

ABSTRACT

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The preparatory and action phases of the forward pass in football were analyzed for U.W. - La Crosse quarterbacks (N=6) under two conditions, with and without protective equipment. Cinematography was used with the speed of the film run at 200 fps. The Ss all threw at the same filming session for both conditions. Random selection with replacement was used to determine the condition the Ss threw under first. Data was collected through the use of a Numonics 1224 Digitizer and processed through the FILMDAT program. This data was then analyzed using a dependant "t" test. There were no significant differences in the angle of the upper arm at the beginning of the preparatory phase, the time interval for the preparatory and action phases, the angle of the elbow at release, and the height of release. There was a significant difference in the angle of maximum layback at the .05 level.

A COMPARATIVE STUDY OF THE FORWARD
PASS OF COLLEGE QUARTERBACKS, WITH
AND WITHOUT PROTECTIVE EQUIPMENT

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CHAPTER I

INTRODUCTION

Throughout the last fifty years the importance of the forward pass in football has increased tremendously. In order to make the football more passable, it has changed from a blunt ended, pumpkin shaped object to the streamline, well balanced ball of today. The quarterback, the person that usually passes the football, has become a major factor in many games, and many coaches feel the quarterback is the most important player on the field.

With the advancement of the passing game in football comes the question of the effect of protective equipment on the passer's ability to throw the football. Although the helmet can not be significantly altered due to the protection it provides the head, shoulder pads can, and are, altered to prevent the quarterback from losing range of motion in the passing arm. These types of "quarterback" pads are lighter and less confining than the pads worn by other players. Even though the quarterback can wear special pads, there is still the question as to whether the protective equipment does alter his passing motion.

With the advancement of biomechanical techniques and

studies, better analysis of athletic skills have been made possible. Cinematography has been the major and most reliable tool used in biomechanical analysis. Through cinematography, one can determine angles and positions at the different stages of release, as well as the time it takes to accomplish certain aspects of the forward pass. Therefore, the purpose of this study was to biomechanically analyze the differences in the preparatory and action phases of the forward passing motion in football, with and without protective equipment.

Need for the Study

A review of literature on the forward pass in football revealed a minimal amount of researchers that biomechanically analyzed the forward pass (Cooper, 1976; Carlson, 1962; Friedman, 1967; Purvis, 1940). There have been numerous articles and books written on the technique of passing a football but few offer biomechanical explanations. This author has been unable to locate any research dealing with the effect of protective equipment on the forward passing motion. Furthermore many authors (Fisk, 1976; Broer, 1973; Dawson, 1972; Namath, 1973) disagree on certain aspects of the forward pass such as: major force contributing factors; wrist action; angle of the forearm to the upper arm at

release; and, angle of upper arm to trunk at release.

For example, the literature, when discussing the angle of release at the elbow joint at the time of release is very conflicting. According to Namath (1973), the elbow should be bent slightly at release; however, Dawson (1972), felt that the elbow should be completely extended. There are differences in the belief of certain passing mechanics besides the example stated. None of the authors attempt to discuss any differences, if any, caused by protective equipment.

Purpose

The purpose of this study was to biomechanically analyze the differences in the quarterback's forward passing motion with and without protective equipment. Specifically, the objectives of this study were to compare the differences in: (1) the angle of the upper arm at the beginning of the preparatory phase; (2) the time interval for the preparatory and action phases; (3) the angle of the elbow at release; (4) the height of release; and, (5) the angle of maximum layback.

Hypotheses

The major hypothesis was that there are no significant differences in the quarterback's forward passing motion with

and without protective equipment. The five specific hypotheses tested were:

1. There are no significant differences between the angle of the upper arm at the beginning of the preparatory phase.

2. There are no significant differences between the time interval for the preparatory and action phases.

3. There are no significant differences between the angle of the elbow at release.

4. There are no significant differences between the height of release of the object.

5. There are no significant differences between the angle of maximum layback.

Limitations

1. Filming was done in only one plane.

2. A three dimensional perspective was lacking during the plotting of segmented end points.

3. Filming was not done during a game condition.

4. Throwing accuracy was not considered as part of the study.

5. Only the preparatory and action phases were analyzed.

6. Subjects' skill levels varied.

7. Stance, grip, and dropback movements were not

considered as part of the preparatory phase.

8. Only the passing arm was analyzed.
9. Only one size of shoulder pads were available.
10. Only six subjects were analyzed.
11. Only right handed quarterbacks were used.
12. Velocity was not included as part of the study.

Assumptions

The following assumptions were recognized:

1. It was assumed that the researcher could objectively and reliably identify, on the digitizer, the 22 segmental endpoints for the specified frames.
2. It was assumed that the quarterbacks used the same motion when filmed as they would have in game conditions.
3. It was assumed that the quarterbacks were not having any physical or psychological problems that would affect their performance.

Definition of Terms

Abduction of Upper Arm - raising the upper arm sideward, until the arm is parallel to the ground.

Action Phase - the phase from the time the shoulder starts forward until the ball is released in the forward passing motion in football.

Angle of Elbow - the angle which is formed by the upper

arm and the forearm.

Catchable Pass - any pass the receiver does not have to jump for, take more than one step to either lateral direction, or catch after the ball bounces.

Cinematography - the method of filming and analyzing human movement through high speed photography.

Cocking of Arm or Ball - the placement of the ball into a position where it is ready to start forward.

Elbow Extension - increasing the angle of the upper arm and forearm until 180 degrees is reached.

