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The relationship between lean body weight and muscular strength in college football players

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THE RELATIONSHIP BETWEEN LEAN BODY WEIGHT
AND MUSCULAR STRENGTH IN COLLEGE
FOOTBALL PLAYERS

by
Jeffrey Mark Kaplan

An Abstract
of a thesis submitted in partial fulfillment
of the requirements for the degree of
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ABSTRACT

The purpose of the investigation was to examine the relationship between lean body weight (LBW) and muscular strength in collegiate football players. Subjects were 212 males between the ages of 18 and 25 years from Ithaca College and Cornell University. Each subject had LBW determined using a Skyndex electronic body fat calculator programmed with the Jackson-Pollock equation, performed a bench press of between 1 and 10 repetitions, and performed a parallel squat of between 1 and 10 repetitions. For both the bench press and squat, the number of repetitions was then used to calculate an estimated 1-repetition maximum (1-RM) for that lift. Pearson product-moment correlations were applied to LBW with bench press and to LBW with squat for the total subject population and also by playing position. Fisher *z* tests were performed on each combination of two positions to determine if there were differences among positions on the Pearson correlations between LBW and bench press and between LBW and squat. Results were statistically significant at the .01 level for the LBW-with-bench-press correlation (r = .570) and LBW-with-squat correlation (r = .460). All playing position subgroups had statistically significant LBW-with-bench-press correlations except the offensive linemen (r = .272) and the defensive backs (r = .299). The LBW-with-squat correlations were statistically significant for all playing positions except the offensive linemen (r = .075), defensive linemen (r = .065), and defensive backs (r = .412). The results showed there was a statistically

significant and positive relationship between LBW and muscular strength in college football players.

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A Thesis Presented to the Faculty of
the Division of Health, Physical
Education, and Recreation at
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Requirements for the Degree
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Jeffrey Mark Kaplan

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Ithaca College
Division of Health, Physical Eduction, and Recreation
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CERTIFICATE OF APPROVAL

MASTER OF SCIENCE THESIS

This is to certify that the Master of Science Thesis of

Jeffrey Mark Kaplan

submitted in partial fulfillment of the requirements for the degree of Master of Science in the Division of Health, Physical Education, and Recreation at Ithaca College has been approved.

Thesis Advisor:

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DEDICATION

I wish to dedicate this thesis to my parents, Saul and Ida Kaplan. Thank you for all your love and support. Whenever I needed it you were always there.

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INTRODUCTION

Football is a game that demands a mixture of size, speed, skill, and strength in its athletes. Players and coaches often attempt to manipulate size and strength at all levels of competition in hopes of maximizing performance. With this in mind, college coaches often recruit high school players who they project will get both heavier and stronger during their collegiate careers. Although maturation plays a role in this size and strength increase, the major reasons for growth are altered strength training and dietary regimes (Nelson & Tew, 1983).

Due to the nature of the game, players are usually chosen to play a position based on their absolute body weight, and they are asked to adjust that weight in order to achieve maximum performance at that position. This problem of maximizing performance by adjusting body weight has been given much thought by players, coaches, trainers, and parents alike, and until recently their approach has been mainly intuitive (Brown, Gorman, Slusarek, Moore, & Daniel, 1985). Several studies (Katch in "Body composition--Part 1", 1987; Leedy, Ismail, Kessler, & Christian, 1965; Nutter & Thorland, 1987) have demonstrated that strength is related to lean body weight (LBW) in both trained and untrained individuals. Because of this, it is reasonable and advisable to consider body fat pecentage and LBW in determining an optimum playing weight.

The advantage of increased LBW and strength for a football player is that he would then have a greater ability to accelerate both his body mass (as in a 40-yd sprint, the standard speed measurement in football) and an external object, such as his opponent's body in blocking and tackling. The implication of this is that when a 100-kg load uses 50% of the athlete's strength, the athlete is better able to accelerate this load as opposed to an athlete for whom the load represents 90% of his maximum strength (Sale & Norman, 1982). It would be beneficial to determine if increased LBW will result in increased levels of muscular strength in collegiate football players. Therefore, the purpose of this investigation was to examine the relationship between LBW and muscular strength in collegiate football players.

Scope of the Problem

Ithaca College and Cornell University football players (n = 212) served as subjects in the investigation of the relationship between LBW and muscular strength. The subjects ranged in age from 18-25 years. The procedures in this investigation included assessment of body fat percentage using the Skyndex electronic body fat calculator, calculation of each athlete's LBW, and measurement of upper and lower body strength by a free-weight bench press and squat, respectively. Subsequently, a correlational analysis between LBW and strength was performed.

Problem Statement

The purpose of this study was to examine the relationship between LBW and muscular strength in college football players. A second purpose was to examine the differences in the LBW-with-strength correlations among different positions on a football team.

Hypothesis

There is no correlation between LBW and muscular strength in college football players. The subhypothesis is there are no differences in the LBW-with-strength correlations among the different positions on a football team.

Assumptions

In order to conduct this study, the following assumptions were made:

1. All athletes have equal experience with weight training involving free weights, therefore experience did not affect results.

2. During the investigation all athletes were equally motivated to lift until muscular fatigue occurred, therefore motivation did not affect results.

3. LBW to a large extent represents contractile protein in muscle and is a determining factor in strength.

Delimitations

The following delimitations were set for this study:

1. Members (n = 212) of the 1988 football teams participating in the off-season conditioning programs at

Ithaca College and Cornell University were tested.

2. Strength levels were measured by an estimated 1-repetition maximum (1-RM) free-weight bench press and parallel squat.

3. Only isotonic strength was measured in this study.

4. Only chest, abdomen, and mid-thigh skinfolds using the Cramer Skyndex electronic body fat calculator programmed with the Jackson-Pollock (Jackson & Pollock, 1978) formula for the calculation of body composition were used.

Limitations

The following limitations were evident in this study:

1. Results should be generalized only to athletes similar to those on the Cornell University and Ithaca College teams who were participating in off-season conditioning in the spring of 1988.

2. Results only apply when isotonic strength is measured by an estimated 1-RM free-weight bench press and parallel squat.

3. Results only apply when chest, abdomen, and mid-thigh skinfolds are used with the Cramer Skyndex electronic body fat calculator programmed with the Jackson-Pollock formula to calculate body composition.

Definition of Terms

The following terms have been defined to clarify the exact connotation used in this thesis:

1. Muscular Strength. The greatest amount of tension

generated by a muscle or muscle group during a maximal contraction.

2. Muscular Fatigue. The point at which no further unassisted repetitions of an isotonic lift can be performed.

3. Skinfold. A double fold of subcutaneous fat measured with calipers. The sites used in this study were chest, abdomen, and mid-thigh.

4. Body Fat Percentage. The ratio of fat weight to total body weight. It is calculated by using the following equations:

% fat = [495-(450/body density)] x 100, and Body Density = 1.10938 - 0.008267(Sum 3) + 0.0000016(Sum 3)^2 - 0.0002574(age), where Sum 3 = sum of chest, abdomen, and mid-thigh skinfolds.

5. Fat Weight (FW). The portion of the body weight that is fat. It is calculated by the equation

FW (lb) = Body weight x % fat/100

6. Lean Body Weight (LBW). The muscular component of body weight. It is calculated by the equation

LBW (lb) = Body weight - FW

7. Upper Body Strength. An estimated 1-RM free-weight bench press.

8. Lower Body Strength. An estimated 1-RM free-weight parallel squat.

9. 1-Repetition Maximum (1-RM). The peak force or torque developed by the muscle during a maximal voluntary contraction. It is usually measured for individual muscle groups.

Chapter 2

REVIEW OF LITERATURE

The purpose of this investigation was to examine the relationship between lean body weight and muscular strength in college football players. For the purpose of related literature review, this topic has been broken down into three areas: (a) body composition, (b) muscular strength, and (c) the relationship between LBW and muscular strength.

Body Composition

In 1942, Welham and Behnke found that a fundamental relationship existed between adiposity and body density. In their study, they found that leaner males of the same body weight always had a higher body density than their fatter counterparts. Based on this finding, they suggested that the amount of fat was subject to wide variation and appeared to be the main factor affecting density values in a person's body.

For the purpose of body composition studies, the body can be divided into two distinct components. These are body fat, which includes the entire content of chemical fats or lipids in the body, and LBW, which includes muscle, bone, connective tissue, and water (Doxey in "Body composition--Part 1", 1987). Body fat is an anhydrous compound that contains no potassium and has a fairly constant density of 0.90 x 10^3 kg/m^3. LBW has a fairly constant density 1.10 x 10^3 kg/m^3, a potassium content of 68 Mequiv/kg in males, and a water content of 720 g/kg (Durnin &

Womersley, 1974).

Regression equations, such as the Siri formula (Johnson & Housh in "Body composition--Part 1", 1987), have been developed to use these relatively constant densities in order to calculate body fat percentage. Since these equations were first developed, it has been found that variations in tissue density do exist, and variations in water and mineral content of the LBW portion of the body can lead to errors of $\pm$ 2.5% fat by the regression equation method. Athough error does exist, body density measurements provides a reasonably accurate and accepted estimate of body composition in the young adult population. In children and the elderly these errors increase, and the Siri formula and other body density equations overestimate body fatness. This has led to the development of multi-component systems that do not assume the LBW is of uniform composition, but instead measure its constituents, such as water and bone mineral content (Lohman in "Body composition--Part 1", 1987).

