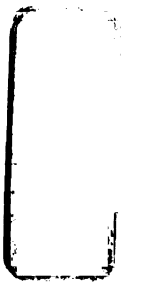
A CINEMATOGRAPHIC ANALYSIS OF THE FOREHAND STROKE IN TENNIS

THESIS FOR THE DEGREE OF M. A.
MICHIGAN STATE UNIVERSITY

BARBARA RUTH SOUTHWARD

1956



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Barbara Ruth Southward

A THESIS

Submitted to the College of Education of Michigan State University of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of

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ACKNOWLEDGMENTS

The writer wishes to express appreciation to Dr. Wayne Van Huss of the Men's Physical Education Department and Dr. Thelma Bishop of the Women's Physical Education Department, Michigan State University, for their help during this research.

B. R. S.

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AN ABSTRACT OF A THESIS

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Approved _____

Wayne V. Van Huss

BARBARA RUTH SOUTHWARD ABSTRACT

Title of Study

A Cinematographic Analysis of the Forehand Stroke in Tennis.

Statement of Problem

To analyze and compare the forehand strokes of tennis players of various skill levels, ranging from beginner to champion.

Methodology

A Bell and Howell 16mm camera was used to photograph four subjects, consisting of a beginner chosen at random from an instructional tennis class; a university varsity tennis member; a university varsity tennis coach, and a Davis Cup player. The pictures were taken from the side for all four subjects, and from overhead for the beginner and the varsity coach. The pictures were analyzed frame by frame with a Bell and Howell Time and Motion Analyzer projector.

Conclusions

The following observations were made in comparing the stroke of the beginner with that of the intermediate and champion players. The beginner did not (1) take the racket back as soon nor as far in the backswing; (2) watch the

flight of the ball and, therefore, was unable to judge where the ball would bounce in relation to the body; (3) use body rotation or keep the forward foot stationary throughout the stroke.

The main observations noted in comparing the patterns formed by the intermediate and the champion players were (1) the varsity player and champion did not cock the wrist on the backswing as much as the varsity coach; (2) the varsity player hit the ball in front of the forward foot; the varsity coach off the forward foot and the champion off the rear foot; (3) the varsity player rotated the body into ball contact; the varsity coach after ball contact, and the champion's body rotated much later in the follow through.

Within the limitations of the data, the evidence seems to indicate that many of the writers and tennis teachers are correct in their analysis of the forehand tennis stroke.

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CHAPTER I

INTRODUCTION AND STATEMENT OF THE PROBLEM

For many years tennis teachers have written books and articles on the mechanics of a forehand stroke. Usually this motion study analysis has been made through watching a champion in action or in reviewing motion pictures. This observational approach has been the method used in analyzing the various elements of the forehand stroke. All of these statements made about what happens during a forehand stroke have been based on observation while the film has sped through the projector quickly. This has made it difficult for a person to see actually what happens and not to have it colored by what he has assumed for many years happens throughout the stroke.

Therefore, the writer with the use of the Bell and Howell Time and Motion Analyzer projector will attempt to plot frame by frame certain trends and patterns of the beginner's forehand, the intermediate's forehand, and the champion's forehand.

Statement of the Problem To plot and analyze patterns of the forehand stroke made by tennis players of various skill levels.

Specific Objectives

1. To compare through analyzing moving pictures the forehand stroking positions of various tennis players.

2. To pattern and compare the various parts of the players' forehand stroke. These parts are: rackethead, wrist, shoulders, head, and feet.

3. To try to establish from the formed patterns what actually happens during a forehand stroke.

Scope of the Study

The sample consisted of four male tennis players: a beginning tennis player chosen at random after having a ten-week term of tennis at a university; one university varsity tennis team member; a university varsity tennis coach; and a United States Davis Cup player. All of the players used an eastern grip.

Significance of the Study

To understand the problems facing a beginning tennis player, it is necessary to plot the patterns of players who have been successful in executing the forehand stroke. It is also necessary to compare these patterns frame by frame with a beginner's stroke pattern to determine where the differences in stroke execution occur.

The study presents, through the medium of cinematographic analysis, the breakdown and comparison of the forehand stroke at the various skill levels. This is a more

exact way to determine what actually happens during a forehand stroke than just to watch the players in action on the court or in a film.

Tennis teachers have established theories as to what happens during a stroke from their years of experience and from watching tennis players. However, they do not seem to have proof to back up these theories. Therefore, it is the writer's desire, through cinematographic analysis of the forehand stroke at the various skill levels to show whether these theories are valid or not.

Limitations of the Study

1. The number of subjects [4] and the number of strokes analyzed is small. Therefore, the results are subject to more error than if the number of strokes analyzed per subject were greater so a mean average of racket velocity could be obtained for each subject.

2. A tennis ball machine which would throw a tennis ball out to bounce at a specific height and at a specific spot would have eliminated the difference in the ball bounce variable.

3. Two cameras for the study would have made it possible to measure the velocity more accurately. Both cameras shooting the stroke at the same time; one from overhead and one from the side. The use of an accelerometer on the rackethead would also measure the velocity more exactly.

Definition of Terms

Forehand Stroke. The forehand is the stroke taken on the right-hand side of the body for right-handed players. The following is an analysis of the forehand stroke by Driver.