Horizontal Abduction - movement backward of an abducted upper arm in the horizontal plane, accompanied by retraction of shoulder and scapula.

Horizontal Adduction - forward movement of an abducted upper arm in the horizontal plane, including protraction of the shoulder and scapula.

Lateral Rotation - the action of the humerus which is caused by outward rotation around its long axis, occurring at the shoulder joint.

Medial Rotation - the action of the humerus which is caused by inward rotation around its long axis, occurring at the shoulder joint.

Preparatory Phase - the phase of the passing sequence beginning when the non-throwing hand parts from the ball,

and the throwing elbow starts backward and ending when the shoulder starts forward.

Pronation of Forearm - inward rotation of the forearm turning the palm downward toward the ground.

Protective Equipment - the use of shoulder pads and helmet when testing.

Quickness of Release - the total time required to deliver the ball starting at the beginning of the preparatory stage and ending at release.

Release - the time when the ball is no longer in contact with the passing hand.

CHAPTER II

REVIEW OF RELATED LITERATURE

The review of literature presented in this chapter has been divided into three sections: (1) overhand throw; (2) football pass; and, (3) summary.

Overhand Throw

In passing a football, the main objective is to have a smooth, quick, accurate delivery, using the force producing levers fully and in correct sequence. This is not easily achieved, but through practice a thrower can become a good passer (Read, 1974).

When looking for qualities in a passer, it is important to look at what mechanical difficulties the passer is having. In evaluating a passer's mechanical qualities, individual differences must be accounted for. Each player has unique qualities and body make-up, which will necessitate for some individual variations in the mechanics of his forward passes (Read, 1974).

The forward pass in football is basically an overhand throw that must be quick, forceful, accurate, and delivered high enough to clear the hands of the on rushing defensive

lineman. Theisman (1975) described the passing motion as having the ball held high by the back shoulder, then cocking the ball while beginning to stride forward with the left leg. The elbow then leads the forearm while the weight moves forward to the left leg through the use of hip and trunk rotation. The ball is then released with the elbow slightly flexed and the hand just in front of the right shoulder.

Although limited studies have been completed on passing a football (Purvis, 1940; Mikszewski, 1968; O'Quinn, 1968) a number of studies have analyzed the overhand throw in baseball (Atwater, 1970; Broer, 1970; Collins, 1960; Fisk, 1976; Peterson, 1975). The baseball throw is a basic overhand pattern, but differs from the football pass because of the time element and size of the object.

Broer (1973) explained that the longer the backswing, the more time to work up momentum in throwing a baseball. In most of these baseball studies (Atwater, 1970; Broer, 1970; Collins, 1960; Peterson, 1975) the thrower had no time limit to complete the throw, thus the subjects could use a longer backswing with more time to develop momentum. A quarterback is trained and learns early that the pass must be delivered quickly to avoid rushing defensive linemen, therefore taking away the luxury of a long backswing.

Levers of Importance. The summation of forces is

necessary to produce a great amount of velocity on a thrown object (Collins, 1960). There is little disagreement that in order to produce a high velocity throw, the more body parts that are brought into the action, if timed correctly, the better (Atwater, 1975; Collins, 1960; Fisk, 1976; Peterson, 1975). The throwing motion has been defined as a properly timed coordination of accelerations and decelerations of all body segments in a sequence of action from the left foot to the right hand that will produce maximum velocity to the right hand (Peterson, 1975). In the study done by Atwater (1975), subjects who had the greatest ball velocity at release were those with the most rapid sequential acceleration and deceleration of trunk and arm segments prior to release when throwing a softball.

Fisk (1976) suggested that a great deal of individual differences and variations exist such as arm action, grip, preparatory elbow angle, height of release, cocked position of the wrist, and ways in the transferring of weight. Even so, the basic need for the summation of forces is necessary for maximum velocity. Fisk (1976) also found the fundamental components of the overhand throw to be the following: transfer of weight, hip rotation, trunk and shoulder rotation, medial rotation of the humerus, elbow extension, wrist flexion, and forearm pronation. These areas can be

combined into three more general areas: (1) arm action; (2) trunk rotation; and, (3) hip rotation.

In a study by Peterson (1975) the percent of contributions of body segments for the overarm throw for total ball velocity was recorded. These findings were as follows: hip rotation including leg force - 36.6 percent; trunk and shoulder girdle rotation - 15.4 percent; arm action - 24.4 percent; and, hand (wrist action) - 23.6 percent. Both Broer (1973) and Hoshikawa, Miyashita, Oguri, and Toyoshima (1971) found similar results in the contributing factors of the overarm throw. Approximately 50 percent came from the hip and trunk rotation. These two studies contradicted the results of a study done by Collins (1960). In this study, the contribution of force producing factors were as follows: wrist action - 60 percent; hip rotation - 20 percent; arm action - 4 percent; and, trunk rotation - 16 percent. Collins (1960) did mention the fact that in his study the wrist was already moving forward before the actual wrist flexion occurred, which possibly would account for a higher percentage of contribution recorded in the study than the wrist actually gives.

According to Atwater (1970), and Cooper and Glassow (1976) the shoulder action of medial rotation of the humerus is the most outstanding characteristic in the overarm throw.

This part of the throwing motion gives the ball the forceful snap heading into release. The forward pass in football has to be released high with an overhand motion. There is little wrist flexion imparting velocity on the football (Dawson, 1972; Read, 1974; Theismann, 1975).