Measurement Techniques

The direct method for body fat determinations involves cadaver analysis; indirect fat analysis methods include bioelectrical impedance, ultrasonography, hydrostatic weighing, and anthropometry. Bioelectrical impedance is the passing of a low-energy, high-frequency electrical signal through the body to determine body composition. It works on the principle that living organisms contain intra- and extracellular fluids that behave as an electrical conductor.

For any given body size, the leaner the subject, the lower the resistance to the electrical current, because the predominant compartment is body water with its conducting electrolytes. Subjects with a greater fat content show more resistance because fat is a poorer conductor of the electrical current. Drawbacks to bioelectrical impedance are (a) the instrument must be well designed; (b) the investigator or technician must receive training on exactly how to place the electrical conductors on the subject; and (c) the subject must not exercise or consume alcohol in the preceding 24 hours, be dehydrated, or eat a large meal within the preceding 2 hours (Lohman in "Body composition--Part 1", 1987; Lukaski, Bolonchuk, Hall, & Sider, 1986).

Ultrasonography acts as an ultrasonic wave generator and echo receiver through the principle that ultrasonic energy produced from an electrically stimulated piezoelectric crystal produces a mechanical wave propagation through biological tissues at a rather constant speed of 1540 m/s. Resistance or impedance to wave propagation is determined by varying tissue density and elasticity. Prediction of body fat percentage is accomplished by using equations to predict body density based on the echo picture received. The reliability of ultrasonography for body density prediction is very good, with a test-retest correlation of $r > .98$. Advantages of this technique are its portability for field use, ability to be used on a great number of sites, and ability to measure severely obese people. Disadvantages include that it is expensive to use, valid generalized regression equations have not been developed, and the technique may display a skin surface-transducer artifact that makes precise measurements of the subcutaneous fat layer difficult (Doxey in "Body composition--Part 1", 1987; Wolz & Ostrove, 1984).

The indirect method available for predicting body density that is considered the standard to which all other methods are compared is hydrostatic weighing (Behnke & Wilmore, 1974; White, 1983; White, Mayhew, & Piper, 1980). The basis for this technique is Archimedes' principle that a body immersed in a fluid is acted on by a buoyancy force. Because fat is less dense than water, it will displace a lesser amount of water than will LBW, which has a greater density than water. Therefore, a person with a larger amount of fatty tissue weighs less underwater than a person of equal body weight who has a greater lean weight component.

Although it serves as the standard, hydrostatic weighing also has some major drawbacks. These drawbacks include the dependency upon tissue density estimates, the time needed for each analysis, the need for expensive and sophisticated equipment, the need for trained and skilled operators, and the subsequent restriction to a laboratory setting (Mattingley, 1980). As a result of these drawbacks, it is an impractical means for field testing large groups (e.g., a football team), hence the need for the development of more practical anthropometric measures and related body composition prediction equations (Johnson & Housh in "Body composition--Part 1", 1987; White, 1983).

Brozek and Keys (1951) first introduced the use of skinfold calipers to determine body composition. Skinfold calipers measure the thickness of a fold of skin, including the underlying fat tissue. This procedure is possible because 50% to 75% of the body's total fat is subcutaneous, and these subcutaneous fat stores correlate closely with total body fat. This has allowed the estimation of the fat and nonfat components of the human body (Katch & McArdle, 1973; Miller, 1984). Because of their simplicity of use and small size, they have allowed determination of body composition estimations to move from the laboratory to the field setting. Brozek and Keys developed prediction equations that used anthropometric variables to predict body density. Calculated body density was then entered into an equation developed by Rathbun and Pace (1945) to determine both percentage and absolute body fat amounts.

Since that time, many different researchers have developed prediction equations to estimate body density and body fat. The primary reason for this is that these equations are population specific (Durnin & Rahaman, 1967; Jackson & Pollock, 1978; Katch & McArdle, 1973; Mattingley, 1980; White, 1983). Research has shown that there appears to be little difference as to whether skinfolds, diameters and circumferences, or some combination of these is used to determine body density and body fat (Mattingley, 1980). Wolf

(1983) has recommended that the Jackson-Pollock equation (Jackson & Pollock, 1978) be used with athletic, college-aged populations.

Body Composition and the Athlete

It is important to be able to easily monitor athletes for body fat levels, because excess body fat limits athletic performance in virtually every event that requires movement of the body. This includes activities such as running and jumping (Leedy et al., 1965; Riendeau et al., 1958; Wilmore & Haskell, 1972). Wickkiser and Kelly (1975) reported a significant ($p < .05$) correlation between body fat percentage and 40-yd dash performance. Their study found that as body fat percentages increased, performance in the 40-yd dash decreased (resulting in increased times). Crews and Meadors (1978) also reported a similar significant ($p < .05$) correlation between 40-yd dash times and body fat percentages in college football players. In addition, they found that the farther a player ran, the greater the effect body fat had on performance.

Upon investigation of the athletes comprising football teams at the college (Scriber, 1986; Smith & Mansfield, 1984; White et al., 1980) and professional levels (Gettman, Storer, & Ward, 1987; Wilmore & Haskell, 1972; Wilmore et al., 1976), consistent body composition trends related to position are found. These trends are that backs (offensive and defensive) are the leanest, followed by linebackers, and those athletes with the highest body fat are linemen (offensive and defensive) (see Table 1).

An important factor to remember when dealing with football players is that although their body weight may be greater than the general population's (up to 25% greater), they are not necessarily fatter. This results from the athletes having a greater LBW (up to 60 lb) and a decreased body fat (6%) (Gettman et al., 1987; Smith & Byrd, 1976). Because of this, most football players (collegiate or professional) will be overweight according to insurance company height-weight charts, yet be underfat when compared to the average male (Lamb, 1984).

Because football players are larger and contain less relative body fat than the average male, one might get the impression that they do not need constant body fat monitoring. This is not the case, for as Wickkiser and Kelly (1975) reported, football players perceived their "ideal weight" as 9.1 lb heavier than the investigator's predicted optimum weight. To add to the situation, the athletes' coaches overestimated optimum weight by 6.2 lb. As a result of these findings, Wickkiser and Kelly agreed with an earlier study by Wilmore and Haskell (1972), that both coaches and athletes place too much emphasis on total body weight, especially in linemen, and too little emphasis on LBW.

Muscular Strength

Strength-building exercises were used sparingly for athletic training and conditioning prior to World War II. At the time it was believed that such exercised resulted in

Table 1

Body Fat Percentage in College and Professional Football Players

	COLLEGE		
	NCAA Div. I Smith & Mansfield (1984)	NCAA Div. II White et al. (1980)	NCAA Div. III Scriber (1986)
Defensive Backs	7.7	7.3	6.99
Offensive Backs and Receivers	7.8	11.5[a]	8.72[a]
Quarterbacks and Kickers	10.9	------	------
Linebackers	11.5	11.6	10.99
Defensive Linemen	13.9	13.2	13.63
Offensive Linemen	19.4	14.8	13.64
	PROFESSIONAL		
	Wilmore & Haskell (1972)	Wilmore et al. (1976)	Gettman et al. (1987)
Defensive Backs	7.7	9.6	6.7
Offensive Backs and Receivers	8.3[a]	9.4	10.4[a]
Quarterbacks and Kickers	------	14.4	------
Linebackers	18.5	14.0	11.6
Defensive Linemen	18.7	18.2	13.3
Offensive Linemen	15.5	15.6	15.7

[a] Offensive backs, receivers, quarterbacks, and kickers are grouped together.

"muscle-boundness" in the participant, and therefore were a detriment to improving athletic performance. It was not until 1948, when DeLorme and Watkins demonstrated success with a heavy resistance program for hospital patient rehabilitation that strength-building exercises found their way into the athletic arena. Since then, resistance training has become accepted as a means of athletic training and intrumental in improving athletic performance.

Strength Development

Muscular strength is the peak force or torque developed by the muscle during a maximal voluntary contraction, and is usually measured for individual muscle groups. This measure is commonly referred to as a 1-RM (Sale & Norman, 1982). The development of maximum muscular strength has two central concepts: (a) specific adaptations to imposed demands (SAID), and (b) the overload principle. SAID states that the training demands must be specific in order to obtain the desired effects. This is also known as specificity of training (Caldwell, 1976; Lamb, 1984; O'Shea, 1976; Sale & Norman, 1982). The overload principle states that the body must initially be subjected to loads greater than those encountered in normal daily living, and these loads must be periodically increased in order to keep pace with increased strength levels. Increasing the load forces the muscles to constantly adapt and results in continued strength gains. Although it is widely accepted that to increase strength one must use heavy loads, there is some debate as to the intensity, number of repetitions, and number of sets that should be performed with these loads.

The data are inconclusive as to what constitutes an effective training intensity (percentage of maximum voluntary contraction). Hettinger (1961) reported that strength increases when muscles train isotonically at 50% of maximum voluntary contraction (MVC), Berger (1965) found no strength gains when training below 67% of MVC, and Westcott (1982) believed that exercise should be performed at 75% of MVC. Stone and Kroll (1978) found that 80-100% of MVC should be used every workout, while Bryant (1984) believed that training should be 70-95% of MVC, because loads less than 70% are insufficient stimuli for optimum strength development and resistances greater than 95% are too difficult to sustain regularly. Current literature indicates that training intensity should be moderate (70-80% of 1-RM) to high (90% of 1-RM) for maximum strength gains (Fleck & Kraemer, 1988).

