>Degree of Change</td>
<td>Frame</td>
<td>Degree of Change</td>
</tr>
<tr>
<td>B-3</td>
<td>-4</td>
<td>M-3</td>
<td>105</td>
</tr>
<tr>
<td>C-3</td>
<td>0</td>
<td>M-4</td>
<td>127</td>
</tr>
<tr>
<td>D-3</td>
<td>6</td>
<td>N-3</td>
<td>143</td>
</tr>
<tr>
<td>E-3</td>
<td>21</td>
<td>O-1</td>
<td>124</td>
</tr>
<tr>
<td>F-1</td>
<td>25</td>
<td>O-4</td>
<td>62</td>
</tr>
<tr>
<td>G-1</td>
<td>32</td>
<td>O-5</td>
<td>47</td>
</tr>
<tr>
<td>H-1</td>
<td>38</td>
<td>P-1</td>
<td>35</td>
</tr>
<tr>
<td>I-1</td>
<td>64</td>
<td>P-2</td>
<td>10</td>
</tr>
<tr>
<td>J-1</td>
<td>85</td>
<td>P-3</td>
<td>-18</td>
</tr>
<tr>
<td>K-1</td>
<td>99</td>
<td>P-4</td>
<td>-27</td>
</tr>
<tr>
<td>L-1</td>
<td>99</td>
<td>P-5</td>
<td>-39</td>
</tr>
<tr>
<td>L-3</td>
<td>105</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
FIGURE 37

TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF JEANIE BUTLER KALENCZKI WHILE EXECUTING THE GOLF DRIVE, FRONT VIEW
FIGURE 38

TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF JEANIE BUTLER KALENCKI WHILE EXECUTING THE GOLF DRIVE, FRONT VIEW
as 143 degrees in "N-3" (Fig. 39), even though the downswing of the clubshaft had occurred six frames earlier. From the point in "N-3" in which the left arm was approximately horizontal to the ground, the right knee was flexing and the right thigh adducting. It may be observed that the left knee was gradually extending in succeeding frames.

Because of the malfunction of the camera, only two front view sequences were recorded for this subject. Neither recorded the frame that showed the clubhead as it contacted the ball. For this reason the linear velocities were averages over two frames. The subject contacted the ball sometime between frame "P-2" and "P-3" (Fig. 40). It may be observed that the wrist angle was thirty-five degrees two frames before contact and ten degrees one frame before contact.

At one frame before contact the head was well behind the ball, the left knee appeared to be extended, and the left arm was extended. The weight of the body seemed to have moved well onto the left foot while the right toe maintained contact with the floor. The hands reached a point well above the head with the right arm extended on the follow-through.

Figures 41 and 42 present overlapped tracings of the path of the clubshaft during the backswing and the downswing. It can be observed that the backswing was completed in fifty-four frames, or .8694 seconds and the downswing in approximately sixteen frames or .2576 seconds.
FIGURE 39

TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF JEANIE BUTLER KALENCKI WHILE EXECUTING THE GOLF DRIVE, FRONT VIEW
FIGURE 40

TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF JEANIE BUTLER KALENCKI WHILE EXECUTING THE GOLF DRIVE, FRONT VIEW
FIGURE 41

OVERLAPPED TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF CLUBSHAFT DURING BACKSWING OF GOLF DRIVE OF JEANIE BUTLER KALENCKI, FRONT VIEW
FIGURE 42
OVERLAPPED TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF CLUBSHAFT DURING DOWNSWING OF GOLF DRIVE OF JEANIE BUTLER KALENCIKI, FRONT VIEW
The downswing was approximately 3.38 times as fast as the backswing.

**Analysis of the Swing in the Side View**

Tracings of the subject in the side view are presented in Figures 43, 44, 45, 46. It may be observed that the clubhead moved away from the ball in a straight line through "C-1." This can be seen also in Figures 47 and 48 which show overlapped tracings of the path of the clubshaft during the backswing and the downswing.

During the backswing the right knee of the subject extended from twenty-two degrees of flexion to seven degrees from "A-1" to "K-1." The knee joint moved three inches back from its position at address by the time the clubshaft reached the top of the backswing in "K-3." It appeared that the left heel had lifted slightly from the turf in "K-1." The right elbow pointed toward the floor at the top of the backswing; the left arm appeared to be extended.

It can be seen in Figures 47 and 48 that the planes for the clubshaft are more similar than dissimilar. The downswing, appeared to be "flatter" than the backswing.

