A MECHANICAL ANALYSIS OF THE FORWARD PASS

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A MECHANICAL ANALYSIS OF THE FORWARD PASS

THESIS

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CHAPTER I

INTRODUCTION

The game of football originates from a game called *harpastum*, which was created out of the competitive nature of man. The men from two small towns in Italy met midway and fought over a ball, trying to take the ball back to their town, which was a distance of some three miles. Harpastum had no rules, no restrictions, no officials, and needless to say was a very unrefined bit of brutal competition.

The game of football has since become highly sophisticated compared to Harpastum with the development of highly protective equipment, intellectual advancement of coaches, skilled medical methods, and specific training programs.

Probably the most significant development in the evolution of football, as we know it today, was the advent of the forward pass. Because it affords a longer gain of yardage in a short period of time, passing has become the most popular method of offensive play. It is considered almost an essential in winning football today.

The act of passing involves intricate timing and specificity of movement. The difference of a foot or a split second may determine whether a pass is accurately thrown. A quarterback must be able to execute a pass consistently many times during a game.

It is the hope of the researcher that this study will illustrate some of the movements which constitute the fundamental execution of the forward pass.

Statement of the Problem

This study was to mechanically analyze the short forward pass and the long forward pass as used in football by a right-handed passer.

Purposes of the Study

1. To determine the basic mechanical movements utilized in executing the long forward pass.

2. To determine the basic mechanical movements utilized in executing the short forward pass.

3. To present a comparative analysis of the two types of forward passes; i.e., the long pass and the short pass and illustrate the fundamental differences.

4. To present a mechanical description of the forward pass that may be used by a quarterback for the purpose of improving his passing ability or by a coach as a teaching resource.

Definitions of Terms

1. Short forward pass--a pass that is thrown for a distance of 0 to 30 yards, normally used for attaining a first down.

2. Long forward pass--a pass that is thrown for a distance over 30 yards, normally used for attaining a long gain or a touchdown.

3. Mechanical movement--any basic movement involving angles of body segments, flexion, extension, and rotation of body joints and parts.

Review of Previous Studies

Many books and articles have been written about the many aspects of football. Although many studies have been conducted regarding mechanical analysis and cinematography, comparatively few have been down in football.

Bunn (1) states, "The mechanics involved in throwing a football are exactly the same as those that apply to throwing a baseball." In view of this fact, the researcher has included baseball in the search for related literature.

Scott (2), as well as Bunn, has included in her book detailed mechanical principles related to nearly all sports, and both books are therefore considered valuable references to the solution of this problem.

Cureton (3) published material explaining in detail the techniques involved in cinematographic analysis. The techniques, as described by Cureton, such as how to avoid gross perceptive errors by moving the camera back, were utilized in collecting and analyzing the data for this study.

Sally Kraska (4) conducted a study in which she mechanically analyzed the basic sand trap shot of three (3) professional golfers. Two cameras were utilized in filming. One was positioned behind the subject, and the other camera was placed to the side of the subject. By analyzing the films, she was able to determine the fundamental movements and to also bring out the similarities and differences in executing the sand trap shot. She used photographs and drawings to illustrate the significant points in the shot.

A mechanical analysis of two badminton serves was conducted at Springfield College by Edwin Tetreault (5). He used Cureton's formula for measuring the velocity of the shuttle. He also measured the racket in centimeters and substituted into the correction factor formula, which was outlined by Cureton. In the study, he was concerned with the mechanics involved in executing the low short serve and the high deep serve. By using two cameras at two different angles from the side of the subjects, he was able to determine the fundamental movements and depict the similarities and differences. He used photographs and drawings to illustrate the basic movements used in executing the two serves.

A cinematographic analysis of the tennis forehand stroke was conducted by Barbara Ruth Southward (6), Michigan State University, in which she used one camera to film players of various levels ranging from beginners to champions. In her analysis, she illustrates and discusses the differences in fundamental execution of the stroke and concludes that teaching techniques used by teachers and coaches are correct. In collecting the data for her study, Miss Southward used only one camera and did not mark the subjects. It is the opinion of this writer that both of these factors are important in making a thorough analysis.