In 1962, Berger looked at the question of what the optimum number of repetitions should be when training with a single set. He examined whether a one-set routine of 4-RM, 6-RM, or 8-RM produced greater strength gains than a one-set routine of 2-RM, 10-RM, or 12-RM. He concluded that when a person trained with one set three times per week, the optimum number of repetitions is between three and nine. Since Berger's initial study, research has shown that training loads of 4-RM to 6-RM produce the greatest strength gains (Fleck & Kraemer, 1988).

Typically, people who participate in weight training perform multiple sets of exercises, not just one. Therefore, Berger (1963) conducted investigations with varying combinations of sets and repetitions. His results indicated that three sets of 6-RM were the most effective for gaining muscular strength. Later investigations by Berger (1965) and O'Shea (1966) disputed this finding, because they were not able to confirm the superiority of a three-set, 6-RM routine over a one-set, 6-RM routine. Currently there is still question as to which is better. Some leading strength coaches (Riley, 1978; Stark, Smith, & Kramer, 1979) believe that a one-set routine is more effective than multiple-set routines because only the last set is the actual stimulus for muscle growth. Other leaders in the field of strength training (Epley, 1988; Morris, 1988; Roberts, 1989) believe that multiple sets of varying repetitions and loads must be used for optimum strength to occur.

Strength Assessment

Strength assessment can be performed in a variety of ways. In the literature, strength has been measured by isometric methods, such as cable tensiometers or hand grip dynamometers (Arnold, Brown, Micheli, & Coker, 1980; Leedy et al., 1965); by isokinetic methods, such as by Cybex equipment (Evert, 1985; Nutter & Thorland, 1987); or by isotonic methods, such as Universal Gym equipment (Jackson, Patton, & Watkins, 1981; Wilmore et al., 1978), Nautilus equipment

(Evans, 1985; Hurley et al., 1984), and free weights (Robertson et al., 1975).

One of the most common field determinations of muscular strength is the isotonic 1-RM (Sale & Norman, 1982). Wilmore et al. (1976) found this to be an accurate measure of muscular strength. In this study they compared maximum bench press strength assessed by a traditional free-weight 1-RM and an isokinetic assessment of the same lift. There was a high correlation between the two lifts ($r = .94$, $p < .01$).

Strength and football coaches at both the collegiate and professional levels currently believe that because an athlete can be psychologically intimidated and physically injured performing a 1-RM strength test, it is better to test for strength by the number of repetitions performed at an assigned lifting weight. An estimated 1-RM can then be calculated from the number of repetitions performed (B. Epley, Head Strength Coach, University of Nebraska, personal communication, November 2, 1987; R. Jones, Head Strength Coach, Buffalo Bills professional football team, personal communication, October 7, 1987).

Strength and Athletic Ability

For years people believed that progressive resistance training aided in the development of strength and endurance but was a detriment to speed, agility, and coordination (Bryant, 1984). Studies by Capen (1950), Chui (1964), Masley, Hairabedian, and Donaldson (1952), Nelson and Tew (1983), Thompson and Stull (1959), and Zorbas and Karpovich

(1951) have shown that not only is this false, but, in fact, strength often enhances speed and power. Strength may also contribute to agility, because adequate strength is required to control body weight against the force of inertia and to move rapidly.

Sale and Norman (1982) stated that increased levels of strength are usually associated with a proportionally greater ability to accelerate either the body mass (as in the 40-yd dash) or an external object (such as an opponent's body in football). The implication of this is that when a 100-kg load uses 50% of an athlete's maximum strength, the athlete will be able to accelerate this load more rapidly than an athlete for whom the load represents 90% of maximum strength.

There is little doubt that a high level of muscular strength is an asset to a football player, and for many years strength training programs have been considered to be crucial both in and out of the playing season. The reason for the emphasis on strength by both coaches and athletic trainers is two-fold. First, it is used to improve performance, and second, it decreases the risk of injury (Olson, 1971; Riley, 1978; Stark et al., 1979).

There is a general pattern among college football players, with regard to absolute strength, that the heavier the athlete, the stronger he is. This is consistent with the findings of Sale and Norman (1982) regarding the general population. In studies involving NCAA Division I, II, and III college football teams (Mayhew, McCormick, Levy, & Evans, 1987; Olson & Hunter, 1985; Scriber, 1986), backs were the lightest in body weight and the weakest and linemen were the heaviest and strongest (see Table 2).

Though most football coaches have their team's strength levels tested to find out who their strongest athletes are, this assessment may have limited value in respect to judging playing ability. The strongest players may not be the most proficient on the playing field, for a player may have "football" strength, not "weight-room" strength (Riley, 1978; Wilmore et al., 1976). This was illustrated by Arnold et al. (1980), who reported that lower extremity muscular strength was not a good predictor of football playing ability. Scholarship athletes (N = 56) were tested in four lower body strength measures (hip abduction, knee flexion, knee extension, and plantar flexion), and these results were correlated with playing ability as judged by their coaches. No correlation obtained for any strength measurement with playing ability was statistically significant ($p > .05$), with the highest ($r = .175$) belonging to hip abduction strength. Thus an athlete's playing ability as judged by his coach was not specifically related to his lower extremity muscular strength.

LBW and Strength

It has been known for a long time that, on average, larger and heavier people are able to exert greater muscular force than smaller ones (Lamphiear & Montoye, 1976). The reason for this is that LBW is one of the main factors

Table 2

Strength Levels and Body Weight in College Football Players

	Bench Press	Squat	Body Weight
	NCAA Division I (Olson & Hunter [1985])		
Wide Receivers	271.1	370.5	203.5
Offensive Backs	309.6	416.0	210.2
Defensive Backs	291.5	384.3	187.6
Offensive Linemen	357.6	478.0	260.7
Defensive Linemen	351.9	457.6	249.7
Linebackers	335.3	435.7	226.5
	NCAA Division II (Mayhew et al. [1987])		
Backs[a]	253	365	188.5
Linemen[b]	279	394	223.4
	NCAA Division III (Scriber [1986])		
Offensive Backs[c]	258.5	403.9	182.9
Defensive Backs	251.3	416.9	178.0
Linemen[d]	285.0	437.9	223.9
Linebackers	293.8	436.9	211.6

Note. All values are expressed in pounds.

[a] Offensive backs, defensive backs, and wide receivers are grouped together. [b] Offensive linemen, defensive linemen, and linebackers are grouped together. [c] Offensive backs and wide receivers are grouped together. [d] Offensive linemen and defensive linemen are grouped together.

responsible for muscular strength, as it is composed of muscle, bone, connective tissue, and water (Doxey in "Body composition--Part 1", 1987), and there is a high correlation (r = .84, p < .05) between body weight and LBW (Leedy et al., 1965).

Some of the earliest research on the relationship between body weight and strength was done by Martin in 1918 and 1921 (cited in Lamphiear & Montoye, 1976). Martin investigated the relationship between weight and muscular strength in adult males and found a correlation of r = .58 (p < .05). Since that time, research has continued to show small to moderate correlations for both body weight and LBW with muscular strength. The magnitude of this correlation depends both on the muscle group being tested and on the type of contraction (isometric, isotonic, or isokinetic).

In 1966, Laubach and McConville studied the relationship between LBW and lower body strength (as measured by trunk flexion, trunk extension, hip flexion, and hip extension) in college-age males and found there were significant correlations (p < .05) for all strength indices studied (r = .51, r = .60, r = .69, r = .49, respectively). They concluded that it was possible to use LBW as a predictor for lower body strength.

Jackson et al. (1981) found significant (p < .05) correlations between body weight and maximum bench press (r = .45) and between body weight and maximum leg press (r = .62) and concluded that it is possible to predict strength via body weight in college-age males. In a study by Katch ("Body composition--Part 1", 1987), it was reported that moderate correlations existed for both body weight and LBW with strength when strength was measured by a free weight 1-RM. For body weight with bench press and body weight with squat the correlations were $\underline{r}$ = .38 and $\underline{r}$ = .55, respectively, yet for LBW with bench press and LBW with squat the correlations were $\underline{r}$ = .52 and $\underline{r}$ = .61.

The relationship between LBW and strength is the same in the athletic population as it is in others. In wrestlers, in whom body fat levels are kept to a minimum in hopes of improving performance, there is a positive relationship between LBW and strength. In one study involving high school wrestlers, it was shown that when LBW increased, strength increased proportionally (Freischlag, 1984). Another study involving wrestlers at the high school level showed that as the total amount of LBW decreased (as when a wrestler "cuts" weight to wrestle at a lower weight class in hope of gaining a strength advantage over his opponent), there is a significant decrease in strength levels (Henjna, Buterusis, Krieger, & Scherrer, 1983).

In contrast to wrestlers, who constantly look to decrease body size, football players often deliberately try to increase their body weight throughout their collegiate careers in hopes of improving athletic performance. With this in mind, coaches, trainers, and the athletes themselves must find out if increased size leads to increased strength.

Research on this subject involving NCAA Division I and II football players (Brown et al., 1985; Mayhew et al., 1987; Nelson & Tew, 1983) found there were positive correlations between amounts of LBW and strength. NCAA Division II players showed low positive correlations with LBW in the bench press, squat, and power clean (r = .32, r = .25, and r = .35, respectively, p < .05) (Mayhew et al., 1987). Another study involving NCAA Division II players (Mayhew, Piper, Schuegler, & Ball, 1989) reported a moderate correlation between a bench press and LBW (r = .60, p < .01). Positive correlations were also seen in Division I athletes. In one study (Brown et al., 1985), deltoid strength was found to have a moderate correlation with LBW (r = .54, p < .05), and in another study with LSU football players (Nelson & Tew, 1983), a low to moderate positive correlation existed between LBW and strength. The highest correlation in the latter study (r = .41, p < .05) existed when whole body LBW was correlated with isotonic leg strength (squats). Nelson and Tew concluded that greater weight accompanied by greater LBW resulted in increased strength.