(1) Grip [Eastern] - Shake hands with the racket with the V on top of the racket. The fingers should be spread and the racket held firmly but not rigidly.
(2) Wrist Action - The wrist action present in the stroke is a hyperextension on the backswing coming to a locked wrist position of extension as the ball is hit. The wrist action insures that the racquet is meeting the ball squarely, and adds speed to the ball.
(3) Body Position - The body is at right angles to the net, with the left foot and shoulder toward the net, and the right foot and shoulder away from the net. The sideways position is parallel with the flight of the ball, feet about eighteen inches apart. The knees are slightly relaxed or flexed, with the body weight carried on the balls of the feet. Body action consists of weight transference to right foot with backswing of racquet and trunk rotation away from the net. The weight is transferred forward and the trunk is rotated to meet the ball. Right shoulder follows the flight of the ball forward . . . .
(4) Backswing of Racquet - Racquet is swung back in line with the sideways position of the body, elbow well away from body. . . .
(5) Forward Swing - . . .
The arm and racquet swing out away from the body to meet the ball.
At the impact the face of the racquet is flat and the grip very firm.
The body weight shifts from the right to the left foot, keeping racquet in contact with the ball and traveling in a straight line forward. The student should use body rotation forward with the stroke as well as a transfer of weight. The right shoulder points in the direction of the ball flight on the follow through. . . .

(6) Position of the Ball at the Impact - The ball is opposite the forward (left) foot at racquet's reach from the body.[1]

Side-to-the net position. The forehand body position as described by Driver defines the side to the net position.

> The body is at right angles to the net, with the left foot and shoulder toward the net, and the right foot and shoulder away from the net. The sideways position is parallel with the flight of the ball, feet about eighteen inches apart.[2]

Diagonal position. The body is turned to a forty-five degree angle to the net. The position is half way between the side to the net position and the open position when the forehand drive is stroked.

Open position. The body faces the net and the feet are pointing perpendicular to the net.

Tennis beginner. A university sophomore chosen at random with a ten-week's term of instructional tennis class experience.

Intermediate player. A University varsity tennis team player and a university varsity tennis coach.

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[1]Helen Irene Driver, Tennis for Teachers (Boston: Spaulding-Moss Company, 1952), pp. 62-68.

[2]Ibid., p. 62.

Champion player. A member of the 1955 Davis Cup team.

Cinematography. The techniques by which mechanical measurements can be taken from an image projected on a screen.[3]

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[3]Thomas Kirk Cureton, "Elementary Principles and Techniques of Cinematographic Analysis as Aids in Athletic Research," Research Quarterly, 10:4, May, 1939.

CHAPTER II

REVIEW OF THE LITERATURE

Much has been written concerning the forehand stroke. The stroke has been analyzed by physical education teachers, coaches, professional tennis teachers, and champion players. However, there has been very little written on the cinematographic analysis of the forehand stroke.

Literature on the elements of the stroke

The literature points out the following statements concerning the component parts comprising the forehand tennis stroke for right-handed players.

1. General body position--the left side is at right angles to the net as soon as the player knows that the ball is going to the forehand side.[4] White[5] disagrees with this statement. He believes that the body should not be rotated to the side until the ball comes over the net.

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[4] Gertrude Goss, Individual Sports for Women (Philadelphia: W. B. Saunders Company, 1949), pp. 362-363.

[5] Harwood White, "Stand Sideways?," American Lawn Tennis, November, 1948, pp.16- 17.

2. Backswing--racket drawn back as far as possible just as soon as the player knows that the ball is going to the forehand side. Mace[6] disagrees and suggests that the racket should not be drawn back in a wide arc because this makes the person hit late and makes him hit up to the ball resulting in an insufficient follow through.

3. Feet--parallel to the net with the weight on the rear foot which pivots forward with the weight ending on the forward foot. Bunn[7] states that the rear foot must be in contact with the court at the moment of impact. The literature is not too clear or in agreement as to when the weight is transferred from the rear foot to the forward foot.

4. Wrist--hyperextended and then locked just before ball contact. Bunn[8] states that added force is attained by bending a joint and that the wrist must be rigid and the grip firm at impact to avoid recoil.

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[6]Wynn Mace, Tennis Techniques Illustrated (New York: A. S. Barnes and Company, 1952), p. 29.

[7]John Bunn, Scientific Principles of Coaching (New York: Prentice-Hall, Inc., 1955), pp. 243-244.

[8]Ibid., p. 68.

5. Elbow--a slightly bent elbow to cut down on the loss of power.

6. Shoulders--right shoulder rotates forward on ball contact. Mace[9] believes that the shoulders should be kept parallel to the sidelines while hitting the ball. White[10], in his denunciation of the side-to-the-net stroking position, states that as the ball bounces the player steps toward the net and begins to turn his right side forward.

7. Head--follows the flight of the ball.

8. Follow-through--racket follows through out over the left shoulder. Budge[11] says that the wrist and elbow are bent on the follow-through. Mace[12] states that a simple wind-up and a longer follow-through gives better direction and power to the ball. The follow-through ends out toward the net with a conterclockwise rotation of the wrist.

Literature on methods and techniques of cinematographical research	A complete description of the techniques used in cinematographic analysis

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[9]Mace, op. cit., p. 29.

[10]Harwood White, "Free Swing," American Lawn Tennis, April, 1949, pp. 14-15.

[11]Lloyd Budge, Tennis Made Easy (New York: A. S. Barnes and Company, 1945), p. 44.

[12]Mace, op. cit., p. 34.

is given by Cureton[13] and Glasgow[14]. These writers agree as to the best techniques to use in cinemotographical research. Fenn[15] used cinematographic methods to throw some light on the fundamental questions, "What is the limiting factor in running?" and "Why is swinging the legs so difficult?"

In the twenty-three theses concerning the various aspects of tennis listed by Cureton[16] there is no evidence of any cinematographical analysis of the forehand tennis stroke.

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[13]Cureton, op. cit., pp. 4-24.

[14]Ruth Glasgow, "Photographical and Cinematographical Research Methods," Research Methods Applied to Health, Physical Education, and Recreation (Washington: American Association for Health, Physical Education, and Recreation, 1952), pp. 204-218.