Figure 49 presents the path of the ball in each succeeding frame as well as the path of the clubshaft on the follow-through. The path of the ball indicated that the subject hit the ball straight ahead. The clubshaft represented as "O-4," was at an inclination of forty-four degrees to the horizontal. The position of the clubshaft was above
FIGURE 43

TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF JEANIE BUTLER KALENCKI WHILE EXECUTING GOLF DRIVE, SIDE VIEW
FIGURE 44

TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF JEANIE BUTLER KALENCKI WHILE EXECUTING GOLF DRIVE, SIDE VIEW
FIGURE 45
TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF JEANIE BUTLER KALENCKI WHILE EXECUTING GOLF DRIVE, SIDE VIEW
FIGURE 46
TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF JEANIE BUTLER KALENCKI WHILE EXECUTING GOLF DRIVE, SIDE VIEW
FIGURE 47

OVERLAPPED TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF CLUBSHAFT DURING BACKSWING OF GOLF DRIVE OF JEANIE BUTLER KALENCKI, SIDE VIEW
FIGURE 48

OVERLAPPED TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF CLUBSHAFT DURING DOWNSWING OF GOLF DRIVE OF JEANIE BUTLER KALENCKI, SIDE VIEW
FIGURE 49

OVERLAPPED TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF BALL AND CLUBSHAFT AFTER CONTACT DURING GOLF DRIVE OF JEANIE BUTLER KALENCKI, SIDE VIEW
the height of the right shoulder.

Analysis of the Swing in the Top View

Figure 50 presents a tracing of the view of the subject from the top camera. The left foot was abducted thirty-nine degrees while the right one pointed straight ahead. The subject was in a slightly "open" stance. The spinal marker indicated that the left shoulder was approximately parallel to the line of flight, while the hip marker indicated that the left hip was slightly "open."

The hips rotated seventy-four degrees on the backswing from frame "B-1," address, to "J-1," the top of the backswing, and 115 degrees on the downswing from "K-1" to "N-4," contact frame (see Figure 51). The spine rotated 112 degrees during the backswing from "B-1" to "K-1" and 141 degrees on the downswing from "K-2" to contact at "N-4," (see Figure 52). The hips rotated four degrees one frame prior to contact and the spine rotated eight degrees. The hips rotated an additional twelve degrees following the contact frame. The spine continued to rotate until the finish of the follow-through.

Body Segment Contributions to Linear Velocity of the Clubhead

Joint angular activity contributing to the linear velocity of the clubhead included: wrist, twenty-two degrees; hip, four degrees; spine, eight degrees; and shoulder, two
FIGURE 50

TRACING MADE FROM FRAME OF MOTION PICTURES OF ADDRESS POSITION OF GOLF DRIVE OF JEANIE BUTLER KALENCKI, TOP VIEW
FIGURE 51

OVERLAPPED TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF HIP ROTATION REPRESENTED BY ALUMINUM RODS DURING BACKSWING AND DOWNSWING OF GOLF DRIVE OF JEANIE BUTLER KALENCIKI, TOP VIEW
FIGURE 52

OVERLAPPED TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF SPINAL ROTATION REPRESENTED BY ALUMINUM RODS DURING BACKSWING AND DOWNSWING OF GOLF DRIVE OF JEANIE BUTLER KALENCKI, TOP VIEW
degrees.

The lengths of the moment arms are shown in Figure 53. The moment arm for the wrist measured 115/50 units; for the shoulder it measured 177/50 units; for the hip it measured 125/50 units; and for the spine it was 150/50 units. Using a conversion factor of 35/50 units equal to twelve inches, the moment arm for the wrist was 3.2 feet, for the shoulder it was 5.0 feet, for the hip it was 3.5 feet, and for the spine, it was 4.3 feet.

The degrees of change for each contributing segment of the body from one frame before contact to contact were determined and converted to linear velocity. Table VI presents these results. In addition the percentage of contribution to the summed linear velocity is presented for each segment of the body.

The summed linear velocities of the body segments were approximately 140.2853 feet per second. Of that total the wrist was the major contributor at 54.42 percent, the spine was second at 26.91 percent, the hip was third at 10.95 percent, and the shoulder least at 7.72 percent.