Cooper and Glassow (1976) reported that next to wrist flexion, medial rotation is the fastest joint action of the upper limb. They also reported that there is less wrist action in the forward pass in football than in a baseball throw. This would tend to be in agreement with other authors (Theisman, 1975; Dawson, 1972; Read, 1970) that the wrist action is not one of the primary force producing actions in the football pass. The wrist and hand are used more for control in the football pass. Plagenhoef (1971) reported that the more overhand a throw, the more medial rotation of the upper arm at the glenohumeral joint occurs. Certainly, the football pass is an overhand throw because it is necessary for the football to clear the defensive linemen.

The contribution of elbow extension as a force producer is minimal according to Broer (1972) and Fisk (1976). The contribution of the extension of the elbow joint to velocity resulted mainly from the torque produced in the arm as a result of body rotation (Hoshikawa, Miyashita, Oguri, and Toyoshima, 1971). Cooper and Glassow (1976) reported that

elbow extension lengthens the arm to take advantage of hip and spinal levers which produces greater total velocity.

Football Pass

The forward pass in football is a form of overhand throw designed to release the football very quickly, accurately and forcefully.

Being able to release the football quickly can be assisted by where the ball is carried prior to the preparatory phase. Authors vary as to the position to hold the football while deciding where and when to pass. Carlson (1962) believed the ball should be carried chest high, which would enable a quick delivery and make it easy to pull the football back in if the pass rush gets to the quarterback. Smith (1970), Theismann (1975), and Welborn (1972) all agreed that the football should be carried high and back by the upper right shoulder. This would decrease the time needed in the preparatory stage.

The preparatory stage, known as cocking the football, is where the quarterback gets the ball in position to begin to put forward force on the football (Theismann, 1975). Smith (1970) stated that some throwing quickness in cocking and initial forward movement is good, however he stated that care must be taken not to stress this too soon, or it will

interrupt the sequence of levers, which would inhibit force and accuracy.

According to Smith (1970) the shoulder position is the single, most important factor in the speed of delivery. The shoulder can be held back in a position ready to come forward, therefore eliminating the wasted motion of the backward movement of the shoulder. Cooper and Glassow (1976) reported that the combinations of backward movement and beginning contractions stretch the tendons and connective tissue in the muscles, making the forward movement more forceful.

The utilization of hip and trunk rotation, along with transfer of weight, are dependant on the stride of the passer (Namath, 1973). When a passer steps forward, or toward the target, a forward transfer of weight should occur. This should aid the passer who used an exaggerated overhand throw, but there is less use of hip rotation in this type of forward step. A step to the left side of the target will give the passer more freedom of hip rotation than that of a forward step (Dawson, 1972). Friedman (1967) felt that there is no other way for consistent accuracy than to step at the target. Dawson (1972) and Namath (1973) stated that a step to the left with the left foot not only helps utilize arm power, but also the leg power, and hip and body rotation.

The elbow is the factor that begins the action phase of the football pass and leads the arm through the throw.

Authors (Hay, 1973; Friedman, 1967; Theismann, 1975; Melpie, 1977; Welborn, 1972; Read, 1970) have stated that the elbow leads the throw, thus making the forearm a major lever.

The angle of the elbow at release is not agreed upon by some authors. Atwater (1970) reported that in an overhand throw, the elbow at the time of release is almost fully extended. When it was extended, the movement caused the ball to move to the right, upward, and forward. A study (Broer, 1967) done on overhand throwing with skilled women, found that the ball was released well before full extension. Dawson (1972) stated that the pass should be brought overhead with the elbow fully extended. Passing with this form, Dawson (1972) felt that body rotation would be maximized. A common fault of passers is to let the ball get too close to the body, thus losing freedom of the throwing arm (Read, 1970). Also, the quarterback must lock the elbow. If the elbow is not locked, full range of the arm has not been taken advantage of, and a snap pass results which is rarely on target according to Read (1970).

The wrist must be straight and parallel to the body with the fingers directly upward until the ball leaves the hand. This means that the wrist will only be flexed during

the follow through stage of the pass. In emphasizing this point, Read (1970) stated that the most fundamental necessity in passing is to keep the wrist straight. Dawson (1972) and Theismann (1975) both supported this opinion by stating that the wrist must be kept straight, with no twisting, and brought down on release.

Namath (1973) felt that his style of passing a football has qualities in it that make his style different from others. Namath steps far to the left instead of forward, in order to get more force out of hip and trunk rotation. Because of the great amount of force gained by the hip rotation, the ball is held out in front of the right shoulder up high and back. After the hips begin to open, the left arm and left shoulder begin to pull the body around in a circular motion with the ball still held up, out, and back, only slightly cocked. When using this type of motion, the quarterback achieves a shorter preparatory stage resulting in a quicker release (Namath, 1973). Also Namath (1973) suggested that if additional height is required by the quarterback, the quarterback can lean to his left, thus raising the angle of the upper arm upward, and getting the ball higher. To sum up Joe Namath's passing style is to say that it is a circular motion using body rotation as a more contributing force producer.

Summary of Related Literature

As stated earlier, there have been many writings on passing the football, but little research has been reported. The authors either felt that protective equipment had no effect on the passing motion, or they did not feel it was a necessary component to consider. There are few studies in which body angles during the throwing motion were defined along the element of time and displacement. There are few research studies that have investigated basic overhand throwing patterns (Atwater, 1970; Broer, 1967; Collins, 1960; Fisk, 1976; Hoshikawa, Miyashita, Oguri, and Toyoshima, 1971). However, there are differences in the football forward pass that do not apply to these studies. There are numerous articles and books written on the forward pass (Carlson, 1962; Dawson, 1972; Friedman, 1970; Namath, 1973; Purvis, 1940; Read, 1970; and Theismann, 1975). These writings only deal with slow speed game films or naked eye observations. In order to get more scientific findings biomechanical research must be done to understand the true principles of the forward pass.