[15]Wallace O. Fenn "A Cinematographic Study of Sprinters," Scientific Monthly, April, 1931, pp. 246-254.

[16]Thomas Kirk Cureton, Masters' Theses in Health, Physical Education, and Recreation (Washington: Department of the National Education Association, 1953), pp. 292.

CHAPTER III

METHODOLOGY OF RESEARCH

Introduction The motion pictures of the forehand drive were taken with a Bell and Howell 16mm camera. The pictures were taken from the same angle for each subject to determine whether a definite pattern of movement for each person could be established.

To plot the patterns, the pictures were analyzed, frame by frame, with a Bell and Howell Time and Motion Analyzer projector.

The subjects, except the United States Davis Cup player, were photographed in June on the same day and under the same court conditions at Michigan State University, East Lansing, Michigan. The United States Davis Cup player was photographed two months later during the 1955 National Doubles Tournament at the Longwood Cricket Club, Chestnut Hills, Massachusetts.

Research Method A camera mounted on a rigging truck designed for use in repairing steet lights was used to obtain pictures of the shoulder rotation. From this height it was possible to take pictures directly above the players. The side-view pictures were taken on the baseline facing the stroker.

The action was taken at 64 frames/second, and the subject was fifteen to twenty feet away from the camera. The camera was set up on a tripod to avoid the possibility of any camera movement.

The photographer set the lens openings and the footage for one particular area and waited for the ball to come within this specified area. The photographer was aided by an assistant who informed the photographer when the ball was coming to the subjects' forehand. The photographer watched the area through the rangefinder and took the picture when the subject came into view.

The execution of several forehand strokes of the beginner and the intermediate players were photographed. From the series of stroke patterns plotted for each of the three subjects, one pattern was analyzed. The one stroke pattern was chosen on the basis of photographic content.

Only the execution of one forehand stroke of the Davis Cup player was photographed. This stroke pattern was plotted and analyzed.

Subjects. The beginner was a university beginning tennis player, chosen at random from one of the mens' instructional classes. The university varsity team member was also chosen at random. Harris Beeman, the varsity tennis coach at Michigan State University and Tony Trabert, the number one 1955 Davis Cup player were the other two subjects.

The analysis of the movie projector methods

The forehand patterns were plotted by projecting pictures on a sheet of white paper 47-1/2 inches from the Bell and Howell Time and Motion Analyzer projector. The film was cranked through the projector frame by frame. To make sure that the projector was aligned after each frame, a spot was selected from the projected film on the first frame of the stroke and marked on the white sheet of paper. On each successive frame, the projector was aligned to this spot and then at the tip of the rackethead a dot was placed on the white sheet of paper to plot the pattern formed by the rackethead. The same procedure was followed every tenth frame in outlining the pattern formed by the body and racket. The pattern formed of the rackethead, wrist, elbow, shoulders, head, and feet was plotted in the same way.

The distance the rackethead traveled each frame beginning five frames before ball contract through five frames after ball contact was measured with calipers to obtain the estimated velocity of the rackethead. The measurement was obtained by measuring with calipers the distance the rackethead traveled frame by frame on the pattern. The mathematical procedure is given by Cureton.[20]

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[20]Cureton, op. cit. pp. 4-24. (Appropriate corrections were made in the multiplier values for differences in picture depth during the stroke. At best, however, the procedure used in the measurement of rackethead velocity involves estimates and is in need of further validation.)

Delimitation of material — Three patterns were formed by each subject; each pattern began with the racket-back position and continued through the follow-through. This was shown graphically by (1) plotting every tenth frame the rackethead, wrist, elbow, shoulders, head, and feet; (2) outlining the body and racket every tenth frame; (3) plotting frame by frame the pattern formed by the rackethead.

To determine the body position when the ball was hit, the author in the final analysis compared the position of the feet, rackethead, wrist, and shoulders at the racketback position, the point of ball contact, and during the follow-through.

The pictures taken of each subject from the sideview were plotted and analyzed. The overhead pictures of the varsity tennis coach and the tennis beginner were plotted and analyzed.