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CHAPTER II

PROCEDURES

Due to the complexity involved in cinematography and techniques for exactness in mechanical analysis, reference is made to the format used by Tetreault (1) regarding the list of movements of the body that were analyzed and the list of points on the body that were marked for analysis. Although the movements involved in throwing a football are quite different from those involved in serving a shuttle, the format used in this study is very similar.

Source of Data

Three 16-millimeter movie cameras were used by photographers to film the subject while executing the forward pass for both short and long distances. After analyzing the films, it was possible to determine the following items:

1. Length of supporting base
2. Degree of knee flexion
3. Degree of radial flexion
4. Angle at which ball is projected at point of release
5. Degree of shoulder rotation
6. Degree of upper arm abduction
7. Degree of shoulder elevation
8. Degree of elbow flexion

The subject was instructed to wear a minimum amount of clothing, consisting of a pair of trunks, socks and a pair of gym shows. With minimal clothing, it was possible to mark the subject with black dots on his body at the following points:

1. The lateral malleolus of the right fibula
2. The medial malleolus of both right and left tibiae
3. The inner aspect of the left thigh
4. The lateral and medial epicondyles of both right and left femurs
5. The right and left patellas
6. The greater trochanter of the right femur
7. The distal end of the third metacarpal bone of the right hand
8. The center of the wrist at the distal end of the right radius and ulna
9. The styloid process of the right ulna
10. The right olecranon process
11. The lateral and medial epicondyles of the right humerus
12. The proximal end of both right and left humeri
13. The proximal end of the right clavicle
14. The distal end of both right and left clavicles

Selection of Subject

Stephen Wayne Ramsey: Mr. Ramsey is 22 years old, weighs 207 pounds, and stands six feet and two inches tall. He holds nearly every record possible for a quarterback at North Texas State University. Mr. Ramsey personally set seven National Collegiate Athletic Association career records in 1969. He is, statistically, one of the best passing quarterbacks in the history of college football.

The subject was selected because he has achieved considerable success in passing, and it was assumed that this success was due in part to effective passing ability.

Experimental Studies

Limited studies in cinematography regarding mechanical analysis of sport skills led the researcher to decide that a pilot study was necessary.

In the first study, the subject was filmed with two 16-millimeter Bell and Howell movie cameras. One camera was positioned 30 feet to the right of the subject and at right angles to the linear movement of the thrower. The other camera was positioned 30 feet directly in front of the subject under the flight of the ball. The cameras were equipped with 25-millimeter lenses and were mounted on tripods approximately 5 feet above the ground. The film was taken at normal motion speed, which is 24 frames per second. Twenty-four sequences were taken of the subject executing the forward pass, 12 sequences of the short pass and 12 of the long pass.

It was necessary to make a size comparison between actual size and the projected image. The football, which has a known length, was used as the corrective measuring device. The subject was marked at those points on his person which would facilitate the analysis of the mechanical movements involved in executing the pass.

The film was processed and a 16-millimeter Lafayette analyzer projector was used in analysis.

After analyzing the film, it was found to be blurred at crucial points; and it was decided that the subject must be filmed at a speed of more than 24 frames per second, thus slowing down the action process. The decision was made to do a study of a subject executing the forward pass during which time the cameras would be calibrated at different speeds ranging from 32 to 64 frames per second.

This study was completed and it was found that filming at 64 frames per second also resulted in blurry results of the crucial point of release.

Since the 16-millimeter Bell and Howell cameras used in these two studies were capable of filming only at 64 frames per second, it was necessary to obtain a camera with greater capabilities. After considerable investigation and experimentation, it was determined that a high-speed camera capable of filming 400 frames per second would be used along with the two Bell and Howell cameras.

Setting and Equipment

A position for throwing was selected which provided a background contrast. A portable partition with a white background was placed behind the subject, and behind the partition was a scaffold on which a photographer was stationed to film from the overhead position.

Owing to the complexity of movements involved in executing the forward pass, three cameras, each equipped with a 25-millimeter lens, were utilized to take in the full range of movement.

Camera #1, a Mitchell 16-millimeter high-speed movie camera, was positioned on a tripod approximately five feet above the floor and thirty feet to the right of the subject at right angles to the linear movement of the thrower.

