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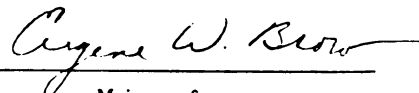
Relationship of a Power Coefficient, Anthropometric
Measures, and Performance Characteristics to Velocity
from a Football Stance

presented by

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has been accepted towards fulfillment
of the requirements for

Masters degree in Kinesiology


Major professor

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**RELATIONSHIPS OF A POWER COEFFICIENT, ANTHROPOMETRIC
MEASURES, AND PERFORMANCE CHARACTERISTICS TO VELOCITY FROM A
FOOTBALL STANCE**

By

Jerome Michael Learman

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ABSTRACT

RELATIONSHIPS OF A POWER COEFFICIENT, ANTHROPOMETRIC MEASURES, AND PERFORMANCE CHARACTERISTICS TO VELOCITY FROM A FOOTBALL STANCE

By

Jerome Michael Learman

The purpose of this study was to examine the relationships between various physical parameters (sprint speed, leg strength, sitting height, body weight, standing height, and arm length) in offensive and defensive linemen and their ability to quickly move three yards from a three-point stance to a blocking dummy. Data collected on each subject were of three types: personal, anthropometric, and performance. Personal data was collected by having the participants fill out a personal information sheet. The anthropometric data were collected with three devices: a free standing anthropometer, a standard scale, and a modified anthropometer. The performance data collected was the 40-yard dash, leg strength, and blocking speed over three yards. The equipment used to collect this data was a Zen-on Metrina Multi stop watch, a squat rack, and the Ariel Performance Analysis System (APAS). An analysis of data on speed from a three-point football stance found that four variables had a significant ($p < .05$) correlations with time over three-yards from a three-point stance: power coefficient ($r = -.22$), subjects' grade level in school ($r = -.37$), number of years subjects played football in high school ($r = -.34$), and playing level ($r = -.34$).

DEDICATION

To my family for their help and support.

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Chapter 1

INTRODUCTION AND REVIEW OF LITERATURE

The sport of American football is unlike any other sport in that there are eleven players on each side of a set line of scrimmage who engage in a series of plays lasting approximately five seconds (Arthur, 1995). Each play is an attempt to advance (by the offense) or prevent (by the defense) the forward movement of the ball. This is established through a coordinated pattern of team work. Athletes with many different physical characteristics participate in football, from 350 pound linemen to 96 pound kickers. Physical differences are usually related to the varying demands required by the positions played and the skills used in the game of football (passing, catching, running, cutting, stopping, starting, balancing, delivering and absorbing blows, place kicking, and punting) (Hay, 1994).

Review of Literature

For players of the “skill” positions (running backs, quarterbacks, flankers, split ends, linebackers, cornerbacks, and safeties), it is universally accepted that ability to run, catch, and throw are the most important characteristics. However, what characteristics are important for linemen? The following review of literature explores research that has investigated athletic performance in American football. In particular, research related directly to linemen and the successful execution of their skills. The

research topics covered are changes in the game, control of the line of scrimmage, methods of study, techniques for offensive and defensive line play, anthropometric data, stances and their variability, studies of sprinting, balance, contribution of momentum to blocking, trends in football studies, charging times in relation to performance, and response to stimuli.

Changes in the Game

Over the past 25 years, two primary factors have precipitated changes in the way American football is played. These factors are physical characteristics of the participants and modifications of the rules.

Physical Characteristics. As the height and weight of the population, in general, has increased, there has been a similar trend in those selected by coaches to play football (Haywood, 1993; Papalia & Olds, 1989). The average player, at the highest levels of play, is heavier and taller than his predecessor. At the same time, the average speed of the participants has increased (Nolan, 1995). Due to the broad range of physiques and running speeds of athletes available to participate, and the very systematic approach used by coaches and scouts to find athletes with predetermined characteristics, there has been a differentiation in the physical characteristics of football players in various roles (linemen, quarterbacks, running backs, receivers, and kickers). These factors have also caused a change in strategies of play. In the 1970's and early 1980's, the wishbone offense was considered the best. In the 1990's, it has been replaced by an offense with three wide receivers and one running back, placing more importance on running speed.

Rule Changes. In addition to the changes in physical characteristics of athletes, three major rule changes have occurred in football over the last 25 years that have altered the way American football is played.

In the past, defensive backs were permitted, by the rules, to maintain contact with the offensive receiver until the ball was thrown for a forward pass. Now, no defensive contact with a potential pass receiver is legally permitted five yards or more beyond the line of scrimmage. This allows the receiver to run freely down the field and has dramatically increased the number of passes attempted per game and subsequently has increased scoring (National Collegiate Athletic Association. NCAA Football: The official 1994 college football records book, 1994).

The second major rule change involves offensive linemen. Previously, while blocking, offensive linemen were permitted to only use their shoulders in contacting their opponents. Now, they can use their open hands and arms in what is called “hands-on blocking.” This has allowed the quarterback more time to throw and has increased the number of passes attempted per game and, subsequently, has increased scoring. An example of how the game has changed because of variations in the rules is highlighted in a dissertation by White (1984). White used a survey of coaches and National Collegiate Athletic Association (NCAA) statistics to determine what Division 1A coaches thought about the use of hands-on blocking and how it has affected the game. This study was conducted after the 1982 season. The NCAA allowed hands-on blocking beginning with the 1979 season. White found that the percentage of passing plays and passing yards increased, while the percentage of rushing plays and rushing yards decreased. The survey

results also revealed that coaches believed that college football was changing and that changes in the rules (primarily hands-on blocking) were responsible for these changes. In addition, White found that coaches overwhelmingly favored hands-on blocking.

The third major change involved tackling protocol. Spearing (tackling or blocking head first) was once legal. In response to the serious injuries that were caused by this practice, rules have been changed to make spearing illegal. Consequently, the game has become much safer (Mueller & Schindler, 1997).

Control of the Line of Scrimmage

Despite the physical changes of the athletes and changes in the rules, one key factor to winning that has remained the same over time has been the ability to control (push the opponent backward) the line of scrimmage (Tranquill, 1996). If a team can control the line of scrimmage on offense, it can more easily advance the ball by running with it (“run the ball”) or provide the quarterback with additional time to advance the ball by throwing it to a teammate (“pass the ball”) thereby enhancing the chance of scoring. On the other hand, if the defensive team can control the line of scrimmage, then the offensive team is not as likely to advance the ball and often will have to give up possession of the ball without scoring.

An important issue for many coaches in football is related to the need to run the ball (Tranquill, 1996). In order to be able to run the ball, quality blocking is required. According to Tranquill, Offensive Coordinator at Michigan State University, “You must be able to run the football to win.” Statistical research also supports this contention. The Ohio State University football staff, after using a computer program written specifically

to analyze their team's offensive and defensive tendencies, determined that their team won all of its games in 1980 when the team ran the ball for over 250 yards (Covault, 1980). This demonstrated that the ability to run the football was a key element in winning.

Methods of Study

Many methods have been used to study the performance of physical tasks associated with American football. These methods include theoretical (Hermanson, 1991), computer database (Stiggins, 1985), force plate (Lamb, 1976), cinematography (Heydman, 1970), and accelerometry (Morrison, 1983). These methods will be briefly reviewed.

A theoretical method can be used when no prior research on a technique had been conducted. A theory can be developed using the principles of mathematics, physics, and anatomy. Such a model was created by Hermanson in 1991. However, what can be theoretically validated may not be physically plausible.

Lamb's (1976) study demonstrated that force plate records are an accurate predictor of the change of speed of the center of gravity. The problem with the use of force plates in evaluating changes in speed is their limited size and inability to predict speed changes over a great distance. They may be the best method to use to calculate speed changes over a short distance in which the feet will fit on the surface of the force plate.

The advantage of cinematography is associated with the many different types of information that can be obtained. An example of this is shown in Table 1 which reports

the variables examined by Heydman (1970). While this information is useful, it is highly unlikely that an unskilled performer, achieving the same values for all variables, would get the same results on a task as a skilled performer would because of differences in physiology and/or motor skill pattern. Another disadvantage of cinematography is the great amount of time needed to analyze data collected for just one subject.

Table 1

Kinematic variables in throwing a football, examined by Heydman (1970) via cinematography

Base of Support
Knee Flexion Right Leg
Knee Flexion Left Leg
Degree of Radial Flexion
Angle of Projection
Degree of Shoulder Rotation
Range of Upper Arm Abduction
Degree of Shoulder Elevation
Degree of Elbow Flexion

Morrison (1983) attached accelerometers to a football helmet to monitor head impact forces during controlled situations. The author suggested using transmitters in future studies because the hard wires were too cumbersome. Other disadvantages of using accelerometry to collect information in football are the great cost and the need to hold the orientation of the helmet to a constant axis system in order to get meaningful results.

All of these methods are valid ways to study physical performance in American football, but problems can be found with each. Force plates, accelerometers, and cinematography are all valid methods to study velocity. The small size of force plates

player with the hands, is that the hands should strike side ways or upward, but not downward. This is because a downward blow will reduce the normal ground reaction force of the defensive player and make him easier to block by the offensive player. However, even in this modern era of football, varied opinions exist among professionals as to which defensive techniques to use.

A sampling of three university football coaches in the Midwest provided three different opinions of how a defensive lineman should play. Dave Steckel, the defensive line coach at the University of Toledo (one of two undefeated Division I football teams in 1996), wanted his defensive linemen moving on the snap of the ball as fast as possible and attacking the offensive linemen or running straight to the ball if contact with the offensive linemen could be avoided (Steckel, 1996). Greg Colby, the defensive line coach at Michigan State University, wanted his players to remain in a low position in moving from their stance (taking no steps, if possible), getting good hand placement (hands inside the offensive lineman's hands on the offensive lineman's chest), and keeping both feet on the ground (Colby, 1996). Coach Colby said, "I feel hand placement is the most important factor in run defense." Greg Mattison, the defensive coordinator and defensive line coach at the University of Michigan, always has his defensive linemen line up offset shoulder to shoulder and never head up. Coach Mattison wants his players to move the foot laterally, to the side of the opponent, back slightly (stagger the feet and move with the foot closest to the opponent first) and fire (move quickly) off the line. After a quick start, the defense makes contact with both hands and the face mask, while simultaneously taking a small "power" step with the foot that is further back (Mattison,

1996).

Mattison's (1996) desire to have players hit with the head is not allowed by the rules and it is not safe. The practice of hitting head first is illegal unless both hands arrive at the same time as the head. Regardless of the legality of leading with the head, this also leads to an increased risk of injury. Milburn (1993) and Torg, Vegso, Neill, and Sennett (1990) found injuries occurred most frequently when the neck is flexed (forward) and the hit occurs with the top of the skull, causing axial loading of the spine. Milburn and Torg et al. also found that any hitting with the head increased the rate of injuries to the spine and neck. Offensive line techniques have become standardized over the last twenty years but this systematization is unlikely for defensive linemen due to the wide variety of defensive philosophies.