CHAPTER IV

PRESENTATION OF DATA

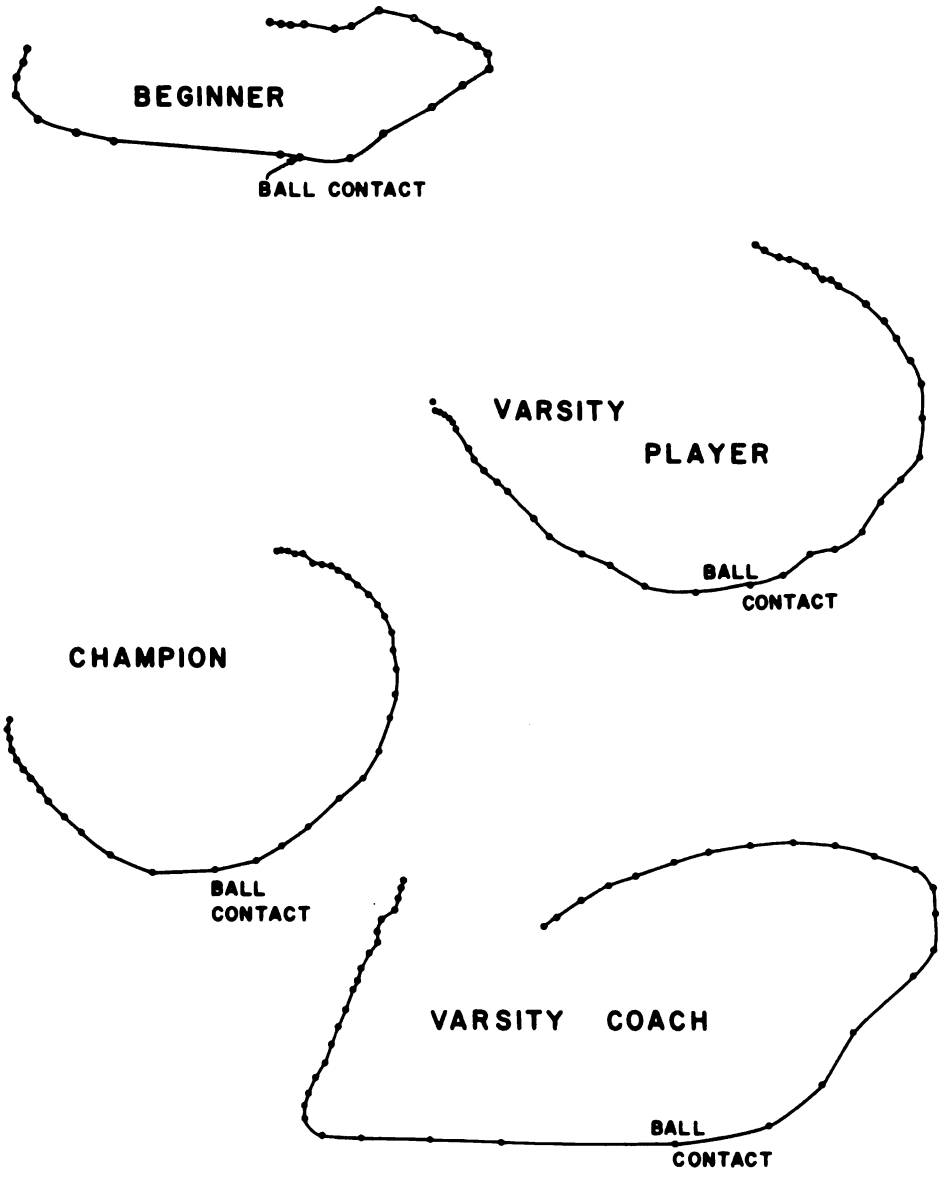
Introduction Motion pictures were taken of four tennis players of various skill levels in order to compare the patterns and trends of the beginner's, the intermediate's, and the champion's forehand stroke by means of a frame by frame analysis.

The analyses presented in this chapter are subdivided into the analysis of the sideview pictures and those taken from overhead.

I. COMPARISON OF PICTURES FROM THE SIDEVIEW

Chart I shows the patterns formed from a frame by frame plotting of the rackethead of each subject during a forehand stroke. The patterns appear different for each subject, not only because of the difference in the strokes of the players, but because of the variability of the ball bounce. The patterns give an indication as to whether the ball was hit close to the body, out in front of the forehand foot, or topspin was imparted to the ball.

The beginner's pattern is narrow in breadth because the ball was hit with the elbow bent and the arm too close to the body.



SIDEVIEW PATTERNS

Rackethead each frame from the racket-back position through the follow-through

CHART I

The pattern of the varsity coach shows that the racket was taken back high near shoulder level and then adjusted to the level of the ball bounce before stroking through the ball.

Both the champion and the varsity team member hit a low ball and imparted topspin which gives the pattern more of a circular appearance.

The estimated velocity of the rackethead was determined by measuring frame by frame with calipers the distance the rackethead traveled each frame. Due to the distortion of the racket as the racket neared the camera, a corrected multiplier for calculating the velocity of the beginner and the varsity coach was estimated from the overhead patterns of the rackethead.

The speed of the rackethead seemed fairly constant for the champion and the varsity team members. The beginner, however, whips the racket from the short racket-back position through fast until one frame before ball contact and then gains speed again on the follow-through. Figure 1 shows the velocities of the rackehead for the tennis coach and the beginner for five frames before ball contact through five frames after ball contact. This relative estimate shows that the varsity coach increases the speed of the rackethead until ball contact and then the speed of the rackethead slows down progressively throughout the rest of the stroke.