IV. ANNE HOLLIER

Analysis of the Swing in the Front View

Tracings of the outline of the fourth subject are shown in Figure 54. It was observed in frame "A-1" that the left lower arm and clubshaft were not extended and in fact
FIGURE 53

MOMENT ARM LENGTHS REPRESENTED BY DOTTED LINES OF WRIST, SHOULDER, SPINE, AND HIP OF JEANIE BUTLER KALENCKI WHILE EXECUTING GOLF DRIVE
**TABLE VI**

BODY SEGMENT CONTRIBUTIONS TO LINEAR VELOCITY OF CLUBHEAD DURING GOLF DRIVE AS EXECUTED BY JEANIE BUTLER KALENCKI

<table>
<thead>
<tr>
<th>Lever</th>
<th>Range</th>
<th>Degrees Per Second</th>
<th>Radians Per Second</th>
<th>Moment Arm (Ft.)</th>
<th>Linear Velocity (Ft./Sec.)</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spine</td>
<td>8</td>
<td>503.1452</td>
<td>8.7815</td>
<td>4.37</td>
<td>37.76</td>
<td>26.91</td>
</tr>
<tr>
<td>Hip</td>
<td>4</td>
<td>251.5723</td>
<td>4.3907</td>
<td>3.5</td>
<td>15.3674</td>
<td>10.95</td>
</tr>
<tr>
<td>Shoulder</td>
<td>2</td>
<td>124.2236</td>
<td>2.1681</td>
<td>5.0</td>
<td>10.8405</td>
<td>7.72</td>
</tr>
<tr>
<td>Wrist</td>
<td>22</td>
<td>1366.4602</td>
<td>23.8492</td>
<td>3.2</td>
<td>76.3174</td>
<td>54.42</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>140.2853</strong></td>
<td><strong>100.00</strong></td>
</tr>
</tbody>
</table>

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FIGURE 54

TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF ANNE HOLLIER WHILE EXECUTING THE GOLF DRIVE, FRONT VIEW
were at 3 degrees of flexion. Five frames later in frame "B-l," the arm had not moved but the clubhead had been taken away, and the angle of the wrist had increased to 19 degrees. In "C-l" the angle had increased to 36 degrees, but the left arm had not moved from the address position. In "E-l" (Fig. 55) shoulder rotation had occurred, and the angle of the club and lower arm increased to 40 degrees and remained the same through "F-l," the point at which the clubshaft was horizontal to the ground.

Table VII depicts change in angle of the wrist joint in the backswing and downswing of the clubshaft. In "H-l" the left knee had flexed, the left thigh had adducted, and the left arm continued to rotate as the wrist angle increased to 84 degrees. The wrist "cock" remained relatively stable in frames "I-l" and "J-l" (Fig. 56), during which time the shoulder and spine continued to rotate. As the subject continued to backswing, following "J-l," the angle in the wrist decreased or "uncocked" while the spine continued to rotate. At the top of the backswing in frame "M-l" (Fig. 57) the clubshaft had reached a position that was ten degrees below horizontal. The left knee was adducted and flexed. It was observed that the hips began to rotate to initiate the downswing in frames "M-3" as the hands "uncocked," simultaneously, through frames "M-4."

It can be seen in "M-l" that tracings of succeeding frames were overlapped to show the movement of the subject
FIGURE 55
TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF
ANNE HOLLIER WHILE EXECUTING THE
GOLF DRIVE, FRONT VIEW
TABLE VII

CHANGES IN ANGLE OF WRIST JOINT DURING VARIOUS PHASES AS REPRESENTED BY FRAMES OF MOTION PICTURES DURING BACKSWING AND DOWNSWING OF GOLF DRIVE OF ANNE HOLLIER

<table>
<thead>
<tr>
<th>Backswing</th>
<th>Frame</th>
<th>Degree of Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-1</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>B-1</td>
<td>19</td>
<td></td>
</tr>
<tr>
<td>C-1</td>
<td>32</td>
<td></td>
</tr>
<tr>
<td>D-1</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>E-1</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>F-1</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>G-1</td>
<td>57</td>
<td></td>
</tr>
<tr>
<td>H-1</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>I-1</td>
<td>109</td>
<td>Q-1</td>
</tr>
<tr>
<td>J-1</td>
<td>108</td>
<td>Q-2</td>
</tr>
<tr>
<td>K-1</td>
<td>103</td>
<td></td>
</tr>
<tr>
<td>L-1</td>
<td>97</td>
<td></td>
</tr>
<tr>
<td>M-1</td>
<td>87</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Downswing</th>
<th>Frame</th>
<th>Degree of Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>N-1</td>
<td>88</td>
<td></td>
</tr>
<tr>
<td>O-1</td>
<td>127</td>
<td></td>
</tr>
<tr>
<td>O-3</td>
<td>105</td>
<td></td>
</tr>
<tr>
<td>P-1</td>
<td>55</td>
<td></td>
</tr>
<tr>
<td>P-2</td>
<td>35</td>
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<tr>
<td>P-3</td>
<td>23</td>
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</tr>
<tr>
<td>P-4</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>P-5</td>
<td>-19</td>
<td></td>
</tr>
<tr>
<td>Q-1</td>
<td>-40</td>
<td></td>
</tr>
<tr>
<td>Q-2</td>
<td>-54</td>
<td></td>
</tr>
</tbody>
</table>
FIGURE 56

TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF ANNE HOLLIER WHILE EXECUTING THE GOLF DRIVE, FRONT VIEW
FIGURE 57

TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF ANNE HOLLLIER WHILE EXECUTING THE GOLF DRIVE, FRONT VIEW
by her hips and body to her left. The hips moved 20/50 units from "M-1" to 0-1," or 6.8 inches, laterally, to the left. In frame "M-4" the investigator observed that the hands moved downward as they began to pull the club into the downswing. This movement in the downswing occurred after the clubshaft was brought back to the horizontal. It was observed in "N-1" that the hips began a lateral movement to their left, although there had been some rotation during the previous three frames of the downswing.

One interesting aspect of the swing was that the wrist angle appeared to increase or "cock" further after "N-1" through "O-1," even though the downswing had already begun. The angle of the wrist was greatest at 127 degrees in "O-1." At this point the left arm was just above a position horizontal to the floor. Throughout the succeeding frames, the angle continued to decrease as the wrist "uncocked." The investigator observed that the left thigh had abducted as early as "M-3."

In Figure 59 it may be seen that the wrist angle progressively decreased through every five frames to "P-4," in which the shaft and left arm were almost extended. The hands, however, were in line with the edge of the right hip. It can be seen that the subject had already extended the clubshaft sometime prior to frame "P-5" contact frame, and, in frame "P-5" had actually flexed the right wrist and hyper-extended the left. The angle of the left arm and clubshaft
FIGURE 58

TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF ANNE HOLLIER WHILE EXECUTING THE GOLF DRIVE, FRONT VIEW
FIGURE 59

TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF ANNE HOLLIER WHILE EXECUTING THE GOLF DRIVE, FRONT VIEW
in "P-5" was minus nineteen degrees. It appeared that the subject allowed the right arm and right hand to produce the action of the club well before the contact frame. Two frames after contact, the subject continued to decrease the wrist angle by minus forty degrees.

The subject's head was well behind the ball at contact, however, it did not appear that all of her weight was on her left foot. The right arm appeared to be flexed and the left wrist was hyperextended at contact. The head remained well in position after contact.

Figures 60 and 61 show overlapped tracings of the path of the clubshaft during the backswing and the downswing. The backswing was completed in sixty-two frames or in one second and the downswing was completed in eighteen frames or in .2898 seconds. The downswing was 3.45 times as fast as the backswing.

Analysis of the Swing in the Side View

Figures 62, 63, 64, 65 and 66 are tracings of the subject from the side view during the backswing and the downswing. The takeaway of the clubhead may be observed as having occurred more at an angle rather than in a straight line from frames "A-1" to "B-1." The right arm can be seen as having moved toward the body in these early frames and the angle of elbow flexion in the right arm was increased very early in the backswing. While the right elbow remained
OVERLAPPED TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF
CLUBSHAFT DURING BACKSWING OF GOLF DRIVE
OF ANNE HOLLIER

FIGURE 60
FIGURE 61
OVERLAPPED TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF CLUBSHAFT DURING DOWNSWING OF GOLF DRIVE OF ANNE HOLLIER
FIGURE 62

TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF ANNE HOLLIER WHILE EXECUTING GOLF DRIVE, SIDE VIEW
FIGURE 63
TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF ANNE HOLLIER WHILE EXECUTING GOLF DRIVE, SIDE VIEW
FIGURE 64

TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF ANNE HOLLIER WHILE EXECUTING GOLF DRIVE, SIDE VIEW
FIGURE 65

TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF ANNE HOLLIER WHILE EXECUTING GOLF DRIVE, SIDE VIEW
FIGURE 66
TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF ANNE HOLLIER WHILE EXECUTING GOLF DRIVE, SIDE VIEW
close to the right side in "H-l," it was well away from the body in "L-l." The right humerus was almost parallel to the floor at the top of the backswing.