Anthropometric Data

Anthropometric data appear to be neglected in the study of football. Presently, only one study in American football has investigated the anthropometric characteristics of the athletes even though both arm and leg length potentially have a great effect on the ability to block and tackle.

Sells (1977) studied 41 defensive tackles from various colleges in the state of Indiana. The subjects were tested on the following performance variables: reaction and movement time in a simulated open skill, a 5-yard sprint time, and a 40-yard sprint time. The following anthropometric variables were also recorded: height, weight, and percent body fat. Coaches ranked the players as 1st, 2nd, or 3rd team. The idea was to use statistical analysis on the selected variables to determine which characteristics could be

attributed to a successful defensive tackle or which may indicate future achievement. The results indicated that four variables (height, weight, 40-yard sprint time, and movement time in an open skills test) were useful indicators of good defensive tackles. The faster times and higher weights were not unexpected results. However, shorter defensive tackles were found to be better than the taller ones. The author did not attempt to explain the basis for this phenomenon.

Future studies are encouraged since the only examination of anthropometric parameters found a relationship to football performance. Many other anthropometric factors have not been studied. Because anthropometric data are highly reliable, great potential exists for future studies.

Stances and Their Variability

A factor that can be controlled by a football player is stance. The following section will examine if one stance may be universally better than other stances, or if certain stances may be better for certain tasks. First, the two-point and the three-point stance will be compared. Second, the effects of hand and foot placement variability will be covered. Third, studies comparing the three-point stance to the four-point stance will be presented. Fourth, variability within the three-point stance will be discussed. Finally, conclusions will be drawn from the results of all the studies looking at stance variability.

Two-Point Versus Three-Point Stance. Holtz (1962) looked at differences in performance from a two- and three-point stance. While his results are more applicable to backs and receivers in situations where a pass is expected, offensive linemen have been known to start from a two-point stance. All subjects were evaluated in both stances three

times, for ten trials each (total of 60 trials per subject). It was found that the three-point stance resulted in significantly faster times over seven-yards, but it was noted that the two-point stance is a more natural position for a running back to take a hand-off.

Hand and Foot Placement Variability. Owens (1960) looked at 40 variations in stances to see which variables had the greatest effect upon the speed of the player and force that could be generated at the shoulder over one yard. The stances varied in toe-to-toe spacing, both lateral and anterior-to-posterior. The stances also varied in anterior-to-posterior hand-to-toe spacing. Both rhythmical and non-rhythmical snap counts were used. The difference in force produced at the shoulder was not significant for any of the 40 variations of the stance. The difference in speed of movement time due to stance and rhythm of the snap count was significant, but none of the variables were significant by themselves. Leg lengths were found to affect optimum foot and hand spacing when force was a criterion. No significant correlation between reaction time and movement time ($r = 0.075$) occurred. The correlation between weight and force at the shoulder was $r = 0.73$. The correlation between movement time and force was $r = -0.95$. (This value is negative because shorter movement time is associated with greater force.)

Three-Point Versus Four-Point Stance. The debate as to which is better, the three- or four-point stance, is one of the oldest in football. In the 1980's and 1990's, the common trend was to use the four-point stance on defense and the three-point stance on offense. The prevalent belief was that more weight was forward in a four-point stance. Offensive linemen want their weight back so they could more easily move in all directions, while defensive linemen primarily need to be able to move forward.

Table 2

Results of studies comparing the three- and four-point stance

Authors, date	Result	Differences if significant
Bolt ,1949; Dillon, 1970; Finch, 1956; Healey, 1974;	no major significant differences	N/A
Olson, 1965 Rohloff, 1972	major differences	when using the three-point stance, subject moved faster in the direction of the down hand

When comparing the three-point stance to the four-point stance in the ability to start quickly, the results are widely varied (Table 2). Some studies found no significant differences between the two stances (Bolt, 1949; Dillon, 1970; Finch, 1956; Healey, 1974) while others found major differences (Olson, 1965; Rohloff, 1972). Using the three-point stance, subjects were faster when pulling in the direction of the hand that was down. Are subjects faster in pulling in the direction of the hand that they choose to place on the ground because they are faster going to the dominant (usually right) side, or is it because of which hand is down? This has not been answered. Overall, it appears that the three-point stance is better than the four-point stance for a faster start in multiple directions.

Variability within the Three-Point Stance. The most common stance used by linemen in American football in the 1990's is the three-point stance. The preceding literature has indicated that the three-point stance is probably the best stance to use. However, within the three-point stance many variables can be changed. It is of great interest to American football coaches to discover how these variables will affect the

outcome of a block.

Abbott (1940) used cinematography to examine how changing the angles of the feet, height of the hips, and the width of the feet would affect movement time. All the articles Abbot reviewed prior to conducting his study suggested that a staggered three-point stance was best for faster movement times, so he did not alter this variable. The angle of the feet did not produce a significant effect on the outcome. The high stance, based upon hip height, produced a significantly (10 %) faster time over three yards than the low stance. The natural (subject selected) foot spread produced a significantly faster (17%) time than both the wide and the narrow foot spread ($\pm 4"$ of the natural foot spread).

Kadatz (1965) examined how weight distribution affected reaction and movement time. Four different weight distributions (5% of body weight forward, 20% of body weight forward, and 35% of body weight forward), as measured by a scale, were used. The person's normal (self-selected) weight distribution was also used. The subject performed in the direction of 0 degrees, 90 degrees to the left, and 90 degrees to the right. It was concluded that the more weight a player had forward the faster his forward reaction time and movement time. The more weight a player had back, the faster his reaction time was going to the left or right.

Wilson (1964), like Kadatz, looked at the effect of weight distribution on reaction and movement time. A three-point staggered stance was used. The test consisted of a straight ahead block, a lateral pull left, and a lateral pull right. Six trials were completed in each direction. Within these six trials, half were executed with the weight balanced

(6% on the hand), while the other half were performed with the weight forward (16% on the hand). Movement time, reaction time, and total time to move five feet were measured. Reaction time had no significant variation due to stance when participants moved forward. However, a significant difference in reaction time occurred when participants moved left or right. A balanced stance produced faster results. For speed of movement in each of the directions evaluated, players were significantly faster with their weight forward. In terms of performance time, moving forward was significantly faster when the weight was forward in the stance. Players' reaction times were significantly faster going to the right than to the left. Athletes' movement times were significantly faster going to the left than to the right. A comparison of the total performance time between left and right movement did not significantly differ. The author concluded that a weight forward stance is the best stance to use in football.

Conclusions. Holtz's (1962) findings that movement from a three-point stance is faster than from a two-point stance agrees with the general thinking of most coaches. Today, a three-point stance is preferred because it is believed to keep the athlete's center of gravity low and provide stability in collisions. Ability to take a hand-off is not a concern for linemen. The significant correlation ($r = 0.73$) between weight and force and the high correlation ($r = -0.95$) between movement time and force, both of which were found by Owens (1960), seems logical. From these two studies it can be concluded that an athlete will be faster from a three-point, as opposed to a two-point, stance. It can also be deduced that greater body weight and/or faster movement time will be associated with an increase in the amount of force generated at the shoulder.

Abbott's (1940) results would have players using a natural (self selected) foot spread and hips in a high (little bend in the knee) position. This agreed with Colby's (1996) opinion "that the hips should be raised to the point that they are above the shoulder blades." Kadatz's (1965) findings support the view that the more weight the player has forward, the faster a lineman can move forward. In contrast, if the player has more weight back, he can move faster to the left or right. It is interesting that he reported the difference in reaction time and not movement time. This is explainable considering that when the weight is back, weight must be transferred forward when movement starts. This transfer would be counted as reaction time. The findings of Kadatz and Abbott agree with the other studies, bearing in mind that the higher the hips (while in a stance) the greater the amount of weight that is forward. What is interesting is that Wilson (1964) found only movement time to be faster when the weight was forward, while Kadatz found significant differences in reaction time and movement time.

What can be concluded is that weight forward enhances forward movement and weight back enhances speed of movement to either side. This conclusion may lead coaches to teach their players how to distribute their weight in stances. However, this needs to be done without divulging the intended movements to the defense.

Studies of Sprinting

Sprinting 100 meters is quite a different task than that of a lineman coming out of his stance and hitting someone three feet away. However, many similarities occur between the movement of a football lineman and a sprinter in track in departing from their stance. Since force is a product of mass and acceleration (Halliday, 1988), a football

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player wants to maximize his acceleration. The sprinter also wants to maximize his acceleration to have the fastest time. A player who has a shorter time over a given distance will have a faster average acceleration, provided that the start is from a stationary position. Due to the similarities between the sprint in track and the movements of a football player coming out of a three-point stance, it is likely that principles which apply to achieving a fast start from a sprinter's stance would also apply to getting a fast start from a football stance.

Canham (1952), a track coach, listed the following as keys to success in sprinting: short reaction time, quickness, agility, and natural strength. Arnold (1974), when comparing standing and crouched starts for sprinting a distance of 20 yards, found the standing start enabled longer mean stride lengths and the crouched start permitted slightly faster initial average velocities. Overall, both starts had comparable results. Both types of starts were faster when arms were held close (as opposed to wide arm swings) to the body, which Arnold believed helped drive the sprinter out of the blocks. Gagnon (1976) found that kneeling starts produced faster times than any of the standing starts, which supports what Arnold found. These results might indicate that Arnold's results of longer stride lengths from a standing start are less meaningful in determining speed. Using a kneeling start is comparable to football coaches' ideas of using a crouched stance. Henry (1952) looked at block spacing and discovered that block spacings of 16 inches and 21 inches gave the best results (fastest times). Krenzer (1974) attempted to compare measures of power coefficient, acceleration, and velocity for phases of the sprint and no correlation was found between any sprint segment and power coefficient test, but strong

relationships ($r = 0.61$) were found between height, weight, and power coefficient.

Krenzer's (1974) findings show that physical characteristics may have a greater effect on power coefficient than other factors, but physical characteristics may not affect speed.

Balance

Balance is a very important concept in football. A football player attempts to stay on his feet, using his body to deliver a force while absorbing one. This is a very dynamic motor skill, especially when a player is unaware of the blow to be received. According to Kreighbaum and Barthels (1990), a body is more stable when the center of gravity is lower and the more centered it is over the base of the support. Turner (1992) also supported this statement. Kreighbaum and Barthels also state that the closer the line of gravity is to an edge of the base of support the more unstable the body is in that direction. The most important principle of Kreighbaum and Barthels, relating to football, is that, when giving or receiving a horizontal force, the body's base of support should be enlarged horizontally in the direction of the horizontal force to be given or received. This would not logically contradict studies that indicate when weight is forward in a football stance the player should be quicker in the forward direction.

Contribution of Momentum to Blocking

In any collision, including blocking in football, the outcome is primarily determined by the momentum and elastic properties of the colliding objects. The elastic properties of colliding football players is not the focus of this investigation and is not likely to change substantially from one player to the next. However, each player has substantial control over the factors that determine momentum.