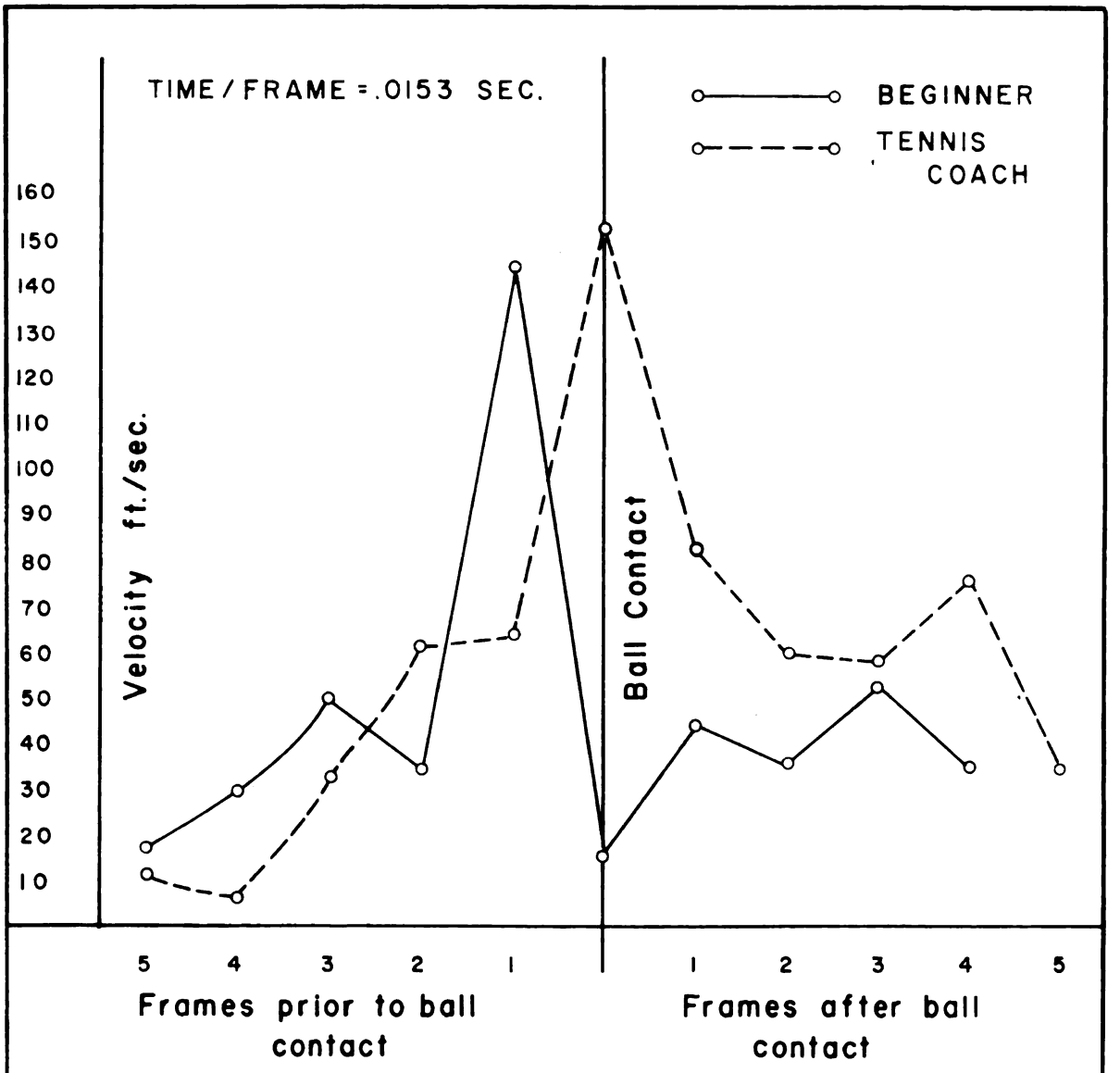


FIGURE 1

SIDE-VIEW VELOCITY OF THE RACKET-HEAD FOR FIVE FRAMES BEFORE BALL CONTACT THROUGH FIVE FRAMES AFTER BALL CONTACT.

The beginner increases the speed of the rackethead up to two frames before ball contact. At this point the rackethead appears to lose speed and then picks up speed the frame before ball contact. At ball contact the speed of the rackethead decreases greatly and then regains speed for the next three frames before slowing down.

The velocity figures for all of the subjects, except the beginner, seem to indicate that the velocity of the rackethead increased up to one or two frames prior to rackethead contact. This same pattern would most likely occur with a beginner when the beginner's eye and racket coordination improve to the extent that the beginner does not have to slow down the rackethead to make sure of the racket contacting the ball. The velocity of the rackethead of the intermediates and the champion was greater each frame before ball contact because a greater force was being applied which was due, not only to a freer arm and wrist movement, but to body rotation as well.

The estimation of the velocity of the rackethead in feet per second in Figure 1 is included not as an absolute measurement but merely for the purpose of comparing the velocities of the rackethead of a beginner and a varsity coach.

Chart II shows the patterns formed by the rackethead, wrist, shoulders, head, and feet every tenth frame for each