CHAPTER III

METHODS

The purpose of this study was to biomechanically analyze the differences in the preparatory and action phases of the forward passing motion in football with and without protective equipment. The biomechanical data was obtained through cinematography.

The methods presented in this chapter are divided into the following sections: subject selection; filming procedures; and, analysis procedures.

Subject Selection

Six quarterbacks from the University of Wisconsin - La Crosse football team, ages 18-22, were selected as the subjects for this study. The subjects were selected because they had completed the spring workouts and had been throwing to receivers two or three times a week for at least three weeks. Five of the six subjects threw for two practice sessions with the protective equipment on during half of their practice time. The other subject threw with protective equipment on once, missing once due to illness. The two sessions with protective equipment enabled the

quarterbacks to become accustomed to the equipment before filming took place. All subjects seemed to be in good condition and none complained of having sore throwing arms.

Filming Procedures

This study was filmed on Memorial Field, of the University of Wisconsin - La Crosse campus on Thursday, May 3, 1979.

Filming Equipment. A Cine - 8, Super 8mm, high speed motion picture camera loaded with 160 ASA Kodak Ektachrome Super 8mm color movie film, was used to film the subjects from a right lateral view. The camera was run at 200 frames per second with an exposure time of 1/450 of a second per frame. The camera was placed on a tripod 45 feet away from where the subjects set up to pass (see figure 1).

The subjects were instructed to plant their right foot, on the fifth step of the dropback, within a foot of a white line which was one yard left of the set-up marker. The set-up marker was in line with the camera one yard back of the area the subjects set up to pass in. Number cards were used to record the condition and trial. A one second sweep clock was positioned in the background in full view of the camera. A yardstick was filmed as a reference measure to provide for the scaling factor. Lighting was achieved

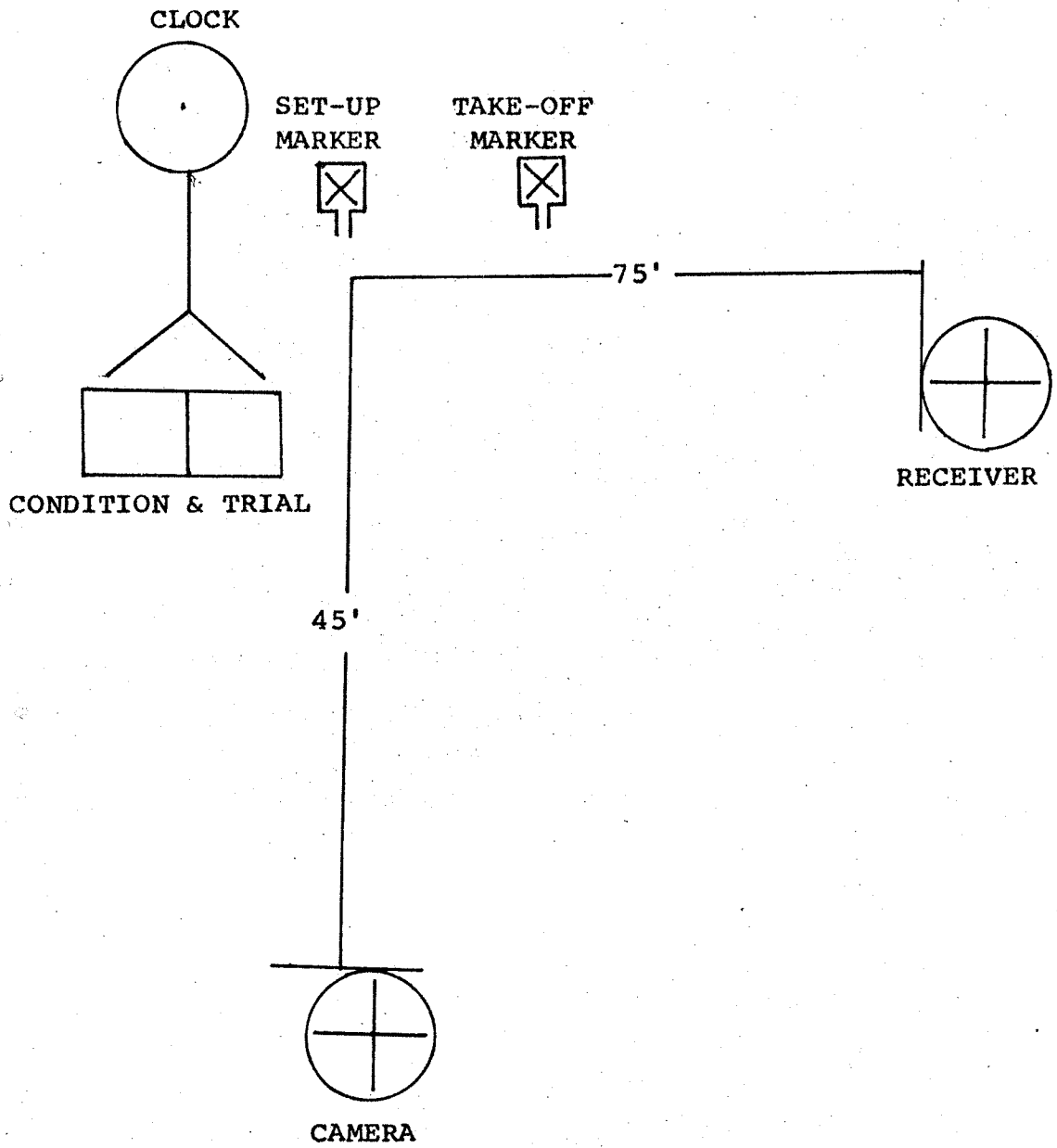


Figure 1

Experimental Setting

through natural sunlight.