Momentum is a product of mass and velocity. If an objective of linemen in blocking is to maximize momentum, this can be achieved by maximizing the product of these two factors. There may, however, be a trade off between increasing each of these factors. (Also, coaches need to take into account functions other than collisions that the linemen are called upon to accomplish.) The impulse-momentum relationship, associated with Newton's second law, provides a basis for this trade off. The football player can increase his weight (mass) through weight training and/or diet. However, the goal of a given football player, about to engage in a collision, is to achieve a maximum velocity of his body prior to contacting his opponent. This can be accomplished, during the time period prior to the collision, by applying maximum horizontal force to his body. This accelerates the body (mass) to achieve maximum velocity. As previously reported, there has been a trend toward using heavier (more massive) linemen. Currently, it is not uncommon for teams in the National Football League to have several linemen whose body weight exceeds 300 pounds. However, if a large (massive) lineman cannot achieve a very large velocity prior to impact, he may not achieve sufficient momentum prior to the collision.

Using what is known about momentum, if mass and velocity are known, momentum can be determined. Why then have no studies to date examined momentum, which would be a key component in football blocking? Due to the fact that football is played on a field with twenty-two different players moving at once, and movement is normally not just linear, velocity and therefore momentum is very hard to measure or estimate. As a result of these difficulties, studies have instead looked at horizontal force

generated at the shoulder, which is believed to be much closer to game values than momentum would be.

Elbel, Wilson, and French (1952), using 45 varsity football players from the University of Kansas, studied horizontal force at the shoulder, movement time, reaction time, and combined (movement plus reaction) time. Each subject had four trials where their horizontal force was measured. This study found no significant correlation between time and force. The correlation between body weight and force was 0.30. An inverse relationship ($r = -0.51$) existed between weight and movement time. The distance of movement used in the tests was not stated.

Rosenfield (1947) measured velocity and horizontal force (at the shoulder) of a straight ahead charge by football players. The study used 55 college football players as subjects. The distance the subjects started from a dummy apparatus, used to measure force data, was not given. One unusual aspect of this study was that players who performed three trials were in full pads. The results showed no significant relationship between force and velocity and between body weight and velocity. A significant but moderate ($r = .5144$) relationship between weight and force exerted was detected. The author found intra-test reliability of velocity to have a correlation of $r = 0.79$ and intra-test reliability of force to have a correlation of $r = 0.851$.

Mellem (1942) measured reaction time and movement time for blocking, and calculated a power coefficient for the performance of blocks (charges) against a sled and a power coefficient for two seven-yard dashes. The subjects were 115 male college students of varying athletic and football experience levels. The tests consisted of nine 18-

inch charges in which reaction time and movement time were measured. The subjects started three trials with auditory signals, three trials with auditory and visual stimulation, and three trials with just visual signals. The subjects also completed two seven-yard runs. A power coefficient was calculated for the best seven yard and 18-inch time. Age, weight, height, along with athletic and football experience were evaluated for significant relationships with the power coefficient. The formula used for power coefficient was $P = F * D/T$ (P = power coefficient, F = body weight (the person mass times acceleration due to gravity), D = distance moved, and T = time to move that distance). The author felt that his results clearly showed that the power coefficient is a better basis for evaluating football talent than just speed because it correlated highly with football playing experience and level of competition. The combined auditory and visual signals resulted in a greater power coefficient being generated, followed by visual, and then lastly the auditory. Unfortunately, the statistical significance of the power coefficient generated, associated with starting signal, was not stated. Age appears to have no bearing on the power coefficient. However, a moderate positive correlation ($\sim .30$) between height, weight, and speed was found. In general, the results suggested to the author that a power coefficient test should be a valuable aid in predicting football playing ability.

Table 3

The relationship of mass and speed to maintaining a steady force

Force (N)	Mass(kg)	Weight (lbs)	Average Acceleration (m/s/s)	40 meter time (s)
127	81.84	180	1.6	3.59
127	90.72	200	1.4	3.78
127	113.39	250	1.12	4.23
127	136.08	300	0.93	4.64
127	158.76	350	0.8	5.00

In Mellem's (1942) study, a significant correlation occurred between weight and force, but no significant correlation between speed and force. Table 3 gives an example of a 350 pound person who could run 40 meters in five seconds and how people of less weight must increase their speed in order to maintain the same amount of force. These times become unrealistic when examining the wide gamut of weights one might see on a football field. Even a difference of 50 pounds between linemen would need a drop of approximately 0.4 seconds in a 40 meter dash to have the same force. This suggests that linemen should get as large as possible as long as they can retain their acceleration and mobility to carry out their assignments. Once this maximum weight is found, speed at this particular weight should be optimized.

Trends in Football Studies

Questions about which directions to have the subjects move, and over what distance to conduct measurements may be answered by looking at previous studies which look at movement from a football stance. Table 4 provides an overview of previous studies. The average number of subjects is near 40, number of directions tested is close to three, and distance tested is almost nine feet (three yards). The directions tested are shown in degrees; 0 degree is straight ahead and the other directions are self explanatory. The two studies that did not list the distance used were force studies so the distance was most likely small. The results of these past studies, that had similar objectives, can be used to recommend the distance over which to test.

Table 4

A summary of studies on differences in stance

Author	Year of Study	Number of Subjects	Direction of Movement	Distance Moved in Feet	Experience Level of Subjects
Abbott	1940	2	0, ± 90	9	FB
Mellem	1942	115	0	2/3 & 35	College
Rosenfield	1947	55	0	not listed	FB
Bolt	1949	10	0, ± 90	2, 8 (± 90)	FB
Elbel et al.	1952	45	0	not listed	FB
Finch	1956	120	0, ± 45 , ± 90	15	College
Owens	1960	20	0	3	FB
Holtz	1962	52	0, ± 90	21	FB
Wilson	1964	34	0, ± 90	5	FB
Kadatz	1965	18	0, ± 90	4	FB
Olson	1965	34	0, ± 90	5	FB
Dillon	1970	20	0, ± 45 , ± 90	9	HS
Rohloff	1972	24	0, ± 90	4	HS
Healey	1974	20	0, ± 90 , 180	4	FB
Average	1958	41	2.79	8.9	

Experience Level of Subjects Key

FB = College football player

HS = High School football player

College = College Student

Charging Time in Relation to Performance

Previous studies have shown that speed is not always the best indicator of force. The saying “speed kills” has been used in football jargon for decades. However, does speed relate to performance? While this is hard to test, it is worth evaluating studies that have tried to examine this potential relationship.

Manolis (1955) looked for correlations between charging time and blocking performance. He used 31 college football players, who completed 20 trials, to test response time over a distance of 12 inches. Three experts also rated the subjects’ blocking performances from game films. No statistically significant relationship was found between speed of charging and blocking performance. A zero relationship existed between game time (time played) and speed of response. Surprisingly, Manolis found no difference in response time and position played. He suggested that the "timing" of a response as opposed to speed is the important factor in executing a block.

Miles (1931) tried to find whether total body reaction time was related to the reaction time of an individual body segment. He used a multiple chronoscope to measure charging times in football and compared them to individual reaction time on a finger trigger. The results indicated no relation, and that reaction time is specific to sports.

Manolis (1955) seems to have found no correlation between speed and being a good football player, especially among linemen. His study may not have been the best evidence since only a distance of 12 inches was used to measure speed and this distance may not be long enough to adequately indicate football talent. Miles (1931) showed that

finger reaction time does not appear to be related to responses for the whole body football tasks. Miles' results lead to the belief that reaction time in football must be developed in drills specific to the sport.

Response to Stimuli

One area often ignored or not accounted for in past studies of the start from a stance in football is how the type of stimuli used to signal the start will affect the results. Many researchers may assume this will not have an effect on the data due to the fact that all subjects are starting via the same stimuli. However, it should be remembered that when comparing different studies, the type of starting stimuli may affect comparisons of otherwise similar studies. Responses to stimuli have been researched and investigators should use these results when conducting future studies.

Hurney (1942) found that subjects had faster charging times when their starts were signaled by using a combination of auditory and visual sequence stimuli, followed by visual alone, and then auditory alone. Miles and Graves (1931) reported that data accumulated in psychological laboratories have shown that response to visual stimuli is 0.04s slower than audio stimuli. Miles and Graves found that reaction to anticipatory stimuli was 0.127s while non-anticipatory was 0.426s, that the best signal to start on was either the fourth or fifth number (off side was diminished and speeds were faster), and that a rhythm of 100 Hz is better than rhythms of 40, 60 and 120 Hz. Owens (1960) and Thompson, Nagle, and Dobias (1958) all found that movement time was faster using a rhythmical start signal. Thompson, Nagle, and Dobias (1958) also discovered that rhythmical, numerical signals resulted in the faster movement times than when rhythmic

word-numbers, non-rhythmic word-numbers, and non-rhythmic color signals were used. Paige (1969) found that a foreperiod (defined as the time from “get set” to “go”) of four seconds yielded faster responses than two seconds and six seconds, but he only looked at three signals (on your mark, get set, and go) and the number of signals may change the results. From these studies, it can be concluded that a rhythmical signal pattern was better than non-rhythmical and that visual cues are as good as auditory cues. Visual cues may be used in the laboratory setting, however, in a game setting visual cues can be seen by both sides there is no advantage for the offense to use visual cues during a game. Any differences due to training of offensive players at being faster from auditory stimuli and of defensive players at being faster from visual stimuli (the normal methods from which these players start) has not yet been studied.

Summary

A wide variety of studies, relating to performance in football, have been conducted. Because these studies involved different purposes, populations and methods, their results and conclusions are different. Cinematography is one of the valid methods used in the evaluation of performance and can be directly applied to movements from a football stance. Typically studies which have evaluated performance from a football stance have looked at movements over an average distance of three yards.

The following are some basic conclusions regarding stances and starts. Football players need to get initial movement of their opponent by maximizing push (which is similar to sprinters trying to achieve good block velocity), impulse, and velocity. A player is faster out of a three-point stance than from a two-point stance. The more weight

forward, the faster a player will be going forward and the more weight back, the faster a player will be going side to side. Within the three-point stance, people are generally faster in pulling in the direction of the hand that is down. A small correlation was found (Mellem, 1942) between weight and power coefficient for speed from a three-point football stance. However, it was determined that no significant correlation existed between speed and power coefficient for speed from a three-point football stance (Mellem, 1942).

Some basic conclusions were found regarding speed and starting stimuli. No correlation existed between speed and being rated as a good football player. Reaction time in football must be drilled specifically to tasks done in the sport (Miles, 1931). A rhythmical signal pattern is better than a non-rhythmical one and visual cues are as good as auditory cues. Visual cues may be used in the laboratory setting, however, they are not useable for offense during a game.

Purpose of the Study

It is generally agreed that control of the line of scrimmage in football is very important. What characteristics do “skilled linemen,” who control the line of scrimmage, possess that their less skilled counterparts do not possess? The purpose of this study is to examine the relationships between various physical parameters (sprint speed, leg strength, sitting height, body weight, standing height, and arm length) in offensive and defensive linemen and their ability to quickly move three yards from a three-point stance to a blocking dummy.