The right knee of the subject did not change position nor angle from the address position to the top of the backswing.

From the side view it appeared that the left knee was slightly flexed when ball contact occurred.

The trunk inclination of this subject at address was forward at thirty-three degrees when she was in the address position in frame "A-l." The inclination did not change until "M-l" when the downswing had begun. At that point the inclination had decreased to twenty-eight degrees, and when contact had occurred, the trunk was inclined at only nineteen degrees.

Figures 67 and 68 present overlapped tracings of the path of the clubshaft on the backswing and downswing. It can be observed that the clubshaft was taken away in a somewhat "flattened" plane. The downswing was more upright. The hands did not follow the same path during the backswing and downswing.

Figure 69 is that of overlapped tracings of the subject from the side showing the follow-through of the shaft and the ball after contact. It may be observed that the ball was "pulled" to the left after contact. The clubshaft shown as frame "Q-3" was forty-one degrees from the
FIGURE 67
OVERLAPPED TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF CLUBSHAFT DURING BACKSWING OF GOLF DRIVE OF ANNE HOLLIER, SIDE VIEW
FIGURE 68

OVERLAPPED TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF CLUBSHAFT DURING DOWNSWING OF GOLF DRIVE OF ANNE HOLLIER, SIDE VIEW
Figure 69

Overlapped tracings made from frames of motion pictures of ball and clubshaft after contact during golf drive of Anne Hollier, side view.
horizontal. The clubshaft was below the right shoulder at that point.

Analysis of the Swing in the Top View

It may be seen in Figure 70 that the spine and hip appeared to be "open" slightly. However, the stance was "square." Each toe was abducted at approximately ten degrees.

Figure 71 represents hip rotation during the backswing and downswing, and Figure 72 represents spinal rotation during the backswing and downswing.

There were sixty-one degrees of hip rotation during the backswing and seventy-nine degrees during the downswing. However, hip rotation during the downswing was complete as early as frame "Q-4," two frames before the contact frame. Therefore, hip rotation was not a contributing lever to the total linear velocity for this subject. There was no change in hip rotation after contact.

There were ninety-four degrees of spinal rotation during the backswing and 113 degrees occurred on the downswing. There were two degrees of spinal rotation one frame before contact.

Body Segment Contributions to Linear Velocity of the Clubhead

Angular activity of joints contributing to the linear velocity of the clubhead included: wrist, twenty-four degrees; shoulder, seven degrees, and spine, two degrees.
FIGURE 70

TRACING MADE FROM FRAME OF MOTION PICTURES OF
ADDRESS POSITION OF GOLF DRIVE OF
ANNE HOLLIER, TOP VIEW
FIGURE 71

OVERLAPPED TRACING MADE FROM FRAMES OF MOTION PICTURES OF HIP ROTATION REPRESENTED BY ALUMINUM RODS DURING BACKSWING AND DOWNSWING OF GOLF DRIVE OF JEANIE BUTLER KALENCKI
FIGURE 72

OVERLAPPED TRACINGS MADE FROM FRAMES OF MOTION PICTURES OF SPINAL ROTATION REPRESENTED BY ALUMINUM RODS DURING BACKSWING AND DOWNSWING OF GOLF DRIVE OF ANNE HOLLIER
The lengths of the moment arms were: wrist, 117/50 units or 3.4 feet; shoulder, 177/50 units or 5.0 feet; hip, 123/50 units or 3.4 feet; and spine, 155/50 units or 4.4 feet (see Figure 73).

The degrees of change for each contributing segment of the body from one frame before contact to contact were determined and converted to linear velocity. Table VIII presents these results. In addition the percentage of contribution to the summed linear velocity is presented for each segment of the body.

The summed linear velocities of the body segments were approximately 132.1776 feet per second. The wrist was the major contributor at 62.98 percent, the shoulder contributed 29.27 percent, and the spine contributed 7.75 percent. There was no hip rotation one frame before contact.
FIGURE 73

MOMENT ARM LENGTHS REPRESENTED BY DOTTED LINES OF WRIST, SHOULDER, SPINE, AND HIP OF ANNE HOLLIER WHILE EXECUTING GOLF DRIVE
TABLE VIII