Football Equipment. A Wilson TD Football was used by the subjects. This was the same type of football that was used for all games and practices except those practices that were rainy, when rubber balls were used. Rawlings' Crusader "Quarterback" shoulder pads, size 17-18, were worn by all of the subjects. Subjects wore either a Riddell "Pac 3" football helmet, or a Kelly Geodetic Suspension football helmet. A white game jersey was worn by the subjects and this number was used to indicate the subject's number. The subjects wore shorts which facilitated locating lower body segmented end points during analysis. All subjects wore football shoes made of molded soles which were in good condition.

Collection of Data. Before the filming session, each subject was allowed to warm up as much as he liked until he felt comfortable and loose. The subjects had to adjust their starting spot so that when completing a normal five step drop, they would be setting up in the area designated by the set-up marker. They would then set up and pass to a receiver standing 25 yards from the set-up marker. The trial was accepted if the ball got to the receiver and was a catchable pass determined subjectively by the author. The receiver was the same for all subjects.

Whether the subject was filmed with or without protective equipment was determined by random selection with replacement. Two slips of paper the same size were taken for the selection. On one "W" was written indicating that the subject would throw with protective equipment on first. The other slip of paper had "W/O" indicating that the subject would throw without protective equipment on first. The two slips of paper were then taken by this researcher and held in front of the subject in closed hands. The subject was instructed to pick one of the hands. The slip in the hand picked would then be the condition in which the subject would start. This procedure resulted in five of the six subjects throwing without protective equipment first. Each subject was given four trials with at least three of the trials being evaluated as a catchable pass. If only two of the trials resulted in a catchable pass, then another trial was completed. Also, if the subject slipped when setting up, the trial was taken over. If all trials were evaluated as a catchable pass, then trials two, three, and four were used for the study. All subjects threw both conditions consecutively.

The subjects were unaware that they had a time limit for their delivery. The subjects were timed from the instant they planted their right foot on the fifth step of

their dropback until the ball was released. The subjects were allowed 1.5 seconds during this time or the trial was not accepted. All of the subjects stayed under this time limit in all of the trials.

Analysis Procedures

The films were examined by means of a Lafayette Analyzer, 8mm projector, to make sure that the trials selected were clear and visible. Four frames were selected from the preparatory phase and four frames were selected from the action phase. The preparatory frames were: (1) separation of left hand from ball; (2) end of horizontal abduction of upper arm; (3) end of abduction of upper arm; and, (4) right shoulder starting forward. The action frames were: (1) elbow starting forward; (2) maximum layback of lower arm; (3) elbow extension; and, (4) release.

Segmental end points were located for each frame through the use of a Numonics 1224 Digitizer. The 22 segmental end points taken were: right hand extremity; right ulnar styloid process; right elbow; right coracoid process; left coracoid process; left elbow; left ulnar styloid process; left hand extremity; right foot extremity; right medial malleolus; right center of knee; right greater trochanter; left greater trochanter; left center of knee; left medial malleolus;

left foot extremity; tragus of ear; top of sternum; crotch or midpoint of trochanters; center of gravity of an object; top of head; and, a reference point (see figure 2). The verticle and horizontal coordinates were recorded through the use of a teletype on paper tape. This data was then transferred to a disc file and processed at the University of Wisconsin - La Crosse Computer Center, applying the FILMDAT program.

Development of Instruction

Upper Arm Angle. The angle of the upper arm during the preparatory and action phases were calculated to determine if the protective equipment affected the subject's ability to keep the angle of the upper arm similar to that angle taken without protective equipment. The data was taken from the Summary of Body Segment Analysis by Frame, which is given as part of the FILMDAT program printout. The angle was measured in degrees.

Time Interval. The time interval for the preparatory and action phases were taken for each frame interval. The data for the time interval was taken from the number of frames to the next action phase of the passing motion. When filming at 200 frames per second, each frame takes .005 seconds. By determining the number of frames to the next