Camera #2, a Bell and Howell 16-millimeter movie camera, was positioned on a tripod approximately five feet above the floor and thirty feet in front of the subject directly in line and under the flight of the ball and ninety degrees right from camera #1.

Camera #3, which was identical to camera #2, was hand-held by a photographer standing on the scaffold. The camera was held approximately fifteen feet above the subject's head.

Two 600-watt stand-up lights were used to supply adequate lighting.

The following diagrams illustrate the position of the cameras and equipment relative to the subject's position.

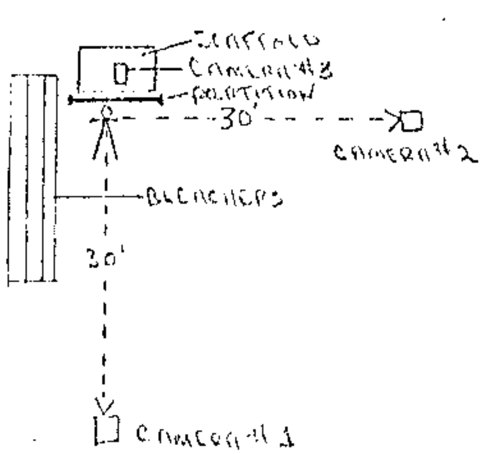

Fig. 1--Overhead view

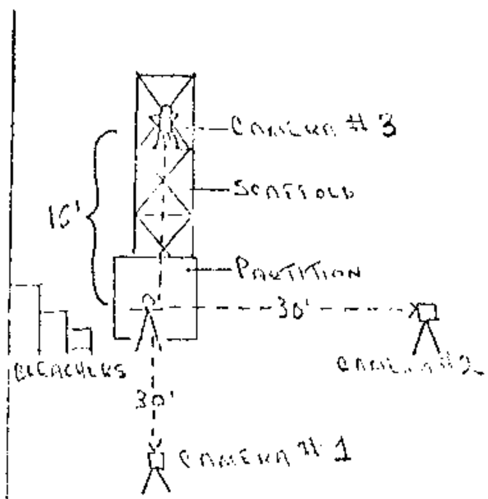

Fig. 2--Side view

Techniques of Collecting Data

The subject was given ample warm-up time and was then instructed to position himself at a point near a piece of tape which was placed on the floor. While executing the pass, the subject was instructed to do so with his rear foot on or near the tape.

A football was placed in front of the subject and he was instructed to pick the ball up and execute both short and long passes alternately beginning with the short pass.

The cameras were started just as the subject touched the ball and ran continuously until he completed his follow through.

A sequence record was kept of the passes by placing a numbered card on the floor beside the subject so both ground cameras were able to film the number of the particular sequence. The number and type of pass (short or long) was recorded on paper. A 16-millimeter Lafayette Analyzer Projector was used in viewing the film.

Procedural Description

In order to make meaningful measurements, it was necessary to establish a size comparison between the projected image and the actual subject.

Two yard sticks were tacked on the partition behind the sbuejct. One was tacked in a vertical position and one was tacked in a horizontal position. Black marks were made on each end of the yard stick and at the 12-inch and 24-inch marks. These marks were used as check points in the film taken from camera position #1. A piece of tape was placed on the end of the partition facing #2 camera position and one-foot marks were measured and marked in black on this tape. This device was used for size comparison in the film taken from #2 position.

The measurement, recorded in centimeters, was substituted into the correction factor formula outlined by Cureton (2).

Actual length of one-foot mark = 12.00 inches = (30.50 cm.)

Length of projected image: One foot = 4.8 cm

Therefore:

$$\frac{12 \text{ in.}}{4.8 \text{ cm}} = \frac{x \text{ in.}}{1 \text{ cm}} = \text{multiplier} = 2.5 \text{ inches per centimeter}$$

Thus, every image measured in centimeters was multiplied by 2.5, in order to arrive at the actual size measurement in inches.

All measurements were taken from the point at which the body or ball began its forward motion to that point at which the ball was released.

The image was projected on a flat sheet of graph paper attached to the wall exactly ten feet from the projector and was measured with a meter stick and/or a protractor. Care was taken to center each frame to get exact relationships between frames.