Need for the Study

This study is needed because many of the physical and performance characteristics of successful linemen have never been examined. If the ultimate goal is to win the game, an understanding of the contribution of these characteristics to this outcome is important. Studies of variations in football stance can be found in the literature. However, no research on velocity patterns or other anthropometric characteristics of linemen has been done to date. The current study should fill a void in the literature and possibly open up new areas of research regarding movement from a three-point stance in football.

Statement of the Problem

The purpose of this study was to examine the relationships between various physical parameters (sprint speed, leg strength, sitting height, body weight, standing height, and arm length) of offensive and defensive linemen and their ability to quickly move three yards from a three-point stance to a blocking dummy.

Sub-problems that were examined are the following:

1. Do selected anthropometric measures correlate significantly with a fast start from a three-point stance?
2. Does greater leg strength of a lineman predict a faster start from a three-point stance?
3. Do offensive and defensive linemen, starting from a three-point stance, cover three yards in the same time?
4. Does a significant relationship exist between running speed (from a three-point stance) for a distance of three yards and for a distance of 40 yards?

Limitations and Delimitations of the Problems

1. Due to the fact that this study was conducted in the summer, high school players had not participated in organized football for about eight months. A re-acclimation phase may have existed for these subjects. However, all subjects would have experienced this effect.
2. One significant restriction of this study was the limited number of high school linemen tested. This study used offensive and defensive linemen from Michigan High School Athletic Association Class AA, A and BB schools.
3. It is not feasible to look at the role of back strength and its effect on speed from a three-point stance.

Hypotheses

1. No difference will be found in speed over three yards, starting from a three-point stance, between offensive and defensive linemen at the same playing level (varsity, junior varsity, or freshmen).
2. Football players at the higher playing levels (where varsity is the highest level, freshmen the lowest level, and junior varsity intermediate) will be faster over a distance of three yards, starting from a three-point stance, than their lower level counterparts.
3. Starters at the same playing level (varsity, junior varsity, or freshmen) will be faster than their non-starting counterparts over a distance of three yards, starting from a three-point stance.
4. No significant correlation will be found between 40 yard dash time, magnitude of

maximum leg press, body segment lengths, body weight, or height and time to move over a distance of three yards, starting from a three-point stance.

5. A significant positive correlation will be discovered between an average power coefficient over a three yard distance from a three-point stance and body weight.
6. Playing level, body weight, and power coefficient will be better predictors of speed over three yards, starting from a three-point stance, than any other measurement taken.

Assumptions

1. Speed over three yards from a football stance is a valid measure of a football linemen's playing ability.
2. The velocity of the subject's right hip was an accurate approximation of velocity at his whole body center of gravity.
3. Subjects knew their one repetition maximum (1RM) for the squat lift.
4. The formula used to calculate the one repetition maximum (1RM), from the number of squat lift repetitions, which was based upon data from college students, also applied to high school students.
5. All equipment used in this study was accurate, individuals assigned to make and record measurements did so accurately, and any error was random.
6. The ideal blocking technique from a three-point stance is the fastest block, using proper technique, to an object three yards away.
7. The three-point stance was the ideal stance because, on average, players can vary their weight distribution on the supporting structures of the body and still achieve

relatively fast displacement of their bodies in different directions without expressing their intended direction of movement.

8. Offensive linemen (tackles, tight ends, guards and centers) and defensive linemen (tackles and ends) had similar techniques based on what side of the ball they play and not on what offensive or defensive position they play.

Definitions of Terms

The following terms are defined as applied in this study:

Center of Gravity - The center of mass distribution of the body

Charging Time - An old football term which means the same as movement time of a blocking task

Down Hand - The hand that is in contact with the ground while in a three-point football stance

Downed Head - Neck is flexed forward so the top of the head would make first contact with an object when moving forward

Hands-On Blocking and Hands Blocking - When an offensive player uses his hands as contact points while attempting to block an opponent

Head Up - When two players on opposite sides of the line of scrimmage position themselves so that their heads are directly across from each other (In this situation both players' left shoulder is across from their opponent's right shoulder and their right shoulder is across from their opponent's left shoulder.)

Line of Gravity - An imaginary line from the body's center of gravity to the center of the earth

Line of Scrimmage (LOS) - An imaginary line, connecting both side lines and running perpendicular to them, that intersects the forward end of the football at the start of each play (Offensive and Defensive squads line up on opposite sides of this line.)

Lineman Firing Out - A lineman starting and moving as quickly as possible in a forward direction from his static position for a distance of three yards

Momentary Muscular Fatigue (MMF) - The point in weight lifting when the athlete can no longer properly perform another good repetition of an exercise

Movement Time - The time from when the subject starts moving to when he moves a specific distance from a starting line

National Strength and Conditioning Association (NSCA) - The primary certifying organization in the United States for coaches of strength and conditioning

Offset Shoulders - When both left shoulders or both right shoulders of two opposing linemen are directly across the line of scrimmage from each other

One Repetition Maximum (1RM) - The maximum amount of weight that an athlete can lift for one repetition demonstrating proper technique

“Pass the Ball” - An attempt by the offensive squad to advance the ball by having an eligible receiver run down field and having the quarterback throw the ball to him in the air

“Playing Ability” - Being able to execute fundamental skills of a sport in a game or competition setting against an opponent (For football linemen, this includes being able to block an opponent successfully and repeatedly throughout the course of a game.)

Power Coefficient - $\text{Power Coefficient} = \text{Force} * \text{Distance} / \text{Time}$ (This study

will employ Mellem's (1942) method of using a subject's body mass in kilograms * gravity (9.8 m/s/s) to equal force. The distance used in this study to calculate power coefficient is three yards. Time will be the subject's time recorded over three yards. It should also be noted that the formula given is not a true measure of power, but more like speed corrected for weight. This is because the force of weight acts downward and the speed measured is in a horizontal plane.)

Power Step - A small step in the direction of intended movement, which gives the body a more stable base

Response Speed - Time period from when a command is given to start a task to the completion of the task

"Run the Ball" - An attempt by the offensive squad to advance the ball by carrying it forward

Side of the Ball - The side of the line of scrimmage where a player lines up (These sides have been termed the offensive and defensive sides of the football.)

Snap Count - The signals used by the offensive team, usually verbal cadence to indicate the hike of the football and the start of the play

Spearing, also Spear Blocking and Spear Tackling - Act of leading with the head (head first) when hitting an opponent in a block or tackle

Three-Point Stance - An offensive football stance with feet spread just outside the width of the shoulders and the foot to the side of the down hand slightly staggered backward (3-6 inches) (One hand is on the ground and the weight of the body is evenly distributed between the hand and the two feet. The buttocks can be slightly higher than

the shoulders and the shoulders are square (parallel to the line of scrimmage). Both heels are slightly off the ground (see Figure 2).)



Figure 2. - The three-point stance.

Two-Way Player - A player that plays both offense and defense during the course of a football game

Chapter 2

METHODS

Introduction

This chapter covers the methods used to collect the data for this study. The subjects, procedures, and instruments are discussed. Reliability of the measures and variables for which data were collected are also presented. Last, the type of statistical analyses used to test each hypothesis is reported.

Subjects

The subjects for the study were offensive and defensive football linemen from high schools in Michigan. The number of subjects tested was 55. However, three were dropped from the study because of incomplete data. Thus, none of their data were included. Table 5 shows the average age, height, and weight of the subjects as well as the range of these variables. The tests were administered in July, 1996. The subjects had not played competitive football for their high school team since the previous November. The subjects planned to return to play football for their high school team in the fall of 1996. Their coaches expected them to be participating in off-season conditioning programs so they would be in good condition for their return to competitive football in the fall. Subjects were recruited to participate in the current study via letter (Appendix A) sent to their high school coaches. Coaches were also provided with 20 informed consent forms

with their letter. The subjects were subsequently informed that they and their coaches would be provided with results of the study upon their request.

Table 5

Age, height, and weight of subjects (n=52)

	Mean	Standard Deviation	Range
Age (years)	16.28	± 0.98	14.27-18.44
Height (cm)	180.1	± 6.86	163.3-194.5
Weight (kg)	91.04	± 16.79	59.7-126.1

Procedures and Instruments

Data collected on each subject were of three types: personal, anthropometric, and performance. Methods associated with the collection of data are subsequently presented. The subjects wore a standard pair of gym shoes, socks, shorts, and tee shirt for the performance testing. Subjects removed their shoes for the anthropometric testing.

The tests were administered in a set order. Because the number of subjects was relatively small, the tests were not randomized. There was a chance that fatigue from one test could have adversely influenced the results of tests that were sequentially administered. Due to the small number of subjects and the order of the tests, it is not likely that trends could have been discovered.

Personal Information

When the subjects arrived at the site for testing, they were required to turn in their signed informed consent form (Appendix B), which they had received earlier from their coaches. After this form was received, they were asked to fill out a personal information sheet (Appendix C). Their names were used by the investigator during data collection,

but they are not revealed in the results. The subjects' names and addresses were used to provide the results to the subjects if they requested them. Subjects were asked to allow video taping of their performance to be used only for instructional purposes by the investigator. For each subject, a personal information sheet was placed on a clip board and a pencil was provided. On this data sheet, the subject entered his name, address, and telephone number. The remainder of the data sheet was filled out by the researchers as the data were collected.

Anthropometric Data

The anthropometric data were collected with three devices. Standing and sitting heights were measured with a free standing anthropometer. Lengths were recorded to the nearest millimeter. Sitting height was used to calculate leg length (standing height - sitting height = leg length). Weight was measured with a standard scale that was calibrated yearly and considered highly reliable. The scale's accuracy was tested to the nearest whole pound with known weights before testing began. Weight was recorded to the nearest 1/10 of a pound. Last, arm length, was measured to the nearest millimeter with a modified anthropometer. All measures were taken by a skilled researcher who had prior experience collecting these data and was familiar with the prescribed guidelines.

The anthropometric data were collected first. Standing height, sitting height, arm length, and weight were measured in order. A standard set of guidelines adopted from the Anthropometric Standardization Reference Manual (Lohman, Roche, & Martorell, 1988), regarding how to take the measurements, was used (Appendix D). Data were collected by one researcher while another researcher recorded the measurements on the

subject's personal data sheet. After recording the data, it was read back to the researcher taking measurements to enhance recording accuracy.

Performance Data

Sprinting Speed. The second set of data collected was the times for the 40 yard dash. Subjects were provided with a five-minute warm up session (Appendix E). Each subject was hand timed by a coach who frequently used this method. Subjects self-started from a three-point stance after the timer gave a verbal indication that he was ready. The timer started timing on the first movement and stopped timing when the finish line was crossed. A self-start prevented bias based on starting stimuli, which the review of literature has indicated could be a factor in the outcome of a timed sprint. Subjects performed two trials and both values were recorded. A second researcher recorded the performance times on the subject's personal data sheet and orally verified the value with the timer.

Sprinting speed over a distance of 40 yards was measured with a Zen-on Metrina Multi stop watch, model number 352. The watch was accurate to 1/100 of a second. The sprinting test was conducted on a dry, level grass surface.