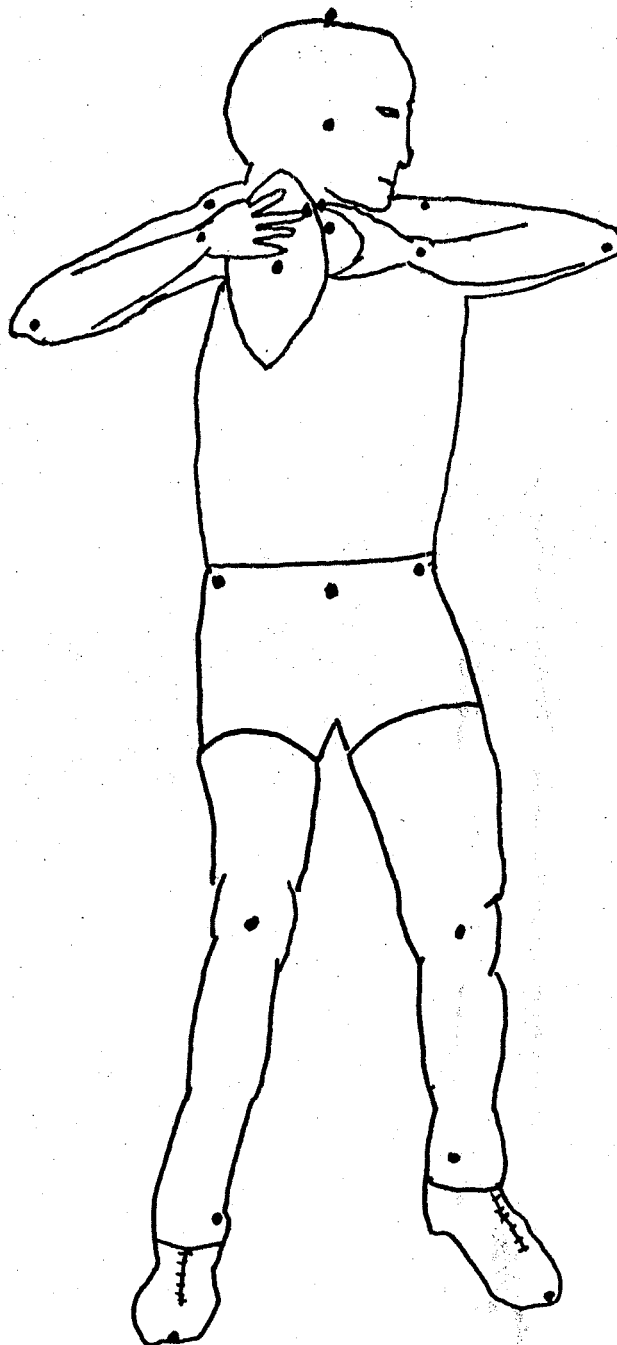


Figure 2

Representation of the 22
Segmental End Points

action phase and multiplying by .005, the time between action phases was calculated. This time was then compared with the one second sweep clock that appeared in each frame as a means of checking camera speed. This was calculated to determine if there were significant differences in the time used for each part of the passing motion, with and without protective equipment.

Angle of Elbow at Release. The elbow angle at time of release was computed from the data given in the Summary of Body Segment Analysis by Frame for the right lower arm and the right upper arm. To find the angle of the elbow at release from this data, the angle of the upper arm was subtracted from the angle of the lower arm. This number, in degrees, was then subtracted from 180 degrees and the result was the angle of the elbow at release. The angle of the elbow at time of release was determined to see if protective equipment affected this angle.

Height of Release. The height of release of the object was calculated to see the effect protective equipment had on how high the football is at the time of release. The height of release was calculated through data taken from the Cognitive Values in Feet printout. The vertical (Y) value for the right shoulder at the time of release was subtracted from the vertical (Y) value for the football. The difference

was assumed to be the height of release of the football.

Angle of Maximum Layback. The angle of maximum layback was taken to see if the protective equipment interfered with the subject's degree of freedom for natural layback when protective equipment was not worn. Data was taken from the Summary of Body Segment Analysis by Frame for the right lower arm. A comparison of the angles was made to see if a significant difference existed with and without protective equipment.

Statistical Treatment of Data

An average was taken for the three trials for each subject under each condition, with and without protective equipment. A correlated "t" test was used to test the hypotheses at the .05 level of significance.

CHAPTER IV

RESULTS AND DISCUSSION

Introduction

The purpose of this study was to biomechanically analyze the differences in the preparatory and action phases of the forward passing motion in football, with and without protective equipment. The biomechanical data presented in this study are presented in the following sections: (1) angle of the upper arm at the beginning of the preparatory phase; (2) timing interval for the preparatory and action phases; (3) angle of the elbow at release; (4) height of release; and, (5) angle of maximum layback.

Subjects

The subjects selected were all college quarterbacks at the University of Wisconsin - La Crosse. All of the subjects were returning for the following football season and were previously involved with the UW - La Crosse football spring workouts. All of the subjects had quarterback experience in high school. Subject No. 20 was a transfer freshman quarterback with one year of varsity playing experience at the college level. He was 6'3" tall and weighed 188 pounds.

Subject No. 21 was a 5'11", 175 pound sophomore quarterback with one year of freshman playing experience and one year of varsity experience. Subject No. 23 was 5'11" tall and weighed 195 pounds. He was a freshman quarterback with one year of freshman playing experience. Subject No. 24 was a junior quarterback with one year of freshman experience and one year of varsity experience. He was 5'11" tall and weighed 170 pounds. Subject No. 25 was a junior quarterback. He was 6'2" tall and weighed 205 pounds. He had one year of freshman experience and two years of varsity experience. Subject No. 26 was a 6'0", 160 pound freshman quarterback with one year of freshman playing experience. None of the subjects complained of any injury or illness at the time of testing.

Angle of the Upper Arm

To determine if the protective equipment affected the position of the upper arm at the beginning of the preparatory phase, the angle of the upper arm was taken from frame 1. The mean for the six subjects was considerably close when comparing the upper arm angle of the subjects at the beginning of the preparatory phase with and without protective equipment as seen in Table 1 (Table 1 and all subsequent tables are the average of 3 trials for each subject). The mean for the upper arm angle at the beginning of the

Table 1

Average of 3 Trials for the Angle of Upper
Arm at the Beginning of the Preparatory Phase

Subject	Without Protective Equipment (degrees)	With Protective Equipment (degrees)
20	234.9	233.8
21	208.9	202.9
23	246.8	246.3
24	212.7	222.7
25	248.7	238.6
26	218.3	214.3
Mean	228.4	226.4

preparatory phase when the subjects were without protective equipment was 228.4 degrees, compared to 226.4 degrees when using protective equipment. The calculated "t" value of .7019 was not significant at the .05 level, thus the null hypothesis, that there is no significant difference in the angle of the upper arm at the beginning of the preparatory phase, was accepted ("t" value of 2.015 was needed for significance at the .05 level).