BODY SEGMENT CONTRIBUTIONS TO LINEAR VELOCITY OF CLUBHEAD DURING GOLF DRIVE AS EXECUTED BY ANNE HOLLIER

<table>
<thead>
<tr>
<th>Lever</th>
<th>Range</th>
<th>Degrees Per Second</th>
<th>Radians Per Second</th>
<th>Moment Arm (Ft.)</th>
<th>Linear Velocity (Ft./Sec.)</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spine</td>
<td>2</td>
<td>125.7861</td>
<td>2.1953</td>
<td>4.657</td>
<td>10.2235</td>
<td>7.75</td>
</tr>
<tr>
<td>Shoulder</td>
<td>7</td>
<td>434.7826</td>
<td>7.588</td>
<td>5.1</td>
<td>38.6988</td>
<td>29.27</td>
</tr>
<tr>
<td>Wrist</td>
<td>24</td>
<td>1490.683</td>
<td>26.0173</td>
<td>3.2</td>
<td>83.2553</td>
<td>62.98</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>132.1776</strong></td>
<td><strong>100.00</strong></td>
</tr>
</tbody>
</table>
CHAPTER V

SUMMARY, FINDINGS, CONCLUSIONS, AND RECOMMENDATIONS

I. SUMMARY

It was the purpose of this study to analyze the movement and timing of selected body segments during the execution of the golf drive by female golfers.

The subjects for this study were four women from Louisiana and Texas who were former amateur state and regional champions. The golfers were filmed indoors in Shreveport, Louisiana, in the fall of 1969. Each subject was filmed from three views, front, side, and overhead, with three sixteen millimeter movie cameras during the time in which she executed the golf drive.

The film was projected through a microfilm reader, and the views for each subject were analyzed. Tracings of the subjects, clubshaft, and ball were completed to aid in the analysis. Movement and timing of selected body segments utilized during the swing were described. Lever contributions to clubhead velocities were calculated as were the percentages of each contributing body segment.
II. FINDINGS

The findings of this study based on previously stated hypotheses in Chapter I were as follows:

1. The clubhead moved in a straight line away from the ball on the backswing for two of the subjects for approximately ten to fifteen frames, however, for two subjects, the clubhead was observed to have moved at an angle rather than a straight line as early as the fifth frame from the take-away.

2. The clubshaft, hands, and arms not only failed to form a straight line at address, but there was an observed change in the wrist angle for all four subjects before the hands had passed the right knee.

3. The hands began to "cock" well before they had reached hip level.

4. The right elbow pointed to the ground for two subjects when the clubshaft had reached the top of the backswing, however, for two, the right upper arm was parallel to the floor.

5. The left arm remained relatively straight throughout the backswing.

6. For three subjects the right knee failed to maintain the same position throughout the backswing.
7. For two subjects the initial movement in the downswing was a lateral hip movement to the left, and for the other two it was a rotation around an axis.

8. For all four subjects the wrists had begun to "uncock" in the downswing by the time the left arm was horizontal to the floor.

9. For two subjects, it appeared that the hands, arms, and clubshaft were extended at contact. However, for the other two there was an angle at the wrist joint at contact.

10. For two of the subjects the left knee appeared to be extended at contact; for the other two, the left knee was noticeably flexed at contact.

11. The linear velocity contributions of the acting joints were not comparable to those cited in Cooper and Glassow,\(^1\) which were 70 percent for the wrist, 20 percent for the shoulder, 5 percent for the hip, and 5 percent for the spine.

12. The downswings for two subjects were less than three times as fast as the backswings, and the downswings for the other two were more than three times as fast as the backswing.

Discussion of Findings

Subject one, Boddie, and subject three, Kalencki, moved the clubhead away from the ball in a relatively straight path on the backswing. Subject two, Hendrix, and subject four, Hollier, moved the clubhead away from the ball more at an angle than did the other two subjects. Subjects one and three also had greater linear velocities for the contributing levers. These same two subjects also initiated the downswing by a lateral hip movement.

Descriptive data which showed changes occurring in the wrist angle for each subject revealed that the wrist had begun to "cock" by the time the hands had reached a position at the center of the body on the backswing. This change may have been pronation and radial flexion of the left wrist and radial flexion and hyperextension of the right. It should be noted that by the time the hands had reached a point at approximately knee level during the backswing, the wrist angle of subject one was sixteen degrees, the angle for subject two was nineteen degrees, for subject three it was twenty-five, and subject four had thirty-six degrees. Most authorities emphasized that the wrists should not "cock" until the hands reached knee position, and some have said that the "cock" should not begin until the hands have reached hip level. These subjects had all "cocked" the wrists approximately forty degrees when the hands had reached right hip level.
It appeared from the analysis of these subjects that the wrist began a gradual "cock" after the takeaway of the clubhead from the ball to a point approximately hip level, at which time the "cock" became quite noticeable to the eye.