Leg Strength. The subjects' leg strength was tested by having them perform a sub-maximum repetition test of the back squat. This was a sub-maximum test so a warm up was not required. Subjects were asked to estimate their one repetition maximum (1RM) for the back squat and this weight was reduced by 20%. The subjects were then asked to perform one set to failure (i.e., the point of momentary muscular fatigue (MMF) at which the athlete could no longer complete another good repetition of the back squat).

The 1RM was estimated using the following formula: Predicted 1RM = [(weight lifted per repetition * 0.033) * number of repetitions + weight lifted per repetition] (Epley, 1985). Epley's (1985) formula was established by using college students. The correlation of predicted 1RM to estimated 1RM was found to be $r = 0.83$. An experienced strength coach from a Division 1A university was in charge of conducting these tests.

The subjects were shown a video of a person doing back squats to the point of MMF to demonstrate what was expected of them. Verbal instructions were also given to the subjects (Appendix F). The National Strength and Conditioning Association (NSCA) guidelines for technique in performing the back squat (Appendix G) were also shown to the subjects. The goal of this test is to measure leg strength that can be used in athletic competition. Therefore, no weight belts were worn by the subjects. Only one spotter was used because the tester was highly experienced in weight training. Subjects were required to perform the repetitions through the full range of motion. Each subject knew when he had reached the full range of motion because the tester called out the sequential count number and the subject could then proceed to the upward phase of the next lift. The number of repetitions and the weights used were recorded by the tester on the subject's personal data sheet.

Blocking Speed. Blocking speed was measured by the Ariel Performance Analysis System (APAS), which uses a known volume of area and digitized video tape to mathematically compute various kinematic parameters. The data were recorded on super VHS video tapes using two Panasonic AG-455P cameras at a field rate of 60 Hz. Using

the APAS system, the video tape was digitized and processed to provide velocity data. The area that was calibrated for video taping was 220 cm high, 180 cm deep, and 450 cm across. This allowed the subject to remain in the defined area for the full distance of the blocking speed test. A 31.5 pound foam lead-foot (a weight in the bottom which allows the dummy to freely stand) football blocking dummy was used for the subject to block. The test was administered on a dry grass surface. All subjects started from a three-point stance.

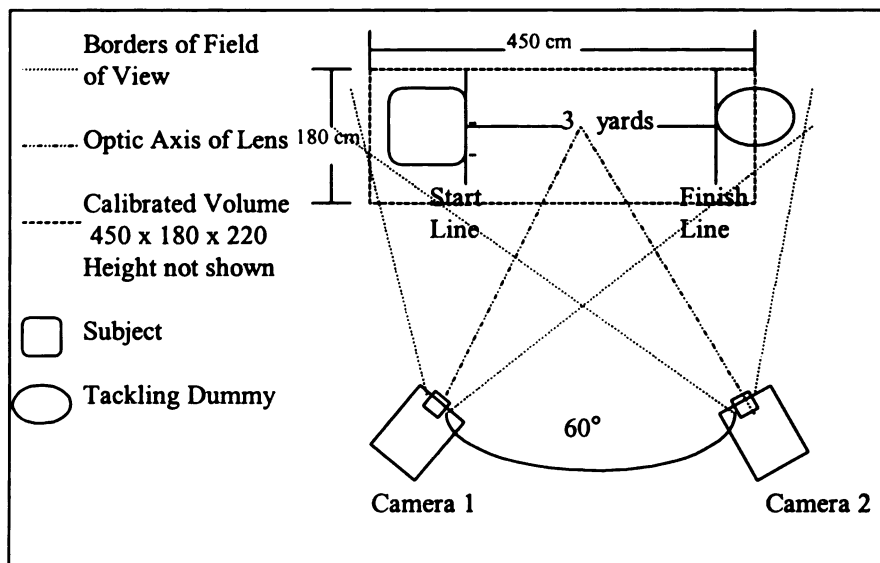


Figure 3. - Configuration of cameras for video taping.

The subjects were outfitted with a marker on the greater trochanter of the right hip. The marker was used to track the position of the body via the APAS system. The subject then lined up behind a yardline marker (starting line) in a three-point stance using self-selected weight distribution. When the subject was ready, he moved as fast as possible, in a blocking technique, and hit a foam football dummy (placed in his path three yards away from the start line). Subjects self-started to avoid any bias from starting

stimuli. The velocity measured was from the subject's first movement to the point of first contact with the blocking dummy. The average velocity over this distance was used. This blocking action is commonly done several times a day in a regular football practice. This action was recorded by two video cameras on the right hand side of the subject, whose optic axes formed a 60 degree angle and intercepted at the center of the calibrated volume (see Figure 3). The cameras were placed approximately three yards away from the subject, but this is not indicated in Figure 3 as it is not drawn to scale.

A practice trial and three recorded trials were performed. A standardized set of instructions were given to the subject (see Appendix H) and a video tape of the action desired (performed by a non-participant of the study) was available for his review. Subjects were not permitted to review their own performance. The average of the three recorded times was used as the criterion measure.

Reliability of the Measures

The reliability of the timed measures was established by the use of the Pearson Product Moment linear coefficient of correlation. The subjects had multiple trials of the blocking test and the 40 yard dash. The multiple trials were used to establish reliability coefficients using Cronback's alpha. The reliability was very high for the multiple trials of the blocking test ($\alpha = .9686$) and the 40 yard dash ($\alpha = .9620$). The data collected were accurate except for human (test administrator) error and any undetectable equipment inaccuracies. Because the testers were experienced and the equipment that was used was accepted as being highly accurate, reliability of these data collection procedures was not considered to be a problem in the study.

Statistical Analysis

Statistical analysis was done on selected variables (Table 6). The Pearson Product Moment linear coefficient of correlation and ANOVA were applied in an attempt to find significant relationships and correlations between the variables. A 0.05 level of significance was used for all measures. A regression analysis was conducted to create a formula that could predict speed in a three yard blocking test. SSPS version 6.1.3 was used to calculate all statistical measures.

Statement of Each Hypotheses

1. No difference will be found in speed over three yards, starting from a three-point stance, between offensive and defensive linemen at the same playing level (varsity, junior varsity, or freshmen). Significance will be evaluated by a 2X3 (side of the ball by playing level) ANOVA.
2. Subjects at higher playing levels (where varsity is the highest level, freshmen the lowest level, and junior varsity intermediate) will be faster over a distance of three yards, starting from a three-point stance, than their lower level counterparts. Significance will be determined by a one way ANOVA and a least significant differences *post hoc* test.
3. Starters at the same playing level (varsity, junior varsity, or freshmen) will be faster than their non-starting counterparts over a distance of three yards, starting from a three-point stance. Significance will be determined by a 3X2 (playing level by starting status) ANOVA.
4. No significant correlation will be found between the 40 yard dash time, magnitude of

maximum leg press, body segment lengths, body weight, or height and time to move a distance of three yards, starting from a three-point stance. Six different Pearson Product Moment linear coefficients of correlations will be used to find these relationships.

5. A significant positive correlation will be discovered between average power coefficient over a three yard distance from a three-point stance and body weight. A Pearson Product Moment linear coefficient of correlation will be used to determine this relationship.
6. Playing level, body weight, and power coefficient will be better predictors of speed over three yards, starting from a three-point stance, than any other measurement taken. The results of this hypothesis will be calculated using a step-wise regression procedure.

Table 6

List of variables used in statistical analyses

Collected Variables	Calculated Variables
football experience level	average three yard blocking time
position played (side of ball)	average power coefficient, three yard blocking time
40 yard dash, trial one times	leg press, one repetition maximum
40 yard dash, trial two times	average 40 yard dash time
three yard blocking, trial one times	leg length
three yard blocking, trial two times	
three yard blocking, trial three times	
squat weight	
number of squat repetitions	
standing height	
body weight	
arm length	
sitting height	

Chapter 3

RESULTS

Introduction

The objective of this study was to examine the relationship between various physical parameters (sprint speed, leg strength, sitting height, body weight, standing height, and arm length) in offensive and defensive linemen and their playing ability. Playing ability of linemen was measured by using the power coefficient computed from body weight and time to move three yards from a three-point stance to a blocking dummy. This measure of playing ability was reported as being valid by Mellem (1942) and Arthur (1997). This objective was accomplished by analyzing the data collected to test six hypotheses. The analysis of each hypothesis will be discussed in this chapter. All data collected are reported in Appendix I.

Analysis of Each Hypotheses

Hypothesis 1. No difference will be found in speed over three yards, starting from a three-point stance, between offensive and defensive linemen at the same playing level (varsity, junior varsity, or freshmen). Significance was evaluated by a 2X3 (side of the ball by playing level) ANOVA. This hypothesis was supported. No main effect for

playing level $\underline{F}(2,37) = 1.410$, $p > .05$. or side of the ball $\underline{F}(1,37) = 0.016$, $p > .05$. was found. There also was not a statistically significant interaction $\underline{F}(2,37) = 0.007$, $p > .05$. between the two variables. The number of subjects used to test this hypothesis was 43. Two-way starters ($n = 9$) were dropped from this ANOVA. Table 7 shows the descriptive statistics for this ANOVA. The measures of speed are reported as time, in seconds, to move three yards.

Table 7

Descriptive statistics for hypothesis 1, level by side of the ball

Level	Offense	Defense	Both
Freshman	$\bar{x} = 1.2162s$ $\sigma = 0.1394s$ $n = 5$	$\bar{x} = 1.2017s$ $\sigma = 0.0s$ $n = 1$	$\bar{x} = 1.2583s$ $\sigma = 0.1296s$ $n = 2$
Junior Varsity	$\bar{x} = 1.1908s$ $\sigma = 0.0857s$ $n = 11$	$\bar{x} = 1.1894s$ $\sigma = 0.0954s$ $n = 3$	$\bar{x} = 1.0892s$ $\sigma = 0.1059s$ $n = 3$
Varsity	$\bar{x} = 1.1323s$ $\sigma = 0.0991s$ $n = 18$	$\bar{x} = 1.1311s$ $\sigma = 0.0700s$ $n = 5$	$\bar{x} = 1.1183s$ $\sigma = 0.1325s$ $n = 4$

Hypothesis 2. Subjects of higher playing levels (where varsity is the highest level, freshmen the lowest level, and junior varsity intermediate) will be faster over a distance of three yards, starting from a three-point stance, than their lower level counterparts. Results of a one-way ANOVA were significant, $\underline{F}(2,49) = 3.11$, $p = .05$. The least significant differences *post hoc* test found that this difference occurs between level one (freshmen) and level three (varsity); the varsity players were faster as shown below in Table 8.

Table 8

Hypothesis 2, mean time values, by level of play, to move three yards

Level	Mean (seconds)	Std. Dev.	N
Freshman	1.2249	.1181	8
Junior Varsity	1.1726	.0934	17
Varsity	1.1300	.0961	27

Hypothesis 3. Starters at the same playing level (varsity, junior varsity, or freshmen), will be faster than their non-starting counterparts over a distance of three yards, starting from a three-point stance. Significance was determined by a 3X2 (playing level by starting status) ANOVA. The results were not statistically significant. A main effect from playing level was found to occur, $F(2,46) = 3.53$. $p < .05$. However, there was no main effect associated with starting, $F(1,46) = 0.53$. $p > .05$ and there was no significant interaction, $F(2,46) = 2.87$. $p > .05$ between the two variables. The results for playing level are different than in hypothesis 1, as all 52 subject were used. Table 9 shows the descriptive statistics for this ANOVA.