Procedural Analysis of Items

Item I: Length of supporting base. This measurement was determined at the point when the base had been firmly established. The length was determined by measuring in centimeters the distance between the toe of the back foot and the heel of the front foot.

The following drawing illustrates the measurement:

Fig. 3--Length of supporting base.

Item II: Degree of knee flexion. This measurement was determined at two points in the sequence: once when the subject had established a firm base and forward motion had begun, and then again at the point of release of the ball. These measurements were determined by drawing a line between the markings at the ankle to the knee to the hip of the back or right leg. Another line was drawn between the markings at the ankle to the knee to the thigh of the front or left leg. These lines were extended and the angles created by the lines that intersected at the knee marks were measured with a protractor and recorded.

The following drawings illustrate the measurement:

Fig. 4--Measurement of knee flexion

Item III: Degree of radial flexion. This measurement was determined by drawing a line from the mark on the lateral epicondyle of the distal end of the right humerus to the mark at the center of the wrist at the distal end of the radius and ulna. Another line was drawn from the center of the wrist to the distal end of the third metacarpal bone in the right hand. The angle created by the intersecting lines at the center of the wrist was measured with a protractor one frame before point of release and one frame after point of release.

The following drawing illustrates the measurement:

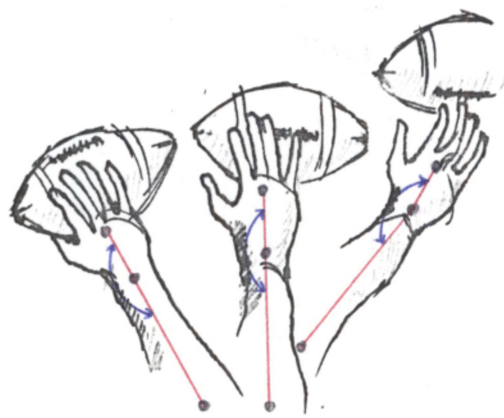

Fig. 5--Measurement of radial flexion.

Item IV: Angle at which ball is projected at point of release. This measurement was determined by drawing a horizontal line through the center of the football at the point of release. The projector was then cranked forward for five frames. On each frame, the center of the football was marked. Another line was drawn connecting these points. The angle created by the intersecting lines at point of release was measured with a protractor and recorded.

The following drawing illustrates the measurement:

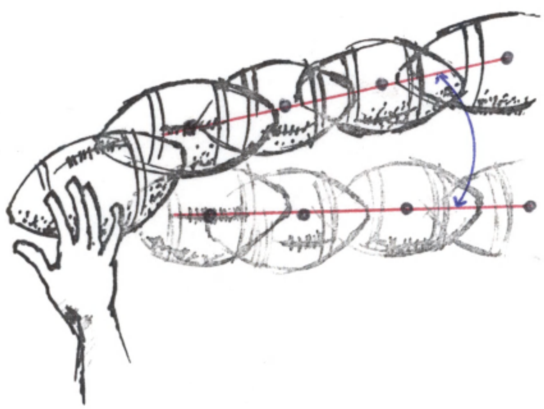

Fig. 6--Measurement of angle of ball projection.

Item V: Degree of shoulder rotation. This measurement was determined by drawing a line between the shoulder markings at the point when the subject began his forward motion and then again at the point of release of the ball. The lines were extended and the angle created by their intersection was measured with a protractor and recorded.

The following drawings illustrate the measurement:

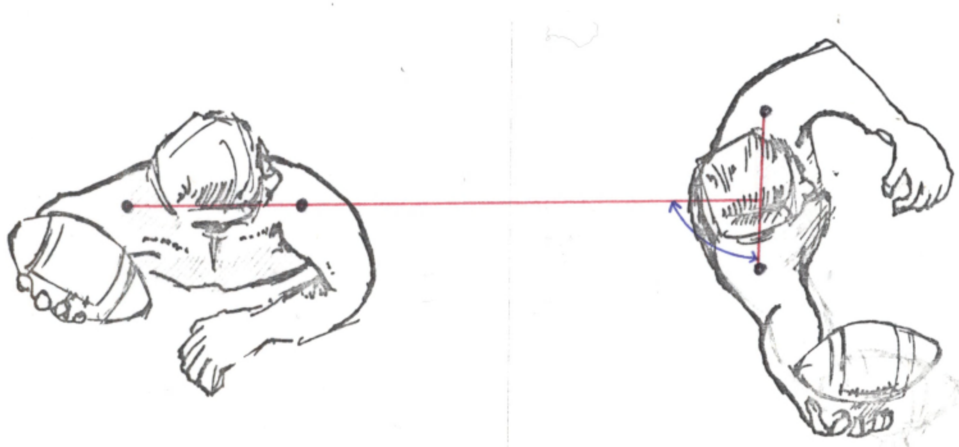

Fig. 7--Measurement of shoulder rotation

Item VI: Degree of upper arm abduction. This measurement was determined by drawing a line perpendicular to the horizontal through the proximal end of the right humerus. Another line was drawn from the proximal end of the humerus to the medial epicondyle of the humerus. The angle created by the intersecting lines at the proximal end of the humerus at point of release of the ball was measured with a protractor and recorded.

The following drawing illustrates the measurement:

Fig. 8--Measurement of upper arm abduction.

Item VII: Degree of shoulder elevation. This measurement was determined by drawing a horizontal line through the marking at the sterno-clavicular junction. Another line was drawn perpendicular to this line at the same junction. At the point of release, another line was drawn from the junction to the marking on the medial epicondyle of the right humerus. The angle created by the intersection of lines at the junction was measured with a protractor and recorded.

The following drawing illustrates the measurement:

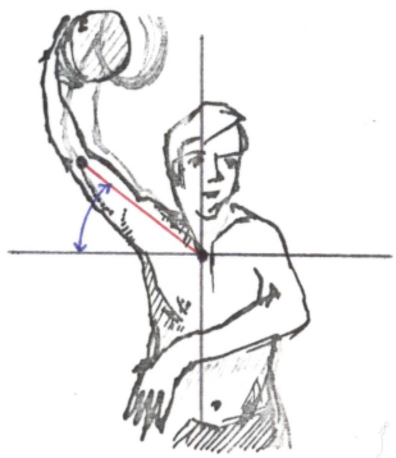

Fig. 9--Measurement of shoulder elevation.

Item VIII: Degree of elbow flexion. This measurement was determined by drawing a line from the proximal end of the right humerus to the mark on the medial epicondyle of the right humerus. Another line was drawn from the mark on the medial epicondyle of the humerus to the mark on the styloid process of the distal end of the ulna. The angle created by the intersecting lines at the medial epicondyle of the humerus was measured at the point of release of the ball. This angle was measured with a protractor and recorded.

The following drawing illustrates the measurement:

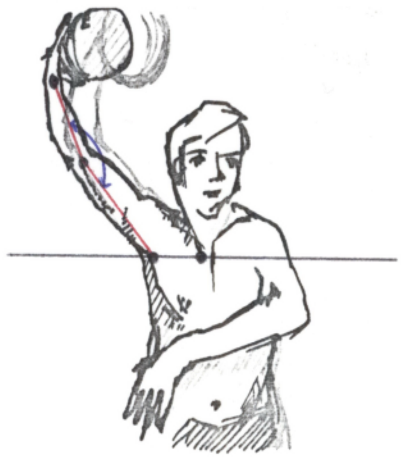

Fig. 10--Measurement of elbow flexion.

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CHAPTER III

ORGANIZATION AND ANALYSIS OF DATA

This chapter contains the data that were collected by the researcher by reviewing the films that were taken of the subject while executing the forward pass for both short and long distances. Owing to the complexity of the data, tables, drawings and short discussions were utilized to illustrate the fundamental differences between the short pass and the long pass and to make the analysis as meaningful as possible.

Measurement I: Length of supporting base. The following table illustrates the range and mean lengths of supporting base.

TABLE I

LENGTH OF SUPPORTING BASE

	Short Pass	Long Pass
Range	23.25-27.75 inches	26.00-28.75 inches
Mean	25.25 inches	27.75 inches

The mean length of base while executing the forward pass was equal to or greater than 33 per cent of the subject's standing height. The length of base was increased by an average of two and one-half inches from the short pass to the long pass. This increase indicates a portion of movement in the overall execution that is required to increase the distance the ball is thrown. The following drawing illustrates the position of the feet at that point when the supporting base had been firmly established:

Fig. 11.--Length of supporting base.