Summary

For the purpose of body composition measurements, the human body can be divided into fat and lean body components. An investigator has many different techniques (e.g., bioelectrical impedance, ultrasonography, hydrostatic weighing, and anthropometry) available to measure these components. Presently the technique considered the reference standard is hydrostatic weighing, and the most common and least expensive is anthropometry. In anthropometry the measurements of various body segments are inserted into a prediction equation to determine body density. The calculated body density is then used to calculate body fat percentage. Prediction equations are population specific, and Wolf (1983) has recommended that the 1978 Jackson-Pollock equation be used for athletic, college-age males.

Coaches and trainers of football players should constantly monitor their athletes' body fat content because these athletes tend to overestimate their optimum playing weight. This overestimation results in undesirable fat levels, and it has been shown that increased fat amounts are a detriment to athletic performance.

Although there are many different methods and techniques available for muscular strength development, the one thing they all have in common is that a tension greater than encountered in normal daily living is placed onto the muscle or muscle group. This tension must be periodically increased, thus forcing the muscles to constantly adapt and increase in strength.

Heavy resistance training programs for athletics did not start until after World War II, when Delorme and Watkins (1948) introduced their strength building program. Prior to that, it was believed that such exercises resulted in muscle-boundness in the participant, and were therefore detrimental to improving athletic performance. Since 1948, strength training has become established in all athletic endeavors because it was found that stronger athletes are able to accelerate both external objects and their own bodies more effectively and with more force than weaker athletes of the same body weight.

Coaches and trainers in football have realized that muscular strength has a two-fold importance: performance improvement and resistance to injuries. It is for these reasons that strength training is emphasized at all levels of competition.

Chapter 3

RESEARCH METHODOLOGY

In this study, the relationship between LBW and strength in college football players was investigated. The specific objectives of the study were (a) determine body fat percentage and LBW, (b) measure upper and lower body strength isotonically through a free-weight bench press and squat, repectively, and (c) determine the correlation between LBW and strength in college football players.

Subjects

Subjects for this study were male athletes between the ages of 18 and 25 years, who had at least 1 year of collegiate football experience. The subjects were recruited from the varsity football programs at Ithaca College and Cornell University. Following a letter requesting the head football coach's permission, a verbal recruitment message was given to the athletes by the investigator. The number of athletes who agreed to participate in the investigation was 212. Human subject consent forms were obtained on the athletes prior to the investigation (see Appendix A).

Body Composition

Each subject arrived at his respective school's training room at a preassigned time, dressed in shorts, T-shirt, and athletic shoes. Upon arrival, the subject's body composition measurement was taken (See Appendix B). All body composition measurements were performed by the same investigator to eliminate intertester error.

Body weight was measured on a standard medical scale. The subject was dressed only in gym shorts during the weighing. Subcutaneous fat stores were measured with the Cramer Skyndex electronic body fat calculator (Cramer Products, Inc.; PO Box 1001; Gardner, KS 66030), programmed with the Jackson-Pollock (Jackson & Pollock, 1978) equation for body density prediction. The Skyndex is preferred over other calipers when testing large numbers of subjects (e.g., an entire football team) for its simplicity, speed, and visual display of results (Kephart & Huegli in "Body composition"--Part 2, 1987). The Skyndex has been found to be an accurate means of determining body fat percentage, and its measurements are highly correlated (r = .98) with measurements of more established skinfold calipers, such as Lange calipers (Zando & Robertson, 1987).

The skinfold sites used were the chest, abdomen, and mid-thigh. All sites were located on the subject's right side, and the average of three consecutive determinations of body fat percentage were recored. If any determination was not within a 1% range of another, the test was repeated (Scriber, 1986; Zando & Robertson, 1987). The skinfolds utilized were as follows (Jackson & Pollock, 1978):

Chest. The site was located over the pectoralis major muscle, 3 cm medial to the axillary fold and crease. The skinfold runs diagonally between the shoulder and opposite hip. The skinfold was taken between the investigator's left thumb and forefinger, with the measurement taken just medial to that fold.

Abdomen. The abdominal site was 3 cm to the right of the middle of the umbilicus. A horizontal fold was taken between the investigator's left thumb and forefinger, and the measurement was taken just medial to that fold.

Mid-thigh. The mid-thigh site was exactly halfway between the middle of the patella and the anterior superior iliac spine on the right leg. A vertical fold of skin on the anterior of the thigh between the investigator's left thumb and forefinger was measured. The measurement was taken just distal to the skinfold.

Strength Measures

Following the body composition measurement, each subject proceeded to the strength test area. The strength tests consisted of different lifts to assess upper body (bench press) and lower body (parallel squat) muscular strength. These were chosen because they are the most widely used in the field of football strength measures (Brown et al., 1985; Mayhew et al., 1987) and would be familiar to the subjects.

Because athletes can likely be psychologically intimidated and physically injured performing a 1-RM strength test, strength and football coaches at both the collegiate and professional levels are now testing for strength by the number of repetitions performed at an assigned lifting weight. The assigned lifting weight can be based on the athlete's body weight, and for this study it was 10 lb over body weight in the bench press and 1.5 times body weight in the parallel squat (B. Epley, personal communication, November 3, 1987; R. Jones, personal communication, October 7, 1987). Research has shown that it is possible to estimate a 1-RM when the number of repetitions performed during testing is between 1 and 10 (Berger, 1961; Landers, 1985; Mayhew, Ball, & Arnold, 1989). Upper and lower body strength values were determined through estimation of a 1-RM by multiplying the weight lifted by a conversion factor based upon the number of repetitions performed (see Appendix C) (B. Epley, personal communication, November 2, 1987; R. Jones, personal communication, October 7, 1987). The equipment used included an Olympic-style free-weight bar and plates, power benches, and power squat racks. The procedures were as follows:

Bench Press. To perform the lift, the subject positioned himself with his back flat on the bench, feet on the floor, knees bent at a 90° angle to the floor, and the bar directly over his chest. The weight was then lifted off the support bars by the spotters into the extended hands of the subject. The subject lowered the weight to his chest, paused (about 1 s), and then pushed it directly toward the ceiling until both elbows were fully extended in a locked position and the weight was controlled. This procedure was repeated until muscular fatigue set in. This occurred when the subject was unable to perform further repetitions without assistance. The subject was not allowed to arch his back or bounce the weight off his chest (McLaughlin & Madsen, 1984;

Scriber, 1986). A starting weight of 10 lb over body weight was used. If the subject performed less than 1 repetition or greater than 10, the weight was adjusted accordingly by 10 lb, and the subject was retested 2 days later, and every 2 days until the effort performed was between 1 and 10 repetitions (see Appendix C).

Parallel Squat. The athlete positioned himself into the squat rack, and the safety bar was placed at the level of the greater trochanters. To perform the squat, with the bar placed on the posterior of the subject's shoulders, the subject lowered himself until he touched the weight to the safety bar, and then he pushed the weight straight up until he stood upright. The supervising coaches determined if the lift was acceptable (O'Shea, 1985; Scriber, 1986). This was repeated until muscular fatique set in. Muscular fatigue was the point at which no further repetitions were able to be performed without the spotters' assistance. A starting weight of 1.5 times body weight was used. If the subject performed less than 1 or greater than 10 repetitions the test weight was adjusted accordingly by 10 lb, and he was retested 2 days later, and every 2 days until the effort performed was between 1 and 10 repetitions (see Appendix D).

Treatment of Data

Pearson product-moment correlation revealed the interrelationship between LBW and each of the two measures of muscular strength as it related to position played. Fisher's z tests (Hopkins, Glass, & Hopkins, 1987) were performed on each combination of two positions to determine if there were differences among positions on the Pearson product-moment correlations between LBW and each of the two measures of muscular strength. The .01 level of statistical significance was utilized to test the null hypotheses.

Chapter 4

ANALYSIS OF DATA

This study investigated the relationship between LBW and muscular strength in collegiate football players. The components measured were height, body weight, body fat percentage, upper body strength as estimated by a free-weight bench press, and lower body strength as estimated by a free-weight squat. Data were collected for 212 players. This included 42 offensive linemen, 10 tight ends, 36 offensive backs, 32 wide receivers, 32 defensive linemen, 29 linebackers, and 31 defensive backs. Raw data for each subject's height, body weight, body fat percentage, LBW, and FW are presented in Appendix B. Appendix D contains estimated 1-RM data for bench press and parallel squat.

Body Composition

Body composition analysis (Table 3) showed that offensive linemen were the largest in body weight, body fat percentage, and LBW (237.2 lb, 18.1%, and 196.4 lb, respectively). Wide receivers weighed the least (174.4 lb) and had the lowest LBW (156.0 lb), and defensive backs had the lowest body fat percentage (10.0%) of all playing positions.