The right elbow of two subjects, one and four, did not point to the ground, however, the right upper arm was parallel to the floor. These two subjects both contacted the ball which resulted in a "hooked" or "pulled" shot. The other two subjects' elbows did point to the ground at the top of the backswing. Their resulting shots were straight and "pushed."

The right knee for three subjects changed from its starting position during the backswing. The literature had emphasized that the right knee maintained its braced position throughout the backswing. The right knee of subject four stayed in the same position throughout the backswing. This could have accounted for the smaller amount of hip rotation for this subject. There were eighty degrees of hip rotation from the start of the backswing to contact for this subject, and over 100 degrees of hip rotation occurred for the other subjects.

The head of each subject failed to maintain the same position throughout the backswing and the downswing. The head of subject one actually lowered prior to contact; however, her body did not. The other subjects' heads moved up, slightly, prior to contact. It seemed that movement of the head did not adversely affect contact with the ball.

Subjects one and two were in "closed" stances,
subject three was in an "open" stance, and subject four assumed a "square" stance.

The follow-through of the shaft of the club, viewed from the right side of subject one, was approximately at forty-seven degrees to the horizontal. When first viewed at that point, it could be seen that it was above shoulder height. The point in the swing for subject two revealed her clubshaft to be thirty-seven degrees and below the right shoulder; subject three's follow-through was forty-four degrees to the horizontal and above the right shoulder; and that of subject four was forty-one degrees to the horizontal and below the right shoulder.

The hip markers revealed that hip rotation in the backswing for all subjects was between sixty and seventy-four degrees. Hip rotation during the downswing was more than 100 degrees for three subjects, with subjects one and three rotating approximately 115 degrees. In observing the overlapped tracings of the hip markers, subject one had moved to her left side by contact frame, subject two appeared to have revolved around a still axis, subject three rotated to a position slightly right of the center of the marker, and subject four was forward and to her right at contact.

It was noted that at contact all subjects' hip markers were to the left of the line of flight; subject one, sixty-five degrees; subject two, fifty-two degrees; subject three, forty-eight degrees; and subject four, thirty-four degrees.
Even though subject one had the greatest amount of rotation beyond the line of flight, the linear velocity percentage contribution of her hip lever was least at 6.96, of the three subjects in which hip rotation made a contribution one frame before contact. The percentages of the hip lever contribution for the other three subjects were: subject two, 10.56 percent; subject three, 10.95 percent; and subject four, zero percent.

Subject four had the least amount of rotation of the spine during the backswing of ninety-four degrees, while the other subjects' spines rotated over 100 degrees. The greatest rotation in the downswing occurred for subject three with 141 degrees. Subject one's spine rotated 124 degrees on the downswing. Although spinal rotation was less for subject one than for subject three, the angle of the spinal marker at contact was thirty-eight degrees to the left of the line of flight for subject one. For subject three the spinal marker was thirty-three degrees. This indicated that subject three had begun her downswing from a position of greater rotation in the spine during the backswing. This was also observed from the tracings of the spinal markers. Subject two's spinal marker was twenty-six degrees to the left of the line of flight, and subject four's marker was twenty-four degrees beyond the imaginary line. The spines of subjects two and three contributed approximately 25 percent to the summed linear velocities of the body segments, while that of subject
one contributed 12 percent. The greater contribution to the summed velocities by subjects two and three was due to more rotation one frame prior to contact and to a longer spinal moment arm. Subject four had only two degrees of spinal rotation one frame prior to contact, which was approximately eight percent of the summed linear velocities.

There was no shoulder rotation observed for subject two one frame prior to contact. The shoulder contribution of subject one to the summed velocities was approximately 14 percent, for subject three 7.7 percent and that of subject four was 29.27 percent. It was observed that most of the spinal rotation had ceased for subject four prior to contact; all of the hip rotation had ceased. The major contribution to the linear velocities of the body segments was by the shoulder and wrists for subject four. For her this was 92 percent of the summed velocities.

The major contributor to the summed linear velocities of the body levers for all subjects was the wrist lever. Angular activity of the wrist lever accounted for approximately 66 percent of the total velocity for subject one; approximately 64 percent for subject two; approximately 54 percent for subject three; and approximately 63 percent for subject four.