Measurement II: Degree of knee flexion. The following table illustrates the range and mean degrees of knee flexion of both right and left knee at position #1 and #2. Position #1 is that position at which the subject had established a firm base. Position #2 is that position of the body at the time the ball was released.

TABLE II

DEGREE OF KNEE FLEXION

	Short Pass	Long Pass
Range		
Right Knee #1	12-18 Degrees	19-28 Degrees
Right Knee #2	31-41 "	44-49 "
Left Knee #1	9-21 "	14-23 "
Left Knee #2	8-13 "	5-13 "
Mean		
Right Knee #1	15.37 Degrees	24.25 Degrees
Right Knee #2	35.50 "	43.00 "
Left Knee #1	15.37 "	18.62 "
Left Knee #2	10.37 "	10.62 "

The smallest increase in knee flexion was found in comparing the left knee at the point of release in the short pass and the left knee at point of release in the long pass. This nominal amount of increase of .25 degrees indicated that the left leg was firmly positioned in both passes. The degree of knee flexion was increased from the short pass to the long pass by an average of 4.97 degrees at all positions measured. This increase indicates a portion of movement in the overall execution that is required to increase the distance the ball was thrown. The following drawings illustrate knee flexion.

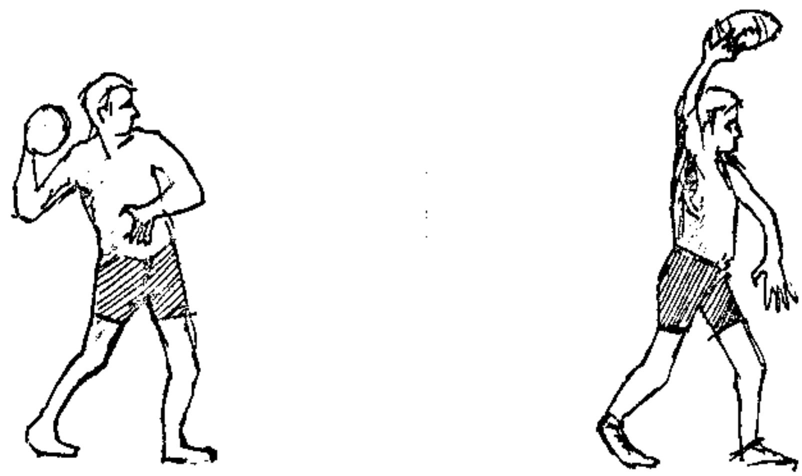

Fig. 12--Knee flexion

Measurement III: Degree of radial flexion. The radial flexion depicted in these frames for both short and long passes was considered as movement toward ulnar flexion involving wrist flexion and wrist pronation which is technically a part of the follow through. Table III illustrates the range and mean degrees of radial flexion at three points: one frame prior to the point of release of the ball, the point of release, and one frame after the point of release of the ball.

TABLE III

DEGREE OF RADIAL FLEXION

	Short Pass	Long Pass
Range		
Frame #1	4-15 Degrees	0-18 Degrees
Frame #2	2-16 "	4-10 "
Frame #3	0-12 "	2- 5 "
Mean		
Frame #1	11.00 Degrees	7.12 Degrees
Frame #2	8.37 "	6.75 "
Frame #3	5.62 "	3.37 "

The decrease in the angle of radial flexion from Frame #1 to Frame #3 for both short and long passes were proportionally the same; however, the mean amount of radial flexion for the short pass was 8.33 degrees as compared to 5.75 degrees for the long pass.

These data indicate that more wrist action is used in executing the short pass. The lesser amount of wrist action of the long pass indicates a more rigid and stable action in executing the long pass. The drawing on the following page illustrates those frames in which radial flexion was measured.