Muscular Strength

The strongest group among all athletes for upper body strength (Table 4) were the offensive linemen, and the weakest were the wide receivers. Offensive linemen had a

Table 3

Body Weight and Body Composition by Playing Position

Group	n	Body Weight[a]		% Body Fat		LBW[a]	
		M	SD	M	SD	M	SD
OL	42	237.2	25.8	18.1	3.2	196.4	18.1
TE	10	211.3	9.0	13.9	2.8	181.9	10.4
OB	36	185.3	16.4	11.5	3.6	163.6	12.1
WR	32	174.4	18.3	10.5	3.4	156.0	14.9
DL	32	222.0	17.6	15.4	4.3	187.6	13.6
LB	29	203.9	11.6	13.0	4.0	178.1	10.9
DB	31	176.3	13.6	10.0	2.9	158.6	11.8
All subjects	212	201.9	23.9	13.3	2.9	174.7	15.3

Note. OL = Offensive Linemen, TE = Tight Ends, OB = Offensive Backs, WR = Wide Receivers, DL = Defensive Linemen, LB = Linebackers, DB = Defensive Backs.

[a]All weight measurements are expressed in pounds.

Table 4

Estimated 1-RM Muscular Strength by Playing Position

Group	n	1-RM Bench Press[a]		1-RM Squat[a]	
		M	SD	M	SD
OL	42	302.25	44.84	446.00	76.30
TE	10	269.80	40.20	395.70	53.70
OB	36	269.27	39.80	402.50	69.00
WR	32	232.90	42.10	345.80	67.50
DL	32	286.76	37.11	442.70	76.10
LB	29	293.50	45.04	473.30	81.20
DB	31	254.30	35.25	400.00	72.10
All subjects	212	272.68	40.62	415.14	70.84

Note. OL = Offensive Linemen, TE = Tight Ends, OB = Offensive Backs, WR = Wide Receivers, DL = Defensive Linemen, LB = Linebackers, DB = Defensive Backs.

[a]All strength measurements are expressed in pounds.

mean estimated bench press of 302.25 lb, but wide receivers had a mean estimated bench press of only 232.90 lb. Wide receivers were also the weakest group of athletes for lower body strength (Table 4), with an estimated mean 1-RM squat of 345.80 lb. The strongest athletes for lower body strength were linebackers, with an average 1-RM squat of 473.30 lb.

Relationship Between LBW and Muscular Strength

Pearson product-moment correlations were performed between LBW and estimated 1-RM bench press and between LBW and estimated 1-RM squat (Table 5) for the entire sample and for each subgroup. A moderate, statistically significant correlation ($p < .01$) with LBW for the total sample existed in both upper body strength ($r = .570$) and lower body strength ($r = .460$).

The highest correlation for the positional subgroups belonged to tight ends for both the bench press and squat ($r = .781$ and $r = .831$, respectively). The lowest correlations were not statistically significant and were obtained with offensive linemen in the bench press ($r = .272$) and defensive linemen in the squat ($r = .068$).

The null hypothesis for the investigation, that there is no relationship between LBW and muscular strength in college football players, was rejected. Instead, the alternate hypothesis, that there is a positive relationship between LBW and muscular strength in college football players, was accepted.

Table 5

Correlations Between LBW and Muscular Strength

Group	n	LBW and Bench Press	LBW and Squat
OL	42	.272	.075
TE	10	.781*	.831*
OB	36	.431*	.489*
WR	32	.490*	.532*
DL	32	.427*	.065
LB	29	.540*	.466*
DB	31	.299	.412
All subjects	212	.570*	.460*

Note. OL = Offensive Linemen, TE = Tight Ends, OB = Offensive Backs, WR = Wide Receivers, DL = Defensive Linemen, LB = Linebackers, DB = Defensive Backs.

*$p < .01$.

Differences in Correlations Between Different Positions

To determine if any statistically significant differences existed between the positional subgroups' correlations, Fisher's *z* tests were performed. The *z* tests involving LBW and upper body strength correlations showed no significant differences ($p < .01$) between any two playing positions (Table 6). The *z* tests between playing positions for the correlations between LBW and squat (Table 7) showed statistically significant differences in correlations ($p < .01$) for offensive linemen and tight ends ($z = -2.72$) and for tight ends and defensive linemen ($z = 2.67$), indicating that tight ends had significantly higher correlations between LBW and squat than either offensive or defensive linemen.

Summary

In summary, Pearson product-moment correlations between LBW and estimated 1-RM bench press and between LBW and estimated 1-RM squat revealed significant correlations for both the entire sample and most playing position subgroups. The only subgroups whose correlations were not statistically significant were offensive linemen (LBW with bench press and LBW with squat), defensive linemen (LBW with squat), and defensive backs (LBW with bench press and LBW with squat).

Fisher's *z* tests were performed on each combination of two positions to determine if there were differences among positions for the Pearson product-moment correlation between LBW and each of the two measures of muscular strength. The

Table 6

Fisher's z Tests for Differences in Correlations Between Playing Positions: LBW with Bench Press

	TE	OB	WR	DL	LB	DB
OL	-1.87	-0.77	-1.05	-0.72	-1.28	0.12
TE		1.41	1.21	1.40	1.04	1.75
OB			-0.29	0.19	-0.54	0.59
WR				0.30	-0.25	0.86
DL					-0.54	0.56
LB						1.08

Note. OL = Offensive Linemen, TE = Tight Ends, OB = Offensive Backs, WR = Wide Receivers, DL = Defensive Linemen, LB = Linebackers, DB = Defensive Backs.

*$p < .01$.

Table 7

Fisher's z Tests for Differences in Correlations Between Playing Positions: LBW with Squat

	TE	OB	WR	DL	LB	DB
OL	-2.72*	-1.95	-2.11	0.03	-1.47	-1.47
TE		1.57	1.42	2.67*	1.61	1.78
OB			-0.23	1.83	0.11	0.38
WR				2.00	0.32	0.58
DL					-1.62	-1.40
LB						0.25

Note. OL = Offensive Linemen, TE = Tight Ends, OB = Offensive Backs, WR = Wide Receivers, DL = Defensive Linemen, LB = Linebackers, DB = Defensive Backs.

*$p < .01$.

only significant differences in correlation obtained were for offensive linemen and tight ends and for tight ends and defensive linemen in the LBW-with-squat correlation, with the greater difference being for offensive linemen and tight ends.

Chapter 5

DISCUSSION

The relationship between LBW and muscular strength in collegiate football players was investigated. For the purpose of discussing the results obtained in this study, this chapter has been divided into the following areas: (a) body composition, (b) muscular strength, (c) relationship between LBW and muscular strength, and (d) summary.

Body Composition

The subjects who participated in this study were quite consistent in body weight, LBW, and body fat percentage with previous studies of football players. Group means in the current study for body weight, LBW, and body fat percentage were 201.9 lb, 174.7 lb, and 13.3%. When positional subgroup mean body weights and LBWs were investigated, offensive linemen were the heaviest, followed by defensive linemen, tight ends, linebackers, offensive backs, defensive backs, and wide receivers. Average body fat percentage was also the highest in offensive linemen, with progressively decreasing percentages in defensive linemen, tight ends, linebackers, offensive backs, wide receivers, and defensive backs.

In a study of high school senior all-star football players, Kollias, Buskirk, and Howley (1972) reported mean body weight and LBW (196.2 lb and 166.0 lb) to be slightly less than those found in the present study of college athletes. At the same time, these authors reported body fat percentage (15.4%) to be slightly higher. The positional trends regarding body weight, LBW, and body fat percentage were similar to those found in the present study, with linemen and linebackers being the largest in all three categories, while backs and ends were the smallest.

Body composition of football players at the collegiate level has been investigated in many studies, and results of those studies were very similar to those of the present study. In Wickkiser and Kelly's (1975) study with small-college football players, the investigators reported that the athletes' body weight (M = 194 lb) and LBW (M = 164.9 lb) were slightly lower than in the present study, but the percentage of body fat (15.0%) was higher. As in the current investigation, offensive linemen were the heaviest and had the highest LBW and body fat percentage. Following offensive linemen with decreasing amounts of body weight, LBW, and body fat percentage were defensive linemen, linebackers, offensive backs, wide receivers, and defensive backs.

As one might expect, those studies performed with either major college (NCAA Division I) or professional football players reported heavier athletes in terms of both body weight and LBW than found in the present study. Although the athletes at these levels were heavier, their body fat percentages were consistent with the present study. Studies by Gettman et al. (1987), Olson and Hunter (1985), Smith and Mansfield (1984), Wilmore and Haskell (1972), and Wilmore et al. (1976) reported body weight means ranging from 208.1 to

235.9 lb and LBW means from 182.9 to 192.7 lb. Body fat percentage in these studies ranged from 12.1% to 18.3%. When the values from positional subgroups from these studies are considered and analyzed, the same general pattern with regard to body weight, LBW, and body fat percentage that was reported in high school and small-college athletes emerges.

Although there is variability in the body fat percentages from one study to another, guidelines for coaches and athletic trainers for positional body fat percentages are established from these and similar studies. These guidelines are that offensive linemen can, and probably should, have the greatest percentage of body fat (14-18%), after which comes defensive linemen (13-15%); linebackers and tight ends (12-14%); and offensive backs, wide receivers, and defensive backs with 8-10% (Stanforth & Emmert in "Body composition--Part 2", 1987). A general conclusion from these studies regarding body weight and body fat percentage based on position played is that those players who rely on size to enhance performance and are constantly involved in physical contact (linemen) need the higher body fat level; those players who rely on speed for optimum performance and are not involved in physical contact on a play-by-play basis (backs) tend to be smaller and possess lower body fat levels.