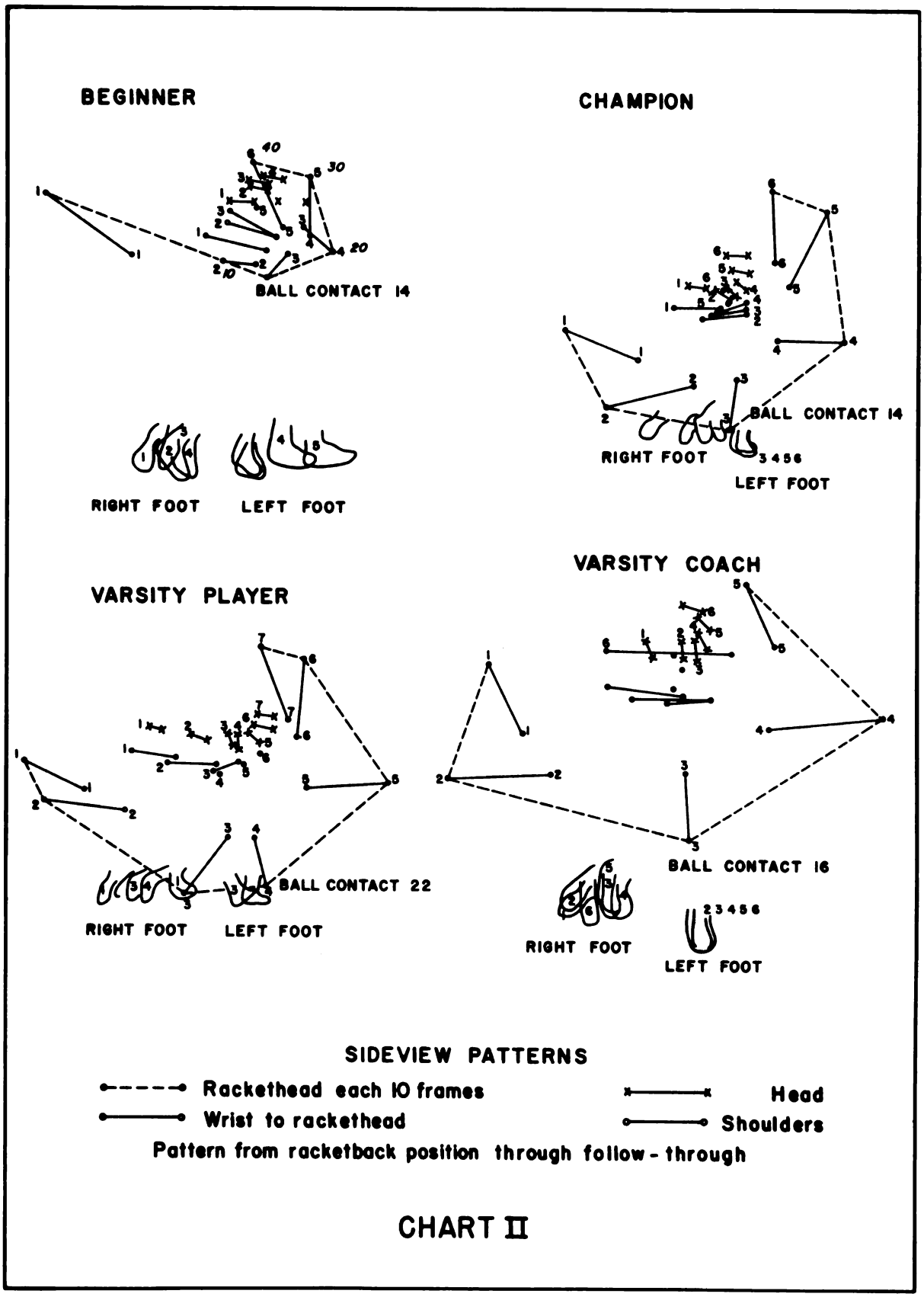

BEGINNER
40
30
20
10
BALL CONTACT 14
RIGHT FOOT
LEFT FOOT
CHAMPION
BALL CONTACT 14
RIGHT FOOT
3 4 5 6
LEFT FOOT
VARSITY PLAYER
BALL CONTACT 22
RIGHT FOOT
LEFT FOOT
VARSITY COACH
BALL CONTACT 16
RIGHT FOOT
2 3 4 5 6
LEFT FOOT
SIDEVIEW PATTERNS
Racketheaad each 10 frames
Head
Wrist to racketheaad
Shoulders
Pattern from racketback position through follow - through

CHART II

subject. At the racket-back position the beginner's shoulders are diagonal to the net, whereas the other three subjects' shoulders are perpendicular to the net. On ball contact the varsity player's shoulders are parallel to the net and the varsity coach's and champion's shoulders are perpendicular to the net. Even though the pattern shows that the beginner's shoulders are perpendicular to the net at the racket-back position and parallel at ball contact, there does not appear to be the body rotation which the other subjects used in the stroke.

The beginner does not seem to watch the flight of the ball and hits the ball off the rear foot. The varsity player hits the ball in front of the forward foot as the body rotates with a rear toe pivot towards the net. The varsity coach hits the ball directly off the forward foot and then rotates the body on a rear toe pivot towards the net. The champion hits the ball behind the forward foot and rotates the body towards the net much later in the stroke.

The forward foot of the varsity player and the champion is fairly stationary throughout the stroke. The varsity coach's forward foot is parallel to the net and stationary throughout the stroke. The beginner's forward foot is perpendicular to the net and the feet are not stationary throughout the stroke. A hop is used to get away from the ball.

In Chart II an idea of the relationship of the wrist and rackethead is shown every tenth frame for each subject. At the racket-back position the head of the racket of all of the subjects is slightly in back of the wrist. As the racket is brought forward the rackethead catches up with the wrist at ball contact and stays with the wrist throughout the rest of the stroke.

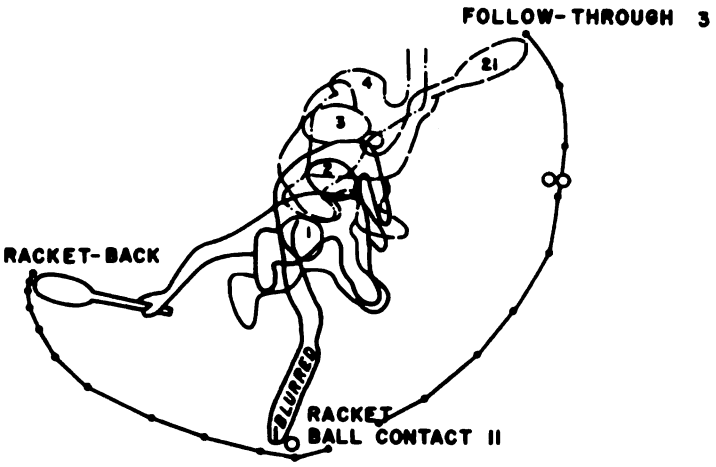
On the follow-through all of the players watch the ball. The beginner's racket follows through with a bent arm near the left shoulder, whereas the other subjects follow through high and away from the body with the elbow only slightly bent.

These patterns indicate that the beginner did not get the racket back and was not ready for the forward swing as soon as the other subjects. There is an indication that the beginner did not pivot on the rear foot and did not keep the forward foot stationary as the body rotated forward and into the stroke. In this stroke pattern the beginner did not know where the ball would bounce in relation to the end of the racket and the forward foot.