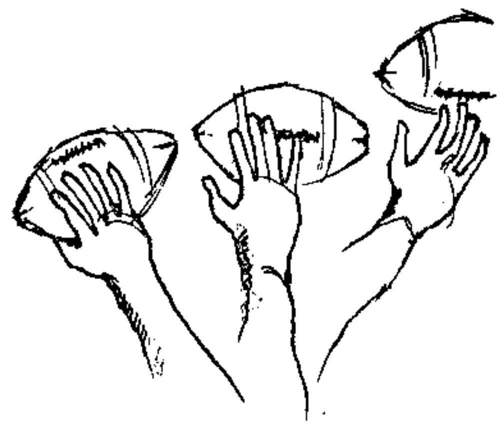

Fig. 13--Radial Flexion

Measurement IV: The angle at which the ball was projected. Table IV illustrates the range and mean degree that the ball was projected after release.

TABLE IV

ANGLE OF PROJECTION

	Short Pass	Long Pass
Range	9-13 Degrees	18-25 Degrees
Mean	11.4 Degrees	21.9 Degrees

The mean difference in the angle from the short pass to the long pass was 10.5 degrees. This difference indicates the necessary increase in the angle of the trajectory of the ball to increase the distance from approximately twenty-five yards to approximately fifty yards. The following drawing illustrates the position of the ball at the point of release and for five frames thereafter:

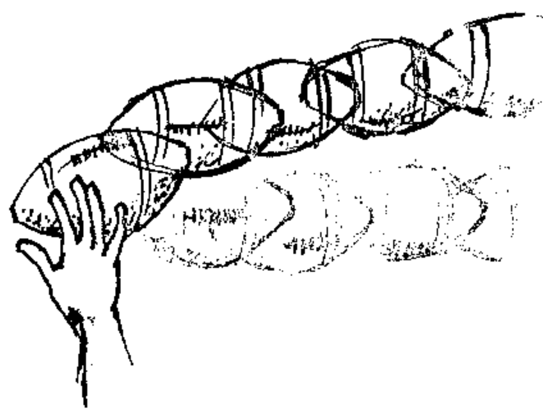

Fig. 14--Angle of ball projection.

Measurement V: Degree of shoulder rotation. The following table illustrates the range and mean amount of shoulder rotation:

TABLE V

DEGREE OF SHOULDER ROTATION

	Short Pass	Long Pass
Range	95-98 Degrees	101-106 Degrees
Mean	96.28 Degrees	103.00 Degrees

The mean increase of 6.72 degrees between the short pass and the long pass indicates that more rotation of the shoulders is necessary to attain a greater force necessary to attain a greater distance of the ball. The following drawings illustrate shoulder rotation:

Fig. 15--Shoulder rotation

Measurement VI: Degree of upper arm abduction. The table illustrates the range and mean amount of upper arm abduction:

TABLE VI

DEGREE OF UPPER ARM ABDUCTION

	Short Pass	Long Pass
Range	135 Degrees	137 Degrees
Mean	135 Degrees	137 Degrees

The slight increase of two degrees indicates t at there is little difference in the amount of upper arm abduction between the short pass and the long pass. Since there is a significant difference in the end result of the two passes, this slight increase indicates that the influence of upper arm abduction on the execution of the pass is nominal. The following drawing illustrates upper arm abduction:

Fig. 16--Upper arm abduction

Measurement VII: Degree of shoulder elevation. The table on the following page illustrates the range and mean amount of shoulder elevation:

TABLE VII

DEGREE OF SHOULDER ELEVATION

	Short Pass	Long Pass
Range	24-25 Degrees	29-30 Degrees
Mean	24.33 Degrees	29.66 Degrees

The increase in shoulder elevation from the short pass to the long pass is 5.33 degrees. This difference indicates that the shoulder was positioned to facilitate a more accessible amount of freedom of the limb to gain more force in attaining a greater distance of the ball. The function of shoulder elevation is to place the glenoid fossa in a position in which the humerus is able to move with maximum freedom. The following drawing illustrates shoulder elevation:

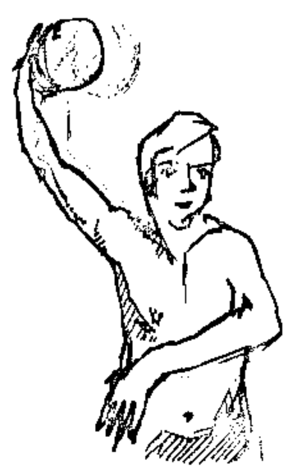

Fig. 17--Shoulder elevation

Measurement VIII: Degree of elbow flexion. The following table illustrates the range and mean degrees of elbow flexion:

TABLE VIII

DEGREE OF ELBOW FLEXION

	Short Pass	Long Pass
Range	6-12 Degrees	1 Degree
Mean	8.33 Degrees	1 Degree

The mean difference between the degree of elbow flexion in the short pass, which was 8.33 degrees, and the degree of elbow flexion in the long pass, which was 1 degree, indicates that less force and leverage were necessary to execute the short pass. It also indicates that an almost maximum amount of leverage is utilized in executing the long pass.