Table 9

Descriptive statistics for hypothesis 3, level by starter

	Non-starter	Starter
Freshman	$\bar{x} = 1.2314s$ $\sigma = 0.1048s$ $n = 6$	$\bar{x} = 1.2055s$ $\sigma = 0.2044s$ $n = 2$
Junior Varsity	$\bar{x} = 1.2310s$ $\sigma = 0.0491s$ $n = 7$	$\bar{x} = 1.1317s$ $\sigma = 0.0969s$ $n = 10$
Varsity	$\bar{x} = 1.0914s$ $\sigma = 0.1119s$ $n = 7$	$\bar{x} = 1.1435s$ $\sigma = 0.0890s$ $n = 20$

Hypothesis 4. No significant correlations will be found between the 40 yard dash time, magnitude of maximum leg press, body segment lengths, body weight, or height and time to move a distance of three yards, starting from a three-point stance. Six Pearson Product Moment linear coefficients of correlation were calculated to determine these relationships. These correlations, as well as relationships obtained between other variables, are reported in Table 10. The correlations between all variables measured, as well as the data, are reported in Appendix I. It is clear that the correlation of the 40 yard dash speed and the speed over three yards ($r = 0.47$) does not support this hypothesis.

Table 10

Hypothesis 4, intercorrelations among variables

Variable	Speed over three yards	40 yard dash speed	Leg strength	Leg length	Arm length	Weight	Height
Speed over three yards	1.00	.47 *	.09	-.17	.10	.26	.04
40 yard dash speed		1.00	-.37 *	.05	.01	.37 *	-.10
Leg strength			1.00	.08	.14	.22	.27 *
Leg length				1.00	.57 *	.37 *	.67 *
Arm length					1.00	.32 *	.79 *
Weight						1.00	.48 *
Height							1.00

Note: * $p < .05$

Therefore, speed over a distance of 40 yards is significantly related to speed over three yards. Leg strength did not support this hypothesis. However, it had a significant correlation with 40 yard dash time ($r = -0.36$). Interpretation of the negative relationship indicates that the stronger the legs, the lower the 40 yard dash time. Weight also appears to be an important factor, but did not quite achieve a $p < .05$ level of significance with speed over three yards. However, it was significantly correlated with the 40 yard dash speed. No other variable had a significant correlation with the 40 yard dash.

Hypothesis 5. A significant positive correlation will be discovered between average power coefficient over a three yard distance from a three-point stance and body weight. A Pearson Product Moment linear coefficient of correlation was used to determine this relationship. This hypothesis was found to be supported, ($r = 0.88$, $p < .05$).

Hypothesis 6. Playing level, body weight, and power coefficient will be better predictors of speed over three yards, starting from a three-point stance, than any other measurement taken. The results of this hypothesis were calculated using a step-wise regression procedure. The first step added playing level which accounted for 11% of the variance. The second step added body weight ($\beta = 2.026$, $t(1) = 42.402$, $p < .05$) which accounted for 18% ($\beta = -2.011$, $t(1) = -41.885$, $p < .05$) of the variance, for a total of 29% of the variance. The third step adds the power coefficient which accounted for 69% of the variance, and a total of 98% of the variance. In the fourth and final step, playing level was dropped and 98% of the total variance in speed over three yards from a three-point stance was accounted and the multiple R was 0.987. This combination of variables

significantly predicted speed over three yards from a three-point stance, $F(2,49) = 944.733$, $p < .05$.

A practitioner attempting to use this formula would not have a value for the power coefficient due to the fact that the power coefficient is a product of mass and velocity. The power coefficient also appears to have had a masking effect on level because it explains so much of the variance. Therefore, the power coefficient was dropped from this regression. After rerunning the step-wise regression procedure with only two variables, it was found that there were two significant predictor variables for speed over three yards from a three-point stance: playing level ($\beta = -.502$, $t(1) = 3.87$, $p < .05$) accounted for 11% of the variance and weight ($\beta = .45$, $t(1) = 3.47$, $p < .05$) accounted for an additional 18% of the variance. This combination of variables significantly predicted speed over three yards from a three-point stance, $F(2,49) = 9.87$, $p < .05$. The multiple R was .536 and accounts for 29% of the total variance in speed over three yards from a three-point stance.

Chapter 4

DISCUSSION AND CONCLUSIONS

This chapter contains a discussion of the analyses of the data and conclusions drawn from the results of the experiments. It also contains a summary of the results and recommendations for future studies.

Predictors of Speed from a Football Stance

The exploration of data on speed from a three-point football stance via correlational relationships resulted in the discovery that certain anthropometric and performance characteristics were highly associated. Noting that an inverse relationship exists between time and velocity to move a certain distance, four variables had a significant ($p < .05$) negative correlation with the criterion measure (time over three-yards from a three-point stance): power coefficient ($r = -.22$), subjects' grade level in school ($r = -.37$), number of years subjects played football in high school ($r = -.34$), and playing level ($r = -.34$). There was a significant and direct correlation ($r = .47$) between 40-yard dash time and the criterion measure. A correlation similar to what Mellem (1942) found ($r > .70$), when he correlated time over a distance of 18 inches from a football stance with time to run a 35-yard dash was expected. However, the correlation in the current study is lower and, if anything, the longer distance of three-yards should lead to an increased correlation. Weight had a low positive correlation ($r = .26$) with the criterion measure,

which means that lighter athletes tend to be faster. This seems reasonable because they have less mass to move. This value is close to the value Mellem found ($r = .30$).

Power coefficient over three-yards had a high positive correlation with weight ($r = .88$). The power coefficient was calculated by using speed over three-yards, weight, and the following formula:

$$P = F * V$$

where F = weight of the subject,
 P = power coefficient,
 D = distance over three-yards,
 T = time in hundredths of a second, and
 V = Velocity = D/T .

Therefore, holding other variables constant, the more speed one has the greater the power coefficient one has; and the more weight one has, the greater the power coefficient. It appears that slower people, while generally weighing more, still generate a greater power coefficient. Mellem did not attempt to correlate his test of speed with his measure of power coefficient, perhaps because there is a naturally high correlation between these variables. He correlated speed and power coefficient with his measure of football playing ability and concluded that the power coefficient measure was a better predictor of football playing ability. In the present study, power coefficient did correlate significantly with the following variables: age ($r = .47$), grade in school ($r = .58$), height ($r = .46$), number of years playing high school football ($r = .48$), leg length ($r = .46$), playing level ($r = .53$), and, as mentioned, weight ($r = .88$).

Arthur (1997) stated that the best predictor of football playing ability was the ten-yard dash. The exact correlation that was found was not given, but stated as being

“high”. This statement contradicts Mellem’s claim that sprint speed and football playing ability were not related. It is not known, however, whether or not Arthur used power as a measure. It should also be remembered that the formula given for power is not a true measure of power, but more like speed corrected for weight. This is due to the fact that force of weight acts downward and the speed measured is in a horizontal plane associated with a horizontal impulse. Mellem called it a “power coefficient”.

The Hypotheses

In this study, hypotheses one, two, five, and six were all statistically supported.

From testing the various hypotheses it can be concluded that:

1. No significant difference existed in speed over three-yards between offensive and defensive linemen at the same playing level (varsity, junior varsity, or freshmen) (Hypothesis 1).
2. Subjects of higher playing levels (where varsity is the highest level, freshmen the lowest level, and junior varsity intermediate) were faster over a distance of three-yards than their lower level counterparts (Hypothesis 2).
3. No significant relationship existed between the leg strength, leg length, arm length, weight, or height and speed over a distance of three-yards. A significant relationship existed between the 40-yard dash speed and the speed over three-yards (Hypothesis 4).
4. A significant positive relationship existed between average power coefficient over a three-yard distance and weight (Hypothesis 5). A significant negative relationship existed between average power coefficient over a three-yard distance and leg strength.

5. Of all factors measured, playing level and weight were the best predictors of speed over three-yards from a three-point stance (Hypothesis 6).
6. Starters at the same playing level (varsity, junior varsity, or freshmen) were not faster than their non-starting counterparts over a distance of three-yards (Hypothesis 3).

Conclusions

The purpose of this study was to examine the relationship between various physical parameters (sprint speed, leg strength, sitting height, body weight, standing height, and arm length) in offensive and defensive linemen and their playing ability. Playing ability of linemen was measured using the power coefficient computed from body weight and time to move three-yards from a three-point stance to a blocking dummy. This measure of playing ability was reported as being valid by Mellem (1942) and Arthur (1997). It is difficult to reach concrete conclusions from this study about how to measure a football lineman's ability. It is possible that the study failed to accurately measure football playing ability or that by itself, speed over three-yards from a football stance, is not a valid measure of a football linemen's playing ability. Another possibility is that the skill level or physical maturity of high school football players, which is generally not as developed as that of college football players, is too low. This could be why the same trends found by Mellem and Arthur with college athletes were not evident in the current study. Mellem's population was also not all football players, he reported them as "115 males attending the University of Oregon, a major part of the football squad out for spring practice were subjects; the other subjects were picked at random from physical education service courses." However, the only other clear conclusion is that power coefficient appears to

be a better predictor of a football linemen's playing ability than speed from a three-point stance. It is hypothesized that this occurs because both mass and velocity play a role in delivering and absorbing blows in football.

This study was needed because a majority of the physical and performance characteristics of successful linemen have never been examined as predictors of a linemen's playing ability. This study did not find any overwhelming indicators of successful versus less successful lineman. The study did match its purpose, to examine the relationship between various physical parameters (sprint speed, leg strength, sitting height, body weight, standing height, and arm length) in offensive and defensive linemen and their ability to quickly move three feet from a three-point stance to a blocking dummy. The following conclusions can be drawn from the sub-problems that were examined in this study:

1. None of the anthropometric measures correlated highly with a faster time from a three-point stance.
2. Leg strength characteristics of a lineman did not predict a faster time from a three-point stance.
3. Offensive and defensive linemen at the same playing level moved at the same average rate from a three-point stance.
4. A significant and negative relationship did not exist between speed from a three-point stance (over a distance of three-yards) and the time for a 40-yard sprint.