All subjects had begun to "uncock" the wrists on the downswing when the hands were approximately chest high. This was contrary to what authorities have said in advocating a
"delayed uncocking of the wrists" until hip level.

Subjects one and two had downswings approximately two and one-half times faster than the backswings, and subjects three and four had downswings approximately 3.4 times as fast as the backswings.

Viewing the contact frames of the subjects from their left sides, it was interesting to observe that subject one was more upright than the other three subjects at contact. She also appeared to hit with more authority.

III. CONCLUSIONS

Within the limitations of this study, the following conclusions were drawn:

1. The results of the study failed to show a consistency relative to swing patterns between subjects concerning:

   a. The movement of the clubhead away from the ball.

   b. The angle of the wrist at the address position.

   c. The amount of wrist angle occurring throughout the swing.

   d. The right knee position during the phase from the address to the top of the backswing.

   e. The movement of the hip when initiating the downswing.
f. The linear velocity contributions of the acting joints.

2. Subject one most nearly achieved the descriptions of the swing by leading authorities.

3. The execution of the golf drive in which the linear velocity of the body segments was greatest was that of subject one for whom there was a definite lateral hip movement. The hip and spine had made their greatest contributions prior to contact. Both knee joints flexed toward the target very early in the downswing. The wrists did not "cock" further on the downswing.

4. The wrist segment was the major contributor to the summed linear velocities for all four subjects.

5. Current literature may be inaccurate in the descriptive analysis of the golf swing.

6. The percentage contribution of the body segments to linear velocity for skilled performance as indicated in the hypothesis may be incorrect for women.

IV. RECOMMENDATIONS

On the basis of this study, the following recommendations are made:

1. All four subjects exhibited greater spinal contributions to summed linear velocity than was listed in
Cooper and Glassow. Conversely, all four subjects exhibited less wrist contribution than reported in Cooper and Glassow. Perhaps further study should be conducted to refute or verify these findings relative to female golfers.

2. A similar study should be undertaken in which a number of excellent golfers are filmed from an overhead view, due to the apparent success of the markers used in pinpointing hip and spinal rotation.

\(^2\text{Ibid. Kinesiology.}\)
SELECTED BIBLIOGRAPHY

A. BOOKS


B. PERIODICALS


C. UNPUBLISHED MATERIALS


The investigator was born in Hunter, Arkansas, on October 29, 1936. She received her secondary education at Brinkley High School, Brinkley, Arkansas, graduating as valedictorian in 1954. She entered the University of Arkansas, Fayetteville and received her Bachelor of Science degree, cum laude, in 1958. While at the university, she was selected for "Who's Who Among Students in American Universities and Colleges" and Mortar Board and received the award for the "Outstanding Graduating Senior in Physical Education."

Following graduation, the investigator taught at Victorville Junior High School in Victorville, California, from 1958 to 1960.

In 1960, she received an assistantship for graduate study at the University of Illinois, Urbana, and was awarded the Master of Science degree in 1961.

Prior to her studies at Louisiana State University, the investigator held positions at the University of Kentucky, Lexington, 1961-62; Southern Methodist University, Dallas, Texas, 1962-63; University of Wisconsin, Madison, 1963-66; and the University of Arkansas, Fayetteville, 1966-68.
In 1968 the investigator received an NDEA Fellowship to Louisiana State University, Baton Rouge, for doctoral study. She was appointed to a full-time faculty position in the Department for Health, Physical, and Recreation Education at Louisiana State University for the academic year, 1969-70.

While at the University of Arkansas, the investigator received two "Outstanding Teacher Awards" from the Associated Women Students and the Greek Sororities Organization. At the Louisiana State University she was elected to Phi Kappa Phi.

Professional contributions include serving as a Lifetime Sports Clinician in Golf, officiating and receiving National Honorary Officials Ratings in basketball and volleyball, serving on professional committees, and addressing professional meetings. She is a member of LAHPER and AAHPER.

The investigator received her Doctor of Education degree at Louisiana State University in August, 1970. In September, 1970, she assumed the position of assistant professor at the University of West Florida, Pensacola.
EXAMINATION AND THESIS REPORT

Candidate:  Linda L. Parchman

Major Field:  Physical Education

Title of Thesis:  Cinematographical and Mechanical Analysis of the Golf Swing of Female Golfers

Approved:

[Signatures]

Major Professor and Chairman

Dean of the Graduate School

EXAMINING COMMITTEE:

[Signatures]

Date of Examination:

July 17, 1970