The following drawing illustrates elbow flexion:

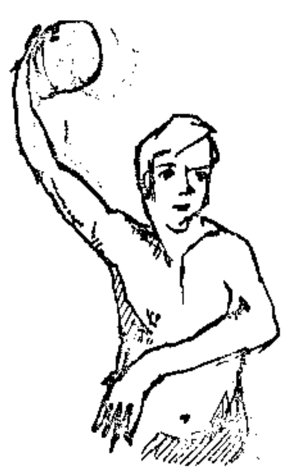

Fig. 18--Elbow flexion

CHAPTER IV

SUMMARY AND CONCLUSIONS

The purpose of this study was to mechanically analyze the short forward pass and the long forward pass as used in football by a right-handed passer. The plan of the study was to present a mechanical description of the forward pass and to present a comparative analysis of the two passes in an effort to illustrate their fundamental differences.

Sixteen-millimeter films were taken of the subject from three camera positions as he executed the forward pass as described and analyzed in this study. Upon reviewing the films, it was possible to mechanically analyze the following items which are fundamental in execution of the forward pass:

1. Length of supporting base
2. Degree of knee flexion
3. Degree of radial flexion
4. Angle of ball at point of release
5. Degree of shoulder rotation
6. Degree of upper arm abduction
7. Degree of shoulder elevation
8. Degree of elbow flexion

Conclusions

The length of supporting base varied according to the pass being executed. The mean difference between the short pass and the long pass was 2.50 inches. It was concluded that this increase in length of base for the long pass was necessary to increase the distance the ball was thrown.

The amount of knee flexion varied from the short pass to the long pass by an average of 4.97 degrees. At the point of release of the ball, the mean amount of knee flexion in the left knee for both short and long passes was 10.50 degrees and differentiated only .25 degrees between the short pass and the long pass. At the point of release of the ball, the right knee was flexed much more than the left knee and was approximately 10 inches off the floor. The right leg was used only as a balance; therefore it was concluded that the flexion of the right knee was relatively insignificant.

The mean amount of radial flexion for the short pass was 8.33 degrees as compared to 5.75 degrees for the long pass. It was concluded that there was more wrist action in executing the short pass, while the lesser amount of wrist action in the long pass indicated a more rigid wrist position.

In order for the subject to increase the distance of the throw from approximately twenty-five yards to fifty yards, it was necessary to increase the amount of shoulder rotation an average of 6.72 degrees from the short pass to the long pass.

In order to place the shoulder in a more advantageous position for a longer throw, it was necessary to elevate the shoulder an average of 5.33 degrees. The amount of upper arm abduction was coincidental with shoulder elevation in that the shoulder elevation increase allowed the upper arm to abduct to the necessary position to throw the ball a greater distance.

An average of 8.33 degrees of elbow flexion was utilized in executing the short pass as compared to only 1 degree of elbow flexion utilized in the long pass. It was, therefore, concluded that a long lever or less elbow flexion was necessary to gain a greater force to increase the distance the ball was thrown.

In analyzing the film taken of the subject, it was possible to determine certain basic differences between the short forward pass and the long forward pass. These differences were deemed necessary to increase the distance the ball was thrown. A longer supporting base, a greater amount of shoulder rotation, upper arm abduction and shoulder elevation were found to be necessary to increase the distance the ball was thrown. A lesser amount of radial flexion and elbow flexion was found to be necessary. Also, an increase in the angle through which the ball traveled from the point of release was found to be necessary.

Most passers will differ somewhat in their styles of throwing and some passers will differ a great deal. For most passers, these basic differences would hold true with only slight variations.

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