Time Interval

The time intervals for the preparatory and action phases

were taken to determine if protective equipment had a significant effect on the time element of passing a football. This time was divided into the preparatory and action phases.

The mean for the time interval of the preparatory phase for the six subjects showed little difference between using and not using protective equipment as seen in Table 2. The mean for the time interval of the preparatory phase for the six subjects was .2088 seconds when passing the football without wearing protective equipment, compared to .2050 seconds when passing the football while protective equipment was worn by the quarterbacks. The calculated "t" value of .4669 was not significant at the .05 level, therefore the null hypothesis, that there is no significant difference between the time intervals of the preparatory phase, was accepted.

The averages for the time interval of the action phase for the six subjects also showed little differences between using and not using protective equipment (see Table 2). The average of the time interval of the action phase for the six subjects was .1788 seconds when passing the football without wearing protective equipment, compared to .1873 seconds when passing the football while wearing protective equipment. A value of 1.212 was the calculated "t" value. This value

was not significant at the .05 level therefore accepting the null hypotheses, that there is no significant difference between the time intervals for the action phases.

Table 2

Average of 3 Trials for the Time Intervals
for the Preparatory and Action Phases

Subject	Without Protective Equipment (seconds)		with Protective Equipment (seconds)	
	Preparatory	Action	Preparatory	Action
20	.207	.191	.218	.212
21	.199	.189	.187	.197
23	.210	.203	.199	.208
24	.219	.146	.190	.175
25	.224	.142	.214	.152
26	.194	.202	.222	.180
Mean	.209	.179	.205	.187

Angle of Elbow at Release

The angle of the elbow at release was calculated to determine the possible effect protective equipment made on this angle when passing a football. The mean of the angle of the elbow at release for the six subjects were similar when compared to using and not using protective equipment as seen in Table 3. A mean of 123.6 degrees was found when

the subjects passed without protective equipment compared to 120.0 degrees when protective equipment was worn. The calculated "t" value of 1.728 was not significant at the .05 level. The null hypothesis which states that there is no significant difference between the angle of the elbow at release with and without protective equipment, was accepted.

Table 3

Average of 3 Trials for the Angle
of the Elbow at Release

Subject	Without Protective Equipment (degrees)	With Protective Equipment (degrees)
20	124.4	115.3
21	145.5	138.1
23	118.1	120.0
24	125.3	117.4
25	90.8	91.5
26	137.4	137.8
Mean	123.6	120.0

Height of Release

The height of release was measured to ascertain the effect of protective equipment on the subjects' ability to release the ball at the height that was achieved without

protective equipment. The averages for the height of release for the six subjects varied very little when the two conditions of using and not using protective equipment were compared (see Table 4). An average height of 1.896 feet was achieved when the subjects passed a football without wearing protective equipment compared to an average of 1.872 feet while protective equipment was worn. The calculated "t" value of .7821 was not significant at the .05 level, therefore accepting the null hypothesis that there is no significant differences in the height of release when comparing passing motion with and without protective equipment.

Table 4

Average of 3 Trials for
the Height of Release

Subject	Without Protective Equipment (feet)	With Protective Equipment (feet)
20	1.900	1.813
21	2.043	2.010
23	2.010	2.083
24	1.923	1.827
25	1.450	1.517
26	2.050	1.980
Mean	1.896	1.872

Angle of Maximum Layback

A final comparison was made on the angle of maximum layback. This comparison was calculated to determine what effect protective equipment had on the range of motion of lateral rotation. The mean of the angle of maximum layback for the six subjects varied by 3.8 degrees when comparing using and not using protective equipment (see Table 5). A mean of 176.3 degrees was found when the subjects passed without protective equipment compared to 172.5 degrees when protective equipment was worn while passing. A "t" value of 2.569 was calculated. This value showed significance at the .05 level, therefore rejecting the null hypothesis that there are no significant differences in the angle of maximum layback when comparing the passing motions of the subjects throwing with and without protective equipment.

Discussion

Through looking at the statistical results of this study, only a small variance in the subjects' passing motion occurred when comparing throwing with and without protective equipment for four of the five hypotheses tested at the .05 level. The only hypotheses rejected at the .05 level was that involving the angle of maximum layback. The five hypotheses tested were: angle of the upper arm at the

Table 5
Average of 3 Trials for the
Angle of Maximum Layback

Subject	Without Protective Equipment (degrees)	With Protective Equipment (degrees)
20	188.5	187.7
21	177.2	171.1
23	177.8	172.5
24	178.3	173.6
25	158.5	160.3
26	177.4	169.8
Mean	176.3	172.5

beginning of the preparatory phase; time interval for the preparatory and action phases; angle of the elbow at release; height of release; and, angle of maximum layback.

The change in the angle of the upper arm at the beginning of the preparatory phase was so slight that it would not hinder a quarterback's throwing motion or time of delivery. This angle's importance is related to the time a quarterback uses to release the football, especially in the preparatory phase. The upper arm angle will decrease the release time if this angle is near 180 degrees. In this study protective equipment did not affect this angle. One of the possible

reasons protective equipment did not affect this angle is that the quarterbacks did not have their elbow high enough when they were not using protective equipment, at the beginning of the preparatory phase, thus not having the good high elbow to compare with when adding protective equipment. The small difference in the angle of the upper arm may be the cause for the small difference in the preparatory time between the conditions with and without protective equipment.