Recommendations for Future Studies

In order to test if high school football players have the physical maturity to show the trends this study attempted to find, it should be replicated on college football players. If the measures used in this study highly correlated with football playing ability for college linemen, then it is likely that high school players are not physically developed enough for these measures or too homogenous a group. Other methods of rating football playing ability could be explored, such as watching game film of each athlete and making subjective ratings, but differences in the ability of opponents would likely influence the ratings received by subjects. A weak opponent could make an average player look great and a great opponent could make an average player look bad. Therefore, a study which makes ratings based upon technique might be the most valid. The fifth assumption in this study, that the ideal blocking technique from a three-point stance would be the fastest towards an object three-yards away, also has potential for future study because in game situations the ability to change direction is important. If the person to be blocked moves laterally, then the blocker has to move laterally. It is doubtful that a person can be moving as fast as possible in one direction and be able to quickly change direction (move laterally). The best blocking technique would allow a blocker to make the block even if the person he was blocking moved. Therefore, studies which correlate lateral movement with straight ahead movement are meaningless in terms of football, unless they look at the ability to change directions.

Practical Implications for Coaches

The intent of this study is hopefully be able to apply something learned into the

field. Obviously, a coach would want to encourage his or her players to maximize their power. As previously discussed, weight and speed determine power. While coaches can encourage their players to eat, they have very little control over the player's weight. However, a coach can drill on speed of movement from a three-point stance over short distances and there is evidence that repetition of this skill will increase speed as the number of years playing high school football correlated moderately with power ($r = 0.48$). Coaches looking to move players up to advanced levels would likely want to look for faster linemen and may already be doing so as playing level also correlated moderately with power ($r = 0.53$).

Due to the fact that offensive and defensive linemen were found to move at the same average rate from a three-point stance, much could be generalized regarding the two positions. The same players could be used on both sides of the ball. Identical drills used for conditioning the aerobic and anaerobic energy systems could be used for players on both sides of the ball. A player's position should be determined on the specific skills of the position and the player's personal skills. Skills should not be taught based upon speed, but rather skills should be practiced to increase speed.

The most important implication for the coach's is the specificity of training which they use for their team. When observing most plays from scrimmage in a football game, most players do not travel more than five yards and most linemen do not travel more than one or two yards. Due to the fact that power does not correlate well with the 40 yard dash time ($r = 0.15$), coaches should train their athletes for short intense bursts of speed and change of direction rather than for longer distances.

Finally, the practical and theoretical implications of this study will vary from coach to coach. The number, size, and speed of players will limit or allow increased flexibility in where a coach is able to position players and how specifically the players can be training. The fastest, biggest, or strongest people are not always the best football players.

APPENDICES

APPENDIX A

APPENDIX A

RECRUITING LETTER FOR COACHES OF SUBJECTS

Head Football Coach
<School name and Address>

Dear Coach,

I am writing to ask for your assistance in finding subjects for my master's thesis. The purpose of this study is to examine the relationships between various physical parameters (sprint speed, leg strength, sitting height, body weight, standing height, and arm length) in offensive and defensive linemen and their ability to quickly move three feet from a three-point stance to a blocking dummy. The subjects I am looking for are offensive and defensive linemen who have played high school football in the fall of 1995 and will be returning for the 1996 season.

As part of this study, subjects will have their weight, standing height, sitting height, and arm length measured. Subjects will also perform two 40 yard dashes for time and a sub-maximum repetition test on the squat lift. Subjects will be questioned about their playing experience. Lastly, the subjects will be asked to perform three starts from a three-point stance where they block a tackling dummy located three yards away.

In exchange for participating in this study, the subjects can receive a copy of their results in relationship to other high school linemen who participate. The coach at each school will be provided with the results of his squad and a copy of overall results of this study.

Each subject will be asked to wear football cleats, socks, shorts, and a T-shirt and bring a pair of standard tennis shoes for performing the squat lift. We can come to your school to test the subjects or we could have your athletes go to another school in the area. If we come to your school, you are asked to provide access to a grass field (preferably a football field) and a squat rack. We would like to test in the middle of June if possible, but we are flexible to fit your schedule. Testing must be done on dry grass or else it will have to be rescheduled.

If you have any questions, please feel free to contact me at 333-3686. Thank you for your time. I hope we can work together soon.

Sincerely,
Jerome Learman
133 IM Sports Circle
Michigan State University
East Lansing, MI 48824

Enclosures:

Response Form to be filled out by you and mailed in enclosed stamped return envelope
Sample Informed Consent Form to be filled out by the subject and their parent
Sample Data Collection Sheet

Response Form

I, _____ Head Football Coach at <School name> have players that

please pick one: are able to ____
 are unable to ____ participate in this study.

I think I will have approximately ____ subjects that will participate.

I would like subjects to be tested at

please pick one: my home field ____
 another site ____

Please give approximate dates and times that would be best for your participants. Note that I will need about one hour to set up all my equipment. It will take each subject about 15 minutes to be tested.

Please tell me the best way and time to contact you.

Please return this form by June 1st

to:
Jerome Learman
133 IM Sports Circle
Michigan State University
East Lansing, MI 48824

APPENDIX B

APPENDIX B

INFORMED WRITTEN CONSENT FORM

For the participants/parents (of subject under age 18) in the study of football blocking techniques.

The purpose of this study is to examine the relationship between various physical parameters (sprint speed, leg strength, sitting height, body weight, standing height, and arm length) in offensive and defensive linemen and the relationship of these parameters to blocking velocity over three feet from a three-point stance.

Items of Consent

1. I have read the explanation of the study and understand what is involved.
2. I understand the names of the participants will not be associated with any publication and/or presentation of the data collected in this study.
3. I understand that video tapes will be taken of my (child's) performances and that these tapes may be used for demonstrations, instruction, and study.
4. I understand that participation in this study does not guarantee any beneficial results.
5. I understand that if I (my child and I) would like additional information and have questions about this study, we can contact the investigators at 432-4073.
6. I understand that I (my child and I) can receive a copy of my (my child's) personal assessment data and/or the group data after the study has been completed.
6. I have read the explanation of the study and have no history of prior injuries which could be aggravated by my participation in this study.
7. I understand that the participants are free to discontinue involvement in this study at any time without penalty.
8. I freely consent to (allow my child to) take part in a scientific study being conducted by Jerome M. Learman and Dr. Eugene W. Brown of Michigan State University.

Signature of participant

Date

Phone number of participant

Signature of parent(guardian)

Date

APPENDIX C

APPENDIX C

SUBJECT'S PERSONAL DATA SHEET

Name _____ Phone # _____

Address (Number, Street, City, Zip Code) _____

Date of Birth ____/____/____

___ Check here to have a copy of the results mail to you when the study is complete.

Number of years playing football before high school _____
in high school _____

Please circle one response: I am a high school student and Fall of 1996 will be my (1st, 2nd, 3rd, 4th) year playing high school football.

High School Playing Experience (please list every position played by year)

Position Played	Year (in school)	Level (Freshman, JV, or Varsity)	Did you start or were you a backup?

INFORMATION BELOW IS TO BE FILLED OUT BY THE RESEARCHERS

Anthropometric Data

Standing height (mm) _____ Sitting height (mm) _____

Arm length (mm) _____ Weight (kg) _____. ____

Sprinting Speed Data

40 yard dash trial one _____. ____ seconds 40 yard dash trial two _____. ____ seconds

Leg Strength Data

Weight used for leg press (lbs) _____ in (kg) _____

Number of repetitions _____ Calculated leg press maximum(kg) _____

Blocking Speed Data will be collected on video tape and entered directly into the computer.

APPENDIX D

APPENDIX D

MEASUREMENT GUIDELINES

Adopted from the Anthropometric Standardization Reference Manual (Lohman, Roche, and Martorell, 1988).

Weight: A beam scale will be used. The subject stands on the center of the scale's platform with the body weight evenly distributed over both feet. The measurer will stand facing the subject to move the beam weights without reaching around the subject. The subject will wear socks, but no shoes.

Standing Height: A standing anthropometer will be used. The subject will stand with his body weight evenly distributed over both feet and the head will be positioned horizontally. The arms will hang freely by the sides of the trunk, with the palms facing the thighs. The heels are placed together and the medial borders of the feet are at about a 60 degree angle. The subject is asked to inhale deeply and maintain his posture. Height will be measured from the highest point on the head with sufficient pressure to compress the hair. The subject will wear socks, but no shoes.

Sitting Height: A standing anthropometer and a table will be used. The subject will sit on the table with his legs hanging unsupported and his knees at right angles. The head will be positioned horizontally. The subject will sit as erect as possible. The hands rest on the thighs with the palms facing downward. The subject is asked to inhale deeply and maintain his posture. Height will be measured from the highest point on the head with sufficient pressure to compress the hair.

Arm Length: An anthropometer will be used. The subject will stand with his body weight evenly distributed over both feet and the head will be positioned horizontally. The right arm will be measured at about a 70 degree angle to the ground. The left arm will hang freely by the side of the trunk. Both palms will be facing the thighs. The heels are placed together and the medial borders of the feet are about at a 60 degree angle. The subject is asked to maintain his posture. Length will be measured from the acromial process to the end of the third digit.

APPENDIX E

APPENDIX E

SPRINTING WARM UP SESSION

To be completed by all subjects before they complete the 40 yard dashes.

Activity: Jog 200 yards

Purpose: Increase blood flow in the body

Activity: Side quadriceps stretch for a 20 count

Purpose: Stretch quadriceps and iliopsoas

Activity: Sitting toe touch for a 20 count

Purpose: Stretch hamstring, spinal erectors, and gastrocnemius

Activity: Butterfly stretch for a 20 count

Purpose: Stretch adductors and sartorius

APPENDIX F

APPENDIX F

INSTRUCTIONS FOR THE BACK SQUAT LIFT

Adopted from the Pennsylvania State University Football Strength Training Manual (Thomas, 1994).

In order for your repetitions to count you must lower and raise the weight through the muscles' full range of motion.

Allow the muscles to raise the weight trying not to make arching, bouncing, throwing, and jerking movements while raising the weight.

Lower the weight in a controlled manner, thereby allowing the muscles to lower the weight. The muscles that are used to raise the weight are the same muscles used to lower the weight. Use 3-4 seconds as a guideline to lower the weight.

You are trying to reach the point of momentary muscular fatigue, which is when the athlete can no longer properly raise the weight for another good repetition. The set must be performed with an all-out effort to momentary muscular fatigue.

The responsibilities of the spotter include:

- Prevent injury - Do not permit arching, bouncing, or jerking of the weights.
- Record all pertinent data on the personal data sheet.
- Record only the good reps lifted.

APPENDIX G

APPENDIX G

NATIONAL STRENGTH AND CONDITIONING ASSOCIATION'S GUIDELINES FOR THE BACK SQUAT

Beginning Position: Lifter

Grasp bar with a closed, pronated grip.

Grip should be slightly wider than shoulder width

Step under the bar and position feet parallel to each other

Move hips under bar.

Position the bar in balanced position on the shoulders in one of two positions:

1. Low bar position across posterior deltoids at the middle of the trapezius
2. High bar position above posterior deltoids at the base of the neck

Lift and hold chest up and out.

Pull shoulder blades toward each other.

Tilt head slightly up.

Lift elbows up to create a "shelf" for the bar.

Straighten both legs to lift bar out of racks.

Take one or two steps backward.

Position feet shoulder-width apart or wider, and even with each other.

Point toes slightly outward.

Beginning Position: Spotters

Two spotters stand at opposite ends of the bar, feet positioned slightly wider than hip-width.