Muscular Strength

Given the importance of muscular strength and the fact that strength training programs have been used for many years in football, there is suprisingly little systematic research available on the subject. Mayhew et al. (1987), Olson and Hunter (1985), and Scriber (1986) tested the strength of collegiate football players by a 1-RM bench press for the upper extremities and a 1-RM squat for the lower extremities. The strength levels in the NCAA Division II (Mayhew el al.) and III (Scriber) studies were very similar to those obtained in the present study. The average lifts ranged from a low of 251.3 lb for defensive backs to a high of 293.8 lb by linebackers in the bench press, and 365.0 lb for wide receivers to 437.9 lb for linemen (offensive and defensive) for the squat. In the present study, positional means ranged from 232.9 lb for wide receivers to 302.3 lb for offensive linemen in the bench press, and in the squat the means ranged from 345.8 lb for wide receivers to 473.3 lb by linebackers. NCAA Division IA athletes (Olson & Hunter, 1985) were able to lift greater amounts than those athletes in the present study, but exhibited the same positional trends: wide receivers lifted the least in both bench press and squat (271.1 and 370.5 lb, respectively), and offensive linemen lifted the most in both lifts (357.6 and 478.0 lb, respectively).

The present study, along with the previous ones mentioned, supports Sale and Norman's (1982) conclusion that the heavier the athlete, the stronger he is. The heaviest athletes in the present study (offensive linemen, defensive linemen, tight ends, and linebackers) were also the strongest when assessed for upper body strength. They had estimated

1-RM bench presses ranging from a low of 269.8 lb for tight ends to a high of 302.3 lb for the offensive linemen. At the same time the lightest athletes (offensive backs, defensive backs, and wide receivers) were the weakest, with estimated 1-RM bench presses ranging from 232.3 to 269.3 lb.

As in the bench press, squat measurements in the present study follow the rule of thumb that the heavier the athletes, the stronger they are. Offensive linemen, defensive linemen, and linebackers were the heaviest players and had the greatest estimated 1-RM squats (442.7 to 473.3 lb) of all players. Offensive backs, defensive backs, and wide receivers were the lightest athletes and had the lowest strength measurements in the lower extremities, with squat values ranging from 345.8 to 402.5 lb.

In the present study, the only exception to Sale and Norman's (1982) conclusion regarding strength and body weight was the tight ends' lower body strength. Tight ends were the third heaviest positional group (211.3 lb), but had the second lowest squat (395.7 lb). A possible explanation for the apparent dichotomy is that the athlete who plays the position of tight end is a hybrid between an offensive lineman and a wide receiver (DeLuca, 1978). Tight ends therefore need the upper body weight and strength of an offensive lineman, for they have to block like an offensive lineman (hence, the third highest body weight and fourth best bench press at 269.8 lb). In addition to needing the upper body size of an offensive lineman, tight ends must also resemble wide receivers in the lower extremities because the position requires great speed and quickness to run pass routes like a wide receiver. This dichotomy may be accomplished by tight ends usually having a decreased concentration of body weight (and therefore strength) in the lower extremity.

LBW and Muscular Strength

The moderate, but statistically significant correlations that exist for the total sample represented in the present study between LBW and upper body strength (r = .570) and LBW and lower body strength (r = .460) are consistent with correlational values between LBW and strength reported in previous studies. In 1966, Laubach and McConville reported significant correlations in adult males between LBW and four lower body strength measures (trunk flexion, trunk extension, hip flexion, and hip extension). They concluded from these correlations that it was possible to use LBW as a predictor of lower body strength. In a study by Katch ("Body composition--Part 1", 1987), the relationship between LBW and muscular strength as measured by a free-weight 1-RM bench press and squat was investigated in college-age males. It was reported that moderate correlations existed for both LBW with bench press (r = .52) and LBW with squat (r = .61).

In addition to moderate positive correlations in adult males, this same relationship has also been reported in collegiate football players. Nelson and Tew (1983) found a correlation (r = .41) in NCAA Division 1A athletes for LBW an squat similar to the correlation reported here. In a 1987 study involving Division II athletes, Mayhew et al. reported a positive correlation ($r = .58$) for LBW and strength. This correlation was similar to the correlation found in the present study.

In addition to the investigation of the relationship between LBW and muscular strength for the entire test population in this study, that relationship for the various positional subgroups was also examined. For LBW-with-bench press correlation, all subgroups showed moderate, statistically significant correlations except tight ends, offensive linemen, and defensive backs. Tight ends had a statistically significant high positive correlation ($r = .781$, $p < .01$), but offensive linemen and defensive backs had statistically nonsignificant correlations. When the correlation between LBW and squat was calculated, most subgroups (excluding tight ends, offensive linemen, and defensive linemen) had r values similar to the value obtained for the entire group. Tight ends showed a high positive correlation ($r = .831$, $p < .01$), and offensive linemen ($r = .075$) and defensive linemen ($r = .065$) displayed virtually no relationship between lower body strength and LBW. It is thought that the high positive correlations found for tight ends can be attributed to both the low number who participated in this investigation ($n = 10$) and the similarity of those subjects with respect to LBW (as shown by the smallest *SD* of all positions at 10.4 lb). These factors seem to have contributed to the spuriously high correlation (Kendall & Stuart, 1979) for tight ends.

The last question was if there were any statistically significant differences between the correlations calculated for each of the various positional subgroups. The only significant differences that existed for any of the measurements were between tight ends and offensive linemen and between tight ends and defensive linemen for the LBW with squat correlations. It is believed that these statistically significant differences are a result of the spuriously high *r* values obtained for LBW with squat correlation from tight ends, and therefore were not of any practical consideration.

Summary

The present study is of practical importance to all who are involved on a daily basis with the collegiate football player. This includes his coaches, his trainer, the team physician, and even the parent. This study shows that any body weight increases that the athlete may experience should by monitored to make sure it is a lean weight increase (and not just a 'body' weight increase), because LBW increases may be accompanied by subsequent strength increases. This is what is desired in collegiate football players: body weight increases accompanied by muscular strength increases.

Chapter 6

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Summary

The purpose of this study was to investigate the relationship between LBW and muscular strength in collegiate football players. In addition, the differences among the playing positions on these correlations were studied.

The subjects for this study were 212 members of the 1988 Cornell University and Ithaca College football teams. Each subject's body fat percentage was determined using a Skyndex electronic body fat calculator. This was followed by muscular strength being assessed by an estimated 1-RM bench press and an estimated 1-RM parallel squat.

Pearson product-moment correlations were obtained for LBW and upper extremity strength (r = .570) and for LBW with lower body muscular strength (r = .460). In addition to the correlations on the entire subject population, subgroup correlations were obtained by playing position. These subgroups were offensive linemen, tight ends, offensive backs, wide receivers, defensive linemen, linebackers, and defensive backs. The subgroup correlations that were found to be statistically significant for LBW and upper body strength were for tight ends (r = .781), offensive backs (r = .431), wide receivers (r = .490), defensive linemen (r = .427), and linebackers (r = .540). The subgroup correlations for LBW and lower body strength that were statistically significant were for tight ends (r = .831), offensive backs (r = .489), wide receivers (r = .532), and linebackers (r = .466). Statistically significant differences between the LBW-with-squat correlation and position played were obtained for offensive linemen and tight ends (z = −2.72) and for tight ends and defensive linemen (z = 2.67).

Conclusions

Based on the findings of this study, the following conclussions were drawn:

1. There exists a moderate, yet significant, correlation (r = .570, p < .01)) between LBW and upper extremity strength in collegiate football players.

2. There exists a moderate, yet significant, correlation (r = .460, p < .01) between LBW and lower extremity strength in collegiate football players.

3. Relationships between LBW and muscular strength are similar for most positional subgroups of football players.

Recommendations

The findings of the present study have raised other questions concerning the relationship between LBW and muscular strength in collegiate football players. Recommendations for future research in this area include the following:

1. A larger positional subgroup sample should be used, especially for the tight end subgroup. Their unexpectedly high correlation may have been due to the small sample

size or to their unusually small variability in scores.

2. Future research should consist of both a pretest before the training program begins and a postest once the training program is completed. This is to find out if the increased muscular strength that occurs after a training program is accompanied by an increase in LBW and how that possible change affects the correlation between each strength measure and LBW.

3. Anatomical differences should be taken into consideration when using free-weight 1-RM as the measure of strength. These differences can have a great affect on the LBW with muscular strength correlations.

4. Athletes should be monitored throughout their college careers to find out if strength increases occur from matriculation to graduation and if these strength increases are related to increased LBW.

Appendix A

INFORMED CONSENT FORM

1. a. Purpose of this study. To examine the relationship between strength and lean body weight in collegiate football players.

b. Benefits. You will be provided with an accurate assessment of your body weight, lean body weight, and strength as determined from skinfold measurements and strength tests. Additionally, this information may prove valuable for determining your optimum playing weight.

2. Method. Part 1 of this study will require you to be weighed and then tested for body composition by three skinfold measurements. This should take approximately 5 min. Part 2 will consist of strength measurements in the bench press and squat at a predetermined weight until muscular fatigue occurs. Muscular fatigue will be the point at which you are unable to perform any more repetitions of the lift without assistance. This should take approximately 25 min.