The action phase also had no significant difference in the time between the two conditions. Less than .01 seconds existed between throwing with and without protective equipment. This time is crucial for the quarterback because the pass must be delivered as quickly as possible before the defense can react.

Although there was a 3.6 degree difference in the angle of the elbow at release, this difference was not significant at the .05 level. The differences in some of the individuals were greater and may cause some of the quarterbacks to adjust their throwing motion by possibly taking away some length of the lever of their arm when using protective equipment. If this adjustment is hard for the quarterback to make then his passing performance may be affected.

The mean of the height of release without protective equipment was nearly identical to the mean obtained with

with protective equipment. There was less than one half inch difference between the two conditions. The height of release is important to the quarterback because the football must be released high enough to clear defensive linemen.

The angle of maximum layback had the largest differences of the five areas tested between the two conditions with and without protective equipment. There was 3.8 degrees less in lateral rotation when protective equipment was used, thus being large enough to show a significant difference at the .05 level. This angle is very important in the throwing motion and could affect the velocity of the pass when the angle of maximum layback is reduced. Both Atwater (1970) and Cooper and Glassow (1976) have reported that medial rotation of the humerus is the most outstanding characteristic in the overhand throw. Medial rotation occurs once lateral rotation is completed. The completion of lateral rotation is the angle of maximum layback. The velocity of a pass is affected mostly by the force applied through medial rotation. Because of this, it would be important to keep the natural maximum layback from being affected by protective equipment.

The results of this study indicate there were no significant differences for four of the five hypotheses tested.

Although there was no significant difference in four areas, the protective equipment did hinder the angle of maximum layback enough to show a significant difference at the .05 level. It is this author's opinion that the protective equipment limits the passing performance of a quarterback because the angle of maximum layback is the most important force producer in the overarm throw.

CHAPTER V

CONCLUSIONS

Summary

The forward pass in football is a difficult skill performed under the adverse conditions of having defensive players attacking the passer. The importance in perfecting this skill is crucial to the success of many teams. Most of the studies on the passing motion today have been done through the use of slow speed game films or naked eye observation. The purpose of this study was to biomechanically analyze the differences in the preparatory and action phases of the forward passing motion in football with and without protective equipment. Cinematography was used for this biomechanical analysis. All six subjects were filmed while throwing the football at 200 frames per second with and without protective equipment. All of the subjects were quarterbacks for the University of Wisconsin - La Crosse football team, and all six subjects had high school quarterback experience along with at least one year of college quarterback experience.

The following data were obtained after analysis of the

film: angle of the arm at the beginning of the preparatory phase; time interval for the preparatory and action phases; angle of the elbow at release; height of release; and, angle of maximum layback. Eight frames were digitized from the separation of the ball and the left hand to the point of release. Three trials were used for each of the subjects under each condition, and each frame was digitized three times. The average of these three trials were used to represent the individual's values.

Conclusions

[Based on the analysis of the data collected in this study the researcher concluded that the only significant difference in the throwing motion of quarterbacks when compared under two conditions, with and without protective equipment, occurred in the angle of maximum layback.] The researcher based this statement on the basis of the data collected, which indicated no significant differences in four of the five areas tested. However there was a significant difference in the angle of maximum layback between the two conditions.

As stated in the related literature, medial rotation is the outstanding characteristic of the overarm throw and it's importance is even more so in football. The wrist

imparts little velocity to a thrown football because it must be kept straight to guide the football. The medial rotation occurs once lateral rotation is completed. The more lateral rotation there is, the farther back the angle of maximum layback can become. The force produced by this layback is the major factor producing velocity in the forward pass in football. Because the protective equipment does hinder the throwing motion in this aspect the passer might lose some force in his pass.

Apparently the protective equipment does not greatly affect the height of release. Height of release is achieved more through positioning the shoulders on an angle with the left shoulder down and the right shoulder up. This researcher believed this to be important because the elbow can then remain in line with the shoulders. This positioning is important because medial rotation can occur at a position where it will be most forceful, directly in line with the shoulders.

This study does show that there is a significant difference in quarterbacks' passing motion when compared under the two conditions stated and the procedure used. This researcher does feel that there is a need to look at the protective equipment for the quarterback to see if any adjustment can be made to help eliminate the reduction of the angle

of maximum layback.

Recommendations

The following suggestions are recommendations for further study:

1. Conduct a similar study using more subjects as well as varying the distance of the throw.
2. Conduct a similar study utilizing either three cameras or a three dimensional view.
3. Conduct a similar study using selected shoulder pads of different structure and make.
4. Conduct a similar study during football season when a quarterback should be at his passing peak.

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APPENDIX A

REQUEST FOR APPROVAL FROM COMMISSIONER



The UNIVERSITY of WISCONSIN - LA CROSSE

LA CROSSE, WISCONSIN 54601

(608) 784-6050

ATHLETIC DEPARTMENT

April 30, 1979

Mr. Max Sparger
WSUC Commissioner
P.O. Box 8010
Madison, WI 53708

Dear Max,

Enclosed is a rough draft of a study by Douglas Miller for his M.S. Degree. Candidates for the football team, quarterbacks, are the subjects, because this is the nature of the experiment. Please note that they are involved only three or four days during the filming.

This letter is to clarify that the players are not practicing, but are part of a M.S. program study.

Sincerely,

E. Wm. Vickroy
Director of Athletics

EWV/jh

Encl.

cc: D. Miller