Cup hands with palms facing upward.

Palms begin and are maintained in a position 5 to 8 cm below the ends of the bar.

Spotters move sideways in unison with the lifter as lifter moves backward.

Once in position, feet are slightly wider than hip-width, knees slightly flexed, back flat.

Downward Movement Phase: Lifter

Focus eyes on wall 30 to 60 cm above eye level.

Slowly and under control, lower bar by flexing at the hips and knees.

Maintain erect body position.

Keep weight over the middle of the foot and heels, not the toes.

Keep heels on the floor.

Keep knees aligned over the feet.

Slowly lower hips until tops of thighs are parallel to floor.

Do not bounce at the bottom of movement.

Downward Movement Phase: Spotters

Spotters squat down in unison with the lifter.

Cup hands 5 to 8 cm below the bar and follow the bar downward.

Maintain body position.

Upward Movement Phase: Lifter

Keep eyes focused on wall 30 to 60 cm above eye level

Slowly raise bar by straightening the hips and knees.

Maintain body position.

Keep knees aligned over the feet.

Do not let knees move in or out.

Do not accelerate the bar at the top of movement.

At the completion of the set, slowly step forward into the rack.

Position hips beneath the bar.

Squat down until the bar is resting in the rack.

Upward Movement Phase: Spotters

Stand up with the lifter.

Keep hands 5 to 8 cm below and close to the bar.

Assist only if necessary.

Walk the lifter back into the rack.

Spotters simultaneously grab onto the bar, keeping it level, and assist lifter with placing the bar in the rack.

Breathing

Inhale during the downward movement phase.

Exhale through the sticking point of the upward movement phase.

APPENDIX H

APPENDIX H

EXAMPLE BLOCKING TEST INSTRUCTIONS

**“Here is a video that shows an example of the technique that you are about to use.”
The subject watch the video.**

**“Do you have any questions?”
Answer any questions the subjects have.**

**“You are to start in a three-point stance behind this line (point out starting line).”
“You may start whenever you are ready once we turn the cameras on.”
“You are to block that dummy (point to the dummy three yards away) as quickly as possible”
“Do one practice trial and then we will do three trials for the study.”
“Remember the object is to block that dummy as quickly as possible.”**

APPENDIX I

APPENDIX I **INTER-VARIABLE CORRELATIONS, KEY FOR SUBJECT DATA, AND SUBJECT DATA**

	Power	Block Time	Age	Arm Length	Before HS	Dash	Grade	Height	High School	Leg Ln	Leg Str	Level	Side of Ball	Starter	Weight
Power	1.00														
Block		-.22	.47	.26	-.44	.15	.58	.46	.48	.46	.20	.53	.01	.14	.88
Time		1.00			.12	.47	-.37	.04	-.34	-.17	.09	-.34	-.07	-.18	.26
Age			1.00	.19	-.18	-.17	.81	.31	.76	.22	.44	.63	-.06	.27	.36
Arm				1.00	.13	-.01	.26	.79	.17	.57	.14	.32	.15	.12	.32
Length															
Before					1.00	-.20	-.31	.62	-.28	-.02	.17	-.19	.17	.03	-.37
HS															
Dash						1.00	-.10	-.10	-.21	.05	-.36	-.13	-.18	-.20	.37
Grade							1.00	.38	.91	.37	.36	.83	.04	.28	.39
Fall															
Height								1.00	.30	.67	.27	.41	.11	.13	.48
High									1.00	.26	.40	.74	.07	.38	.31
School															
Leg										1.00	.08	.43	.04	.09	.37
Length															
Leg Str										1.00	.33	.01	.24	.23	
Level											1.00		-.03	.34	.37
Side of													1.00	.08	-.02
Ball															
Starter														1.00	.07
Weight															1.00

Subject Number	Randomly assigned subject number
Age	Age in years, to the nearest one hundredth of a year
BHS	Years playing football before high school
HS	Years playing football in high school
Side of Ball	Offense = O, Defense = D, B = Both
Starter	If the subject started the year before
Grade in Fall	Grade subject was entering in Fall 1996
Height	Height to nearest millimeter
Leg Ln	Leg length to nearest millimeter
Arm Ln	Arm length to nearest millimeter
Weight	Weight in pounds
Dash	40 yard dash time
Leg Strength	Calculated back squat 1RM in pounds
Yard	Speed over three yards from a three-point stance
Power	Calculated power coefficient

Subject Number	Age	BHS	HS	Side of Ball	Starter	Grade in Fall	Height	Leg Ln	Arm Ln	Weight	Dash	Leg Strength	Yard	Power
1	17.03	1	4	O	Yes	12	181.4	97.5	78.4	217	5.72	341.12	1.02	863.33
2	17.32	0	1	O	No	12	193.1	101.3	85.5	260	8.20	227.74	1.26	837.64
3	15.99	2	1	O	Yes	10	176.8	98.3	79.2	188	5.71	175.10	1.08	705.38
4	14.27	1	0	O	Yes	9	173.8	91.3	77.8	226.8	7.19	209.42	1.30	709.13
5	16.79	1	2	O	Yes	11	186.7	102.1	82.4	254	6.10	327.12	1.17	884.94
6	17.20	1	3	B	Yes	12	189.6	99	85.2	211	5.68	399.00	1.11	773.82
7	16.49	1	1	O	No	10	165.3	82.6	70.8	192	6.59	232.43	1.27	615.31
8	17.15	6	2	B	Yes	11	191.6	99.1	83.9	209.5	5.71	289.29	1.08	790.92
9	17.39	1	3	B	Yes	12	184.6	98.2	81.7	221.25	5.69	365.75	0.99	911.47
10	14.61	0	0	O	No	9	177.8	87.35	81.5	177.25	6.19	186.88	1.20	601.22
11	17.80	4	3	O	Yes	12	180.3	86.5	79.7	184	5.42	280.98	1.12	666.78
12	15.08	0	1	O	Yes	10	186.9	84.2	79.7	190	5.46	221.58	1.18	655.41
13	15.43	4	1	O	No	10	170	82.65	74.85	182	7.65	139.65	1.26	587.12
14	15.17	2	1	O	Yes	10	163.3	80.95	73.9	151.5	6.78	152.95	1.06	579.12
15	14.87	4	0	B	No	9	173.4	81.2	76	160	6.01	211.27	1.17	557.44
16	15.68	3	1	B	Yes	10	178.9	89.15	82.5	148	6.02	168.13	1.05	575.67
17	16.79	0	2	D	Yes	11	182.3	88.1	77.2	184	5.41	197.37	1.14	654.91
18	17.31	3	1	O	Yes	10	177.4	85.1	80.7	201.5	5.78	166.19	1.15	712.21
19	16.56	0	2	O	Yes	11	181.9	84.55	81.5	204.5	5.45	239.95	1.12	744.39
20	14.93	5	1	D	No	10	182.5	88.2	82.75	145.5	5.72	160.54	1.03	572.34
21	15.67	4	1	O	No	10	176.5	86.1	76.8	188.5	5.74	439.74	1.28	599.37
22	16.59	5	1	O	Yes	10	178.3	87.8	79.1	136	5.55	435.01	1.23	450.04
23	15.81	5	1	O	Yes	10	180.2	86.2	78.2	146.8	5.44	321.43	1.13	526.5
24	16.88	5	2	O	Yes	11	194.5	95.7	83.4	245	5.44	512.51	1.23	807.45
25	15.76	5	1	D	Yes	10	182.9	84.3	79.9	234	5.57	502.11	1.19	799.28
26	15.43	5	0	O	No	9	188.2	92.1	82.6	169	5.68	236.84	1.32	521.72
27	17.14	3	2	D	Yes	11	180.9	83.3	77.9	185	5.17	439.74	1.08	696.27

Subject Number	Age	BHS	HS	Side of Ball	Starter	Grade in Fall	Height	Leg Ln	Arm Ln	Weight	Dash	Leg Strength	Yard	Power
28	16.53	5	1	O	Yes	10	188	90.31	84.2	246	6.12	408.56	1.34	747.13
29	16.82	2	2	O	Yes	11	171.2	85.5	76.4	146.8	5.34	410.63	1.12	531.18
30	16.53	0	2	B	Yes	11	180	87.2	79.2	191	5.50	477.45	1.30	596.54
31	16.71	6	1	O	No	10	183.5	92.7	79	151.5	5.22	286.47	1.13	543.35
32	16.21	5	1	B	Yes	10	170.4	87.1	70.2	153	4.91	308.75	1.01	614.22
33	16.34	5	1	D	Yes	10	183.6	91.41	80.1	220.2	7.06	206.28	1.26	713.18
34	14.63	3	0	D	No	9	170.6	90.2	77.4	131.5	5.50	170.64	1.20	444.81
35	14.77	1	0	O	Yes	9	174.5	87	74.4	155.5	5.55	179.55	1.06	595.72
36	15.76	1	0	O	No	9	173.1	80.91	74.4	203	6.93	258.26	1.40	591.49
37	14.80	5	0	B	Yes	9	183.3	87.8	79.1	242	5.77	272.65	1.35	728.63
38	16.15	0	2	O	Yes	11	191.3	97.7	82.5	269	6.37	299.25	1.17	933.2
39	15.80	0	1	O	no	10	179.4	91.2	77	223	6.37	221.63	1.23	734.94
40	16.12	0	2	O	no	11	173.2	87.7	70.4	201	6.03	306.68	1.01	810.25
41	17.54	0	3	D	yes	12	178.5	87.6	80.4	278	6.44	343.80	1.20	941.65
42	16.21	2	2	O	yes	11	181.8	93	74.5	183	5.56	306.68	1.01	734.05
43	18.22	0	2	O	yes	11	180.8	89.5	76	208	5.62	254.70	1.11	761.67
44	16.28	2	0	O	no	11	175.7	89.8	77.4	231.5	5.77	239.85	1.03	910.62
45	17.73	0	3	O	yes	12	182.8	87.4	79.3	208	5.48	293.15	1.10	770.93
46	16.63	0	2	O	no	11	181.5	88.5	81.4	183	5.26	254.70	0.98	759.02
47	15.80	0	1	D	no	10	186.3	91.9	79.3	225	6.15	184.01	1.23	741.53
48	15.85	0	1	O	yes	10	186	89.7	77.2	247	6.45	233.84	1.12	899.09
49	16.90	0	0	O	no	9	174.3	84.4	76.5	222	5.60	380.93	1.11	812.94
50	17.39	0	3	D	no	12	188.1	92.7	79.6	240	5.51	258.26	1.09	894.98
51	15.49	0	1	B	no	10	174.2	85.2	77.2	219	6.17	148.37	1.21	735.68
52	18.44	0	4	O	yes	12	176.2	81.8	76.3	247	6.31	388.35	1.26	798.92
Mean	16.29	2.08	1.4	-	-	10.44	180.14	89.25	78.70	200.7	5.92	282.18	1.16	706.63
Std Dev	0.98	2.10	1.0	-	-	0.98	6.86	5.42	3.53	37.0	0.64	98.62	0.10	128.71

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