3. Will this hurt? Participation in this study does not involve any major risks. Unusual physical discomfort, pain, or injury is not expected. However, possibility of injury is always present when performing explosive or maximal effort movements. Muscle soreness is also possible the following day. Adequate warmup, carefully selected test protocol, and spotters should minimize the chance of injury or muscle soreness.

4. Need more information? Additional information can be obtained from either Jeffrey M. Kaplan at (607) 257-3849 or Dr. G. A. Sforzo at (607) 274-3359. All questions are welcomed and will be answered.

5. Withdrawal from this study. Participation in this study is completely voluntary. You are free to withdraw your consent and participation at any time without penalty. If you withdraw, it would be appreciated, but not necesary, that you give advance notice to the researchers.

6. Will the data be maintained confidential? All data will be confidential. Once data are collected, all names will be coded into numbers and referred to by that number only. Your personal data are available only to you and not to your coach or anyone else. However, your coach may be provided with the general results of the study if he requests.

I have read the above, and I understand its contents and I agree to participate in this study. I acknowledge that I am at least 18 years of age or older and meet the eligibility requirements of this study.

SIGNATURE________________________ DATE__________

Appendix B

BODY COMPOSITION MEASUREMENTS

SUBJECT	HT(in.)	WT(lb)	BODY FAT(%)	FW(lb)	LBW(lb)
1	74.75	324	21.4	69.34	254.66
2	78.00	253	12.7	32.13	220.87
3	76.25	216	12.2	26.35	189.65
4	73.00	236	17.8	42.00	194.00
5	72.50	246	20.4	50.18	195.82
6	75.75	269	21.3	57.30	211.70
7	76.00	250	16.7	41.75	208.25
8	72.50	256	20.2	51.71	204.29
9	73.00	260	21.4	55.64	204.36
10	77.00	262	17.9	46.90	215.10
11	73.25	259	18.8	48.70	210.30
12	73.25	217	15.6	33.85	183.15
13	74.75	221	13.3	29.39	191.61
14	74.00	240	12.0	28.80	211.20
15	74.00	216	15.9	34.34	181.66
16	75.50	246	19.7	48.46	197.54
17	75.25	226	14.2	32.09	193.91
18	75.25	266	19.0	50.54	215.46
19	74.50	229	18.0	41.22	187.78
20	73.25	239	19.1	45.65	193.35
21	77.00	255	20.6	52.53	202.47
22	77.75	263	20.0	52.60	210.40
23	72.00	245	15.1	36.99	208.01
24	73.00	275	18.7	51.43	223.57
25	73.00	229	17.1	39.16	189.84
26	70.00	234	19.4	45.40	188.60
27	73.00	222	17.0	37.74	184.26
28	74.00	287	19.5	55.97	231.03
29	70.00	251	19.6	49.20	201.80
30	74.00	194	13.6	26.38	167.62
31	74.00	223	25.1	55.97	167.03
32	71.00	200	11.7	23.40	176.60
33	71.00	245	25.6	62.72	182.28
34	75.00	244	21.7	52.95	191.05
35	74.00	217	19.7	42.75	174.25
36	74.00	202	19.8	40.00	162.00
37	72.00	230	16.4	37.72	192.28
38	75.00	238	20.8	49.50	188.50
39	74.00	216	18.6	40.18	175.82
40	71.00	224	16.8	37.63	186.37
41	72.00	220	16.8	36.96	183.04
42	73.00	237	17.8	42.19	194.81
43	72.75	195	13.2	25.74	169.26
44	76.75	211	8.8	18.57	192.43
45	74.25	211	13.5	28.49	182.51
46	71.25	220	12.8	28.16	191.84

Table continues

SUBJECT	HT(in.)	WT(lb)	BODY FAT(%)	FW(lb)	LBW(lb)
47	74.00	220	12.4	27.28	192.72
48	73.00	218	11.9	25.94	192.06
49	76.00	206	15.1	31.11	174.89
50	73.00	198	15.5	30.69	167.31
51	74.00	210	18.5	38.85	171.15
52	75.00	224	17.3	38.75	185.25
53	69.75	174	9.6	16.70	157.30
54	71.50	192	10.6	20.35	171.65
55	74.00	197	10.7	21.08	175.92
56	73.75	208	12.3	25.58	182.42
57	73.50	214	19.9	42.59	171.41
58	73.00	198	15.6	30.89	167.11
59	72.00	200	16.0	32.00	168.00
60	70.00	177	11.4	20.18	156.82
61	70.00	187	15.6	29.17	157.83
62	70.00	162	14.9	24.14	137.86
63	69.00	162	13.2	21.38	140.62
64	69.25	168	6.3	10.58	157.42
65	70.75	207	14.5	30.02	176.98
66	70.00	188	7.8	14.66	173.33
67	70.00	165	6.6	10.89	154.11
68	66.50	171	11.9	20.35	150.65
69	69.75	182	6.3	11.47	170.53
70	67.00	163	10.5	17.12	145.88
71	70.50	194	6.4	12.42	181.58
72	71.50	199	13.9	27.66	171.34
73	71.50	200	14.4	28.80	171.20
74	71.00	178	8.3	14.77	163.23
75	72.75	198	7.9	15.64	182.36
76	70.00	198	10.0	19.80	178.20
77	70.25	178	10.3	18.33	159.67
78	71.00	222	17.6	39.07	182.93
79	68.00	156	7.9	12.32	143.68
80	70.00	199	20.2	40.20	158.80
81	70.00	184	14.9	27.42	156.58
82	73.00	193	14.1	27.21	165.79
83	70.00	171	11.7	20.01	150.99
84	66.00	170	4.8	8.16	161.84
85	69.00	192	12.2	23.42	168.58
86	67.00	183	11.2	20.50	162.50
87	70.00	168	7.3	12.26	155.74
88	70.00	185	14.5	26.83	158.17
89	73.25	183	7.9	14.46	168.54
90	73.50	186	10.3	19.16	166.84
91	70.50	179	7.1	12.71	166.29
92	70.75	179	8.6	15.39	163.61
93	73.00	204	13.1	26.72	177.28
94	69.00	184	15.5	28.52	155.48
95	71.00	189	10.0	18.90	170.10
96	75.00	199	12.1	24.08	174.92

Table continues

SUBJECT	HT(in.)	WT(1b)	BODY FAT(%)	FW(1b)	LBW(1b)
97	71.00	170	7.8	13.26	156.74
98	68.75	168	8.1	13.61	154.39
99	68.75	175	6.1	10.68	164.32
100	71.00	172	8.1	13.93	158.07
101	74.75	180	9.1	16.38	163.62
102	67.25	156	9.6	14.98	141.02
103	69.50	172	8.1	13.93	158.07
104	66.75	122	9.9	12.08	109.92
105	66.75	157	7.6	11.93	145.07
106	73.25	197	10.6	20.88	176.12
107	67.25	168	11.5	19.32	148.68
108	71.00	161	10.9	17.55	143.45
109	71.00	169	12.5	21.13	147.87
110	74.00	187	17.0	31.79	155.21
111	72.00	201	15.2	30.55	170.45
112	72.00	197	17.4	34.29	162.73
113	73.00	181	10.3	18.64	162.36
114	69.00	180	11.0	19.80	160.20
115	70.00	153	5.7	8.72	144.28
116	67.00	135	7.3	9.86	125.14
117	74.00	181	8.1	14.66	166.34
118	72.00	165	7.9	13.04	151.96
119	72.00	152	11.7	17.78	134.22
120	66.00	183	19.4	35.50	147.50
121	69.00	244	21.4	52.22	191.78
122	70.00	218	19.2	41.86	176.14
123	74.50	225	15.7	35,33	189.67
124	67.50	213	17.6	37.49	175.51
125	73.25	212	9.6	20.35	191.65
126	71.25	219	17.1	37.45	181.55
127	72.50	219	12.5	27.38	191.62
128	73.50	219	7.7	16.86	202.14
129	73.25	243	20.8	50.54	192.46
130	74.25	234	18.5	43.29	190.71
131	74.50	245	19.6	48.02	196.98
132	74.50	226	10.6	23.96	202.04
133	71.00	229	20.9	47.86	181.14
134	72.50	220	13.6	29.92	190.08
135	75.25	227	9.9	22.47	204.53
136	73.00	219	17.7	38.76	180.24
137	74.00	229	9.6	21.98	207.17
138	72.50	283	21.8	61.69	221.31
139	74.75	218	12.0	26.16	191.84
140	71.00	200	19.7	39.40	160.60
141	73.75	214	14.8	31.67	182.33
142	72.00	201	14.0	28.14	172.86
143	68.00	208	17.9	37.23	170.77
144	73.00	233	20.8	48.46	184.54
145	77.00	215	9.5	20.43	194.57
146	71.00	203	9.4	19.08	183.92