II. COMPARISON OF PICTURES FROM OVERHEAD

Chart III shows the overhead pattern of a varsity tennis coach and of a beginning tennis player. The patterns were formed by plotting the racket and body every tenth

BEGINNER



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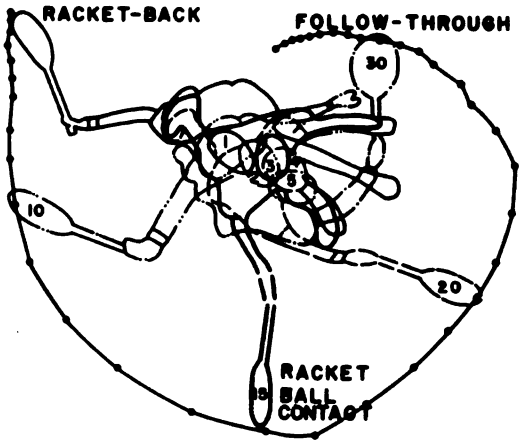
VARSITY COACH



OVERHEAD PATTERNS

Racket-back through the follow-through

Rackethead plotted each frame —o—

Body positions and racket each ten frames

CHART III

frame and by plotting the rackethead each frame from the racket-back position through the follow-through. The pictures for this chart were taken from thirty-five feet above the subject.

The patterns appear similar except the beginner's backswing is shorter and the follow-through does not swing in toward the left shoulder.

The varsity coach's follow-through gradually stops; whereas, the beginner has a tendency to let the wrist snap around causing a slightly increased speed of the rackethead during the follow-through.

Figure 2 shows the estimated velocity of the rackethead for five frames before ball contact through five frames after ball contact for the varsity coach and the beginner. The varsity coach swings the racket faster than the beginner. The beginner increases the speed of the rackethead progressively until two frames before ball contact and then the rackethead slows down progressively until the fourth frame after ball contact where the greatest rackethead speed is attained. In the second frame before ball contact the velocity of the tennis coach's rackethead reaches the greatest speed. The rackethead progressively decreases in speed until three frames after ball contact where it again gains speed, but the gain is not as great as was observed in the beginner. Again as was noted two frames before ball

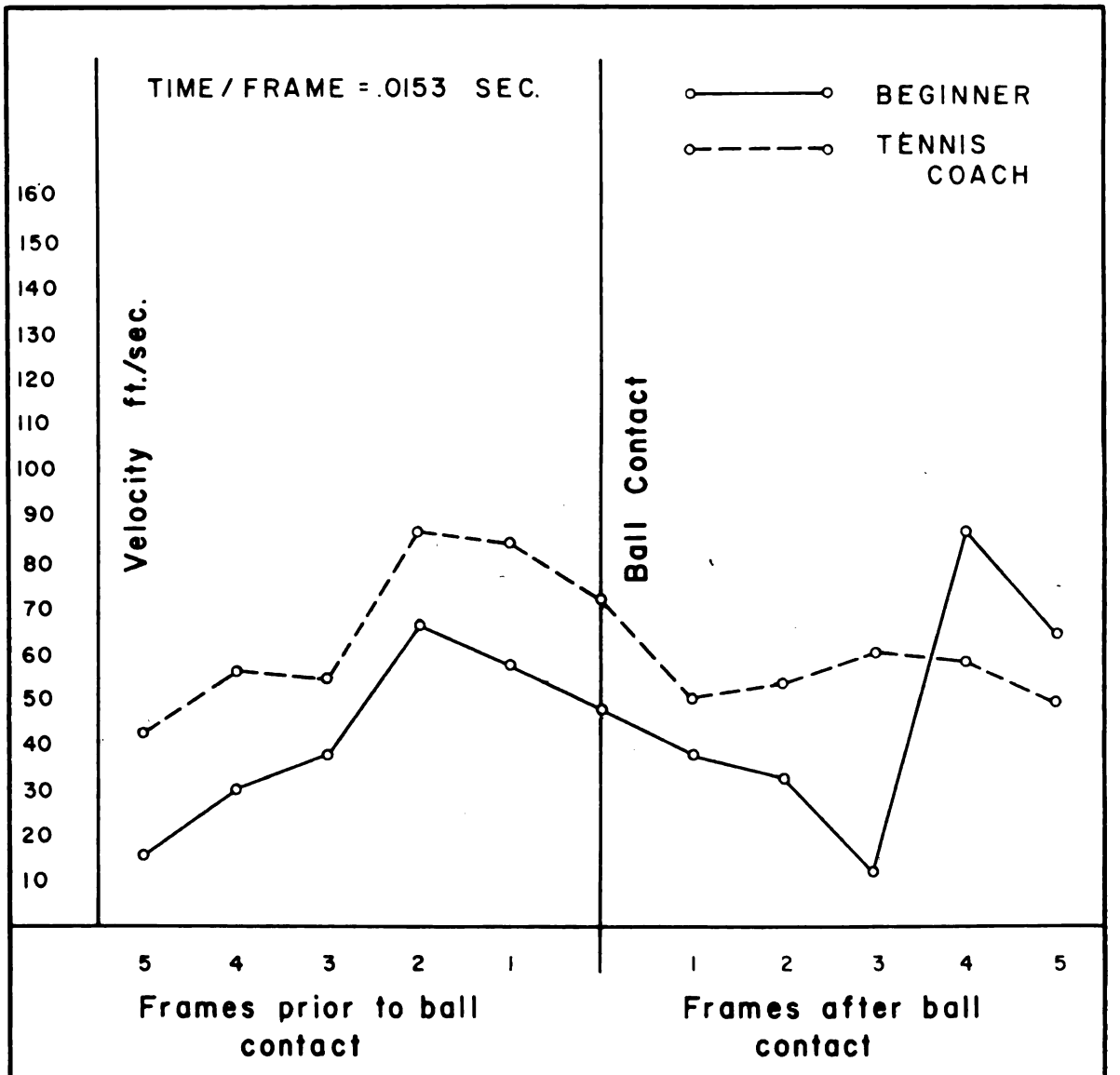


FIGURE 2

OVERHEAD VELOCITY OF THE RACKET-HEAD FOR FIVE FRAMES BEFORE BALL CONTACT THROUGH FIVE FRAMES AFTER BALL CONTACT.

contact in Figure 1, the rackethead of the beginner slows down slightly on the third frame before ball contact.