Table continues

SUBJECT	HT(in.)	WT(lb)	BODY FAT(%)	FW(lb)	LBW(lb)
147	75.00	224	18.2	40.77	183.23
148	70.00	232	15.8	36.66	195.34
149	72.00	176	13.6	23.94	152.06
150	71.00	221	18.1	40.00	181.00
151	73.00	222	10.1	22.42	199.58
152	73.00	215	15.0	32.25	182.75
153	68.75	216	12.8	27.65	188.35
154	70.00	189	8.6	16.25	172.75
155	69.50	191	12.5	23.49	167.51
156	73.00	196	11.5	22.54	173.46
157	73.25	211	16.0	33.76	177.24
158	71.00	203	10.8	21.92	181.08
159	72.00	215	6.4	13.76	201.24
160	72.00	230	12.8	29.44	200.56
161	77.00	197	13.1	25.81	171.19
162	72.50	198	7.1	14.06	183.94
163	71.50	187	10.6	19.82	167.18
164	72.50	196	11.7	22.93	173.07
165	71.25	211	15.2	32.07	178.93
166	71.00	188	4.7	8.84	179.16
167	75.00	209	6.8	14.21	194.79
168	72.75	198	16.4	32.47	165.53
169	73.00	199	12.3	24.48	174.52
170	73.00	198	15.3	30.29	167.68
171	72.00	229	17.4	39.85	189.15
172	73.00	242	20.4	49.37	192.63
173	72.00	195	17.4	33.93	161.07
174	71.00	205	15.0	30.75	174.25
175	69.00	200	17.6	35.20	164.80
176	70.00	217	16.7	36.24	180.76
177	71.00	217	16.8	36.46	180.54
178	70.00	197	10.1	19.90	177.10
179	71.00	193	9.6	18.53	174.47
180	74.00	215	12.2	26.23	188.77
181	73.00	200	18.9	37.80	162.20
182	71.00	195	7.3	14,24	180.76
183	69.50	174	8.5	14.79	159.21
184	66.75	150	10.4	15.60	134.40
185	73.50	173	6.5	11.24	161.75
186	71.00	190	12.0	22.80	167.20
187	69.00	161	8.1	13.04	147.96
188	69.75	179	9.8	17.54	161.46
189	67.00	157	8.3	13.03	143.97
190	67.00	177	11.0	19.47	157.53
191	72.00	183	8.5	15.55	167.45
192	73.25	187	4.2	7.85	179.15
193	68.00	154	5.0	7.70	146.30
194	69.00	170	9.4	15.98	154.02
195	71.00	187	11.5	21.51	165.49
196	69.00	153	8.1	12.39	140.61

Table continues

SUBJECT	HT(in.)	WT(lb)	BODY FAT(%)	FW(lb)	LBW(lb)
197	70.00	170	13.8	23.46	146.54
198	68.00	173	11.8	20.41	152.59
199	71.00	183	9.7	17.75	165.25
200	72.00	169	6.7	11.32	157.68
201	70.00	193	11.4	22.00	171.00
202	73.00	194	10.6	20.56	173.44
203	68.00	161	12.6	20.29	140.71
204	68.00	156	7.9	12.32	143.68
205	68.00	180	14.2	25.56	154.44
206	72.00	190	11.2	21.28	168.72
207	71.00	187	17.2	32.16	154.84
208	73.00	192	9.3	17.86	174.14
209	69.00	171	7.0	11.97	159.03
210	75.00	197	13.9	27.38	169.62
211	69.00	181	10.2	18.46	162.54
212	64.00	182	14.4	26.21	155.79

Note: Subject = Subject Number, HT = Height, WT = Weight, FW = Fat Weight, LBW = Lean Body Weight.

Position	Subject Number
Offensive Linemen	1-42
Tight Ends	43-52
Offensive Backs	53-88
Wide Receivers	89-120
Defensive Linemen	121-152
Linebackers	153-181
Defensive Backs	182-212

Appendix C

CONVERSION FACTOR TO EXTRAPOLATE AN ESTIMATED 1-RM FROM THE NUMBER OF REPETITIONS PERFORMED

Number of Repetitions	Conversion Factor
1	1.00
2	1.06
3	1.09
4	1.12
5	1.15
6	1.18
7	1.21
8	1.24
9	1.27
10	1.30

Note. From B. Epley (personal communication, October 7, 1987).

Appendix D

STRENGTH MEASUREMENTS (ESTIMATED 1-RM)

SUBJECT	Bench Press(lb)	Squat(lb)
1	265.00	420.00
2	291.50	420.00
3	255.00	365.00
4	365.75	566.25
5	341.00	600.00
6	270.25	420.00
7	341.00	465.00
8	365.75	465.00
9	349.25	487.50
10	275.00	442.50
11	308.00	453.75
12	291.50	532.50
13	265.00	442.50
14	357.50	476.25
15	256.15	365.00
16	316.25	532.50
17	238.50	355.10
18	308.00	375.00
19	324.50	566.25
20	316.25	465.00
21	375.00	245.25
22	299.75	543.75
23	292.50	469.90
24	379.05	514.60
25	230.00	386.40
26	362.60	429.55
27	257.60	409.20
28	295.00	420.00
29	330.20	543.75
30	278.80	427.75
31	215.00	310.00
32	298.20	435.00
33	323.85	592.00
34	386.95	414.40
35	306.00	471.25
36	228.90	486.00
37	297.60	386.40
38	240.00	392.40
39	272.25	354.25
40	333.70	472.60
41	264.50	349.80
42	325.85	461.50
43	250.00	340.00
44	265.00	444.50
45	295.00	381.50
46	272.50	434.00

Table continues

SUBJECT	Bench Press(lb)	Squat(lb)
47	325.00	455.00
48	333.50	478.50
49	260.15	375.10
50	200.00	327.00
51	233.20	381.15
52	263.20	340.00
53	238.50	305.00
54	299.25	373.75
55	225.00	325.00
56	326.25	490.75
57	312.75	373.75
58	292.50	364.00
59	190.00	372.00
60	229.90	383.40
61	296.00	421.80
62	221.00	441.60
63	236.30	326.40
64	281.50	328.60
65	332.50	381.50
66	311.50	560.00
67	220.00	340.00
68	272.50	476.00
69	287.50	476.00
70	343.80	371.00
71	317.50	539.00
72	265.00	402.50
73	240.00	476.00
74	230.00	358.40
75	265.00	444.50
76	317.50	392.00
77	240.00	392.00
78	317.50	528.50
79	254.10	270.25
80	235.20	336.00
81	259.35	364.00
82	272.65	453.00
83	212.40	369.75
84	244.80	400.35
85	260.00	421.80
86	323.70	490.00
87	239.40	326.25
88	282.75	414.40
89	248.00	408.00
90	272.00	318.00
91	284.00	363.00
92	212.00	408.00
93	200.00	462.00
94	212.00	390.00
95	254.00	435.00
96	200.00	318.00

Table continues

SUBJECT	Bench Press(lb)	Squat(lb)
97	248.00	453.00
98	242.00	435.00
99	296.00	435.00
100	230.00	390.00
101	212.00	300.00
102	248.00	270.00
103	278.00	363.00
104	170.00	240.00
105	190.00	327.00
106	302.00	327.00
107	230.00	280.00
108	190.00	260.00
109	250.20	392.70
110	241.80	364.00
111	298.20	336.00
112	272.25	290.00
113	174.90	260.00
114	315.40	408.00
115	224.40	347.80
116	158.05	260.35
117	190.00	383.40
118	222.25	240.00
119	212.80	245.25
120	175.00	355.60
121	341.00	465.00
122	270.30	552.45
123	275.00	500.50
124	265.00	397.50
125	270.25	420.00
126	324.50	510.00
127	275.00	487.50
128	280.50	510.00
129	245.25	521.25
130	324.50	397.50
131	308.00	532.50
132	280.50	510.00
133	275.00	375.00
134	280.50	375.00
135	280.50	365.00
136	235.00	375.00
137	332.75	365.00
138	275.00	465.00
139	256.15	375.00
140	280.50	487.50
141	332.75	397.50
142	260.40	462.00
143	279.40	551.25
144	267.05	386.95
145	326.26	383.54
146	311.75	514.60

Table continues

SUBJECT	Bench Press(lb)	Squat(lb)
147	319.60	564.40
148	362.40	510.60
149	185.00	296.80
150	250.70	359.70
151	340.40	438.90
152	265.50	412.75
153	340.00	560.00
154	250.00	476.00
155	287.50	465.50
156	240.00	444.50
157	250.00	434.00
158	310.00	528.50
159	355.00	591.50
160	362.50	581.00
161	280.00	371.00
162	287.50	507.50
163	250.00	392.00
164	250.00	423.50
165	302.50	455.00
166	310.00	518.00
167	272.50	497.50
168	280.00	381.50
169	228.90	423.00
170	304.50	525.00
171	254.40	541.65
172	354.00	398.85
173	260.35	498.55
174	234.25	523.90
175	279.30	525.00
176	380.25	520.00
177	360.00	617.50
178	358.75	515.25
179	321.85	295.00
180	306.00	422.50
181	241.50	290.00
182	279.00	461.50
183	315.00	312.75
184	225.00	422.50
185	215.00	344.50
186	252.00	354.25
187	252.00	393.35
188	326.35	403.00
189	217.30	422.50
190	258.75	403.00
191	292.50	422.50
192	225.00	442.00
193	279.00	403.00
194	258.75	529.75
195	312.75	520.00
196	224.40	306.00

Table continues

SUBJECT	Bench Press(lb)	Squat(lb)
197	196.20	255.00
198	229.40	463.75
199	224.25	364.00
200	266.40	408.00
201	315.70	560.50
202	266.50	436.60
203	277.10	290.40
204	200.60	340.80
205	264.10	367.20
206	266.00	456.00
207	206.70	364.00
208	218.00	413.25
209	255.60	408.00
210	235.75	339.25
211	264.10	472.50
212	264.10	351.10

Position	Subject Number
Offensive Linemen	1-42
Tight Ends	43-52
Offensive Backs	53-88
Wide Receivers	89-120
Defensive Linemen	121-152
Linebackers	153-181
Defensive Backs	182-212

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