Although the measurement of the velocity of the rackethead from the pictures taken from overhead is a more accurate measurement than the pictures taken from the side, there still can be errors in measuring with calipers the distance the rackethead traveled each frame. Therefore, Figure 2 is included not as an absolute measurement but merely for the purpose of comparing the velocities of the racketheads of a beginner and a varsity coach.

The velocity figures in Figure 1 cannot be compared with the velocity figures in Figure 2 because the pictures were taken of two different strokes.

The racket and body positions every tenth frame from the racket-back position patterned in Chart III show clearly the constant moving of the beginner's feet as well as the direction of the head during ball contact. The beginner does not look at the ball; whereas, the varsity coach appears to be looking right at the ball during ball contact and throughout the entire stroke. Body rotation is very evident in the varsity coach's pattern as the body pivots on the rear foot to the forward foot on ball contact. The feet are stationary throughout the stroke.

The racket positions of the beginner and the varsity coach in Chart III show that the varsity coach has a greater

backswing and gets the racket back sooner than does the beginner.

Even though the patterns of the varsity coach, the Davis Cup player, and the varsity member are not identical, They do emphasize certain trends when contrasted with the pattern of the beginner. The beginner has the tendency to stroke the ball with a bent elbow because the ball bounces too close to the body. Because the beginner does not know where the ball will bounce in relation to the body, the forward foot and the end of the racketheadi the beginner hops away from the ball and is forced to swing with a bent elbow.

The beginner fails to watch the ball, get a long enough backswing or take the racket back soon enough. The beginner also lets the wrist snap the racketheadi through the stroke.

Even though the other subjects pivot on the rear foot and rotate the body to stroke the ball, there was practically no evidence of body rotation by the beginner.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

From years of experience and from watching tennis players, tennis teachers have formed certain theories as to the mechanics of a forehand tennis stroke. These theories have been assumed and have been merely opinions. Therefore, the author attempted through cinematographic analysis to find evidence to support these theories.

In reviewing the literature the author found no evidence of comparative research through cinematographic techniques written on the forehand stroke for players of various skill levels.

With the aid of the Bell and Howell Time and Motion Analyzer projector, the forehand stroke of the beginner, the intermediate, and the champion tennis player was analyzed. The patterns of the various skill levels of players were plotted to show certain trends throughout the forehand stroke.

Four subjects were photographed with a Bell and Howell 16mm. camera and then the stroke was plotted frame by frame from the pictures.

The subjects consisted of a beginner chosen at random after having a ten-week instructional tennis class; a

university varsity tennis team member; a university varsity coach, and a member of the 1955 Davis Cup team. The subjects were all men and the eastern grip was used by each. There was no way of controlling whether the subject imparted topspin to the ball, stroked the ball flat, or chopped the ball. This variable did not seem to affect the results of the study. The pictures were taken from the side for all four subjects. Pictures were also taken from overhead of the beginner and the varsity coach.

Findings and Conclusions The following observations were made in comparing the strokes of the beginner, the intermediate, and the champion.

1. The beginner did not take the racket back as soon nor as far in the backswing and, therefore, was not ready to stroke the ball in time.

2. The beginner did not watch the flight of the ball and was unable to judge where the ball would bounce in relation to the body, the end of the racket, and the forward foot.

3. The beginner did not pivot on the rear foot towards the net and rotate the body from the hips. There was no apparent transference of weight from the rear foot to the forward foot at ball contact. The feet were never stationary throughout the stroke.

4. The beginner did not seem to keep the velocity of the rackethead relatively constant throughout the stroke but slowed the racket down prior to ball contact and then let the rackethead whip past the wrist on the follow-through.

5. The varsity player and champion did not hyper-extend (cock) the wrist on the backswing as much as the varsity coach. Therefore, the speed of the rackethead coming through to ball contact for the varsity coach was greater.

6. The pattern of the varsity player and the champion was similar. Both of these players used more top-spin in the stroke than the varsity coach.

7. The varsity player, varsity coach, and champion used body rotation throughout the stroke. Then pivoted towards the net on the rear foot as the forward foot stayed practically stationary throughout the stroke.

8. The varsity player hit the ball in front of the forward foot and rotated the body into the ball contact. The varsity coach hit the ball off the forward foot and rotated the body after ball contact. The champion hit the ball from behind the forward foot and rotated the body much later in the stroke.

9. The intermediate players and the champion player watched the ball throughout the stroke, got the racket back in time to adjust to the oncoming ball and followed through with a gradual decrease in the rackethead velocity.

From the small sample and from the analysis of the execution of one forehand stroke for each subject, the evidence has a tendency to indicate that many of the writers and tennis teachers are correct in their analysis of the forehand stroke. However, there needs to be more analyses made of larger groups before significant patterns can be established.

Recommendations The writer would like to offer the following recommendations concerning cinematographic research on the forehand tennis stroke.

1. Analyze ten forehand strokes for each player to obtain a mean pattern average for each subject.

2. Take pictures of the stroke from overhead and from the side at the same time.

3. Use an accelerometer to measure the velocity of the rackethead.

4. Take the entire stroke from the ready position through the follow-through.

5. Use a tennis machine to toss out tennis balls to fall at the same spot and to bounce at the same height.

6. Use markings on the body and racket to help identify body parts in analyzing the various parts of the stroke. The markings should be put on the following parts:

a. Inside of the wrist--determine wrist flexion.

b. Edge of the acromion process of each shoulder--body rotation.

c. Medial and lateral malleolus of both ankles--pivoting of the feet.

d. Edges of the soles of the tennis shoes--movements of the feet.

e. Center of the frontal bone to the crown of the head--movements of the head.

f. End of the racketheaad--making plotting of the racketheaad easier and more accurate.

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