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Fitness changes in division I-A offensive receivers during a 16- week college football season

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FITNESS CHANGES IN DIVISION I-A OFFENSIVE RECEIVERS DURING A 16-WEEK COLLEGE FOOTBALL SEASON

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ABSTRACT

FITNESS CHANGES IN DIVISION I-A OFFENSIVE RECEIVERS DURING A 16-WEEK COLLEGE FOOTBALL SEASON

By Scott S. Setterlund

The purpose of this research study was to determine the fitness changes in offensive receivers during a 16-week playing season. The subjects were 10 healthy young men who ranged in age from 18 to 24 years. Standard laboratory procedures included measurement of aerobic and anaerobic work indices, body composition and bodybuild characteristics, flexibility, and muscular strength. Body somatotype ratings and body weight did not change over the playing season. Relative fat, anaerobic power, fatigue index, arm flexion strength, leg extension strength, and VO2max slightly decreased over the playing season. Slight increases were found for fat-free weight, body density, arm extension strength, leg flexion strength, VAT, and %VO2max. Anaerobic capacity and shoulder flexion strength significantly ($\underline{p} \leq .05$) decreased and shoulder extension strength significantly ($\underline{p} \leq .05$) increased over the course of the season. Post-season fitness measures for leg flexion strength and anaerobic power were moderately correlated ($\underline{r}$ = -.63 to -.83) to four game performance statistics and, thus, were determined as significant fitness variables. In conclusion, although no significant changes were found in almost every category measured, the trend toward a lower state of fitness at the conclusion of the season was apparent. A significant decrease in anaerobic capacity, which is a desirable component for successful performance, suggests that speed drills need to be emphasized throughout the season.

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FOR KRISTINE

Whose love, patience, and encouragement transformed a floundering athlete into a shining student of life. Without her enthusiasm and understanding, this thesis would not have been possible. She has been a constant source of fulfillment throughout the entire process. To her, this book is dedicated.

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CHAPTER I

Introduction

This chapter is divided into several sections as follows: background for the study, statement of the purpose, null hypothesis, delimitations, limitations, operational definitions, and significance of the problem.

Background for the Study

To resolve the clamor to ban football from university campuses and the subsequent escalating brutality style of play, the forward pass was introduced into American football on January 12, 1906. Far more than anything else, the forward pass changed the character of football and transformed the game from an elementary, prosaic, close-order test of brawn and muscle into a contest of skill and intelligence as well as a game of speed, deception, faking, manual dexterity, flanking movements, and spectacular passing operations, with every member carrying out an assigned role in an attack of daring, imagination, and split-second precision (Danzig, 1956).

The effectiveness of the forward pass, however, was underestimated until 1913 when an under-rated Norte Dame University soundly defeated a heavily favored Navy team. Under the guidance of coach Eddie Cochems, Gus Dorais threw to Knute

Rockne for an unheard of 243 yards in 17 attempts for 14 catches and stunned the pretentious Ivy league powerhouse (Danzig, 1956). This initiated a revolution in offensive strategy that combined both ground and aerial assaults into one of the most thrilling and charismatic spectacles in sport.

Because the inception of the forward pass has broadened the scope of the game, the scope of physical talent has expanded as well. Today, a football player's performance is assessed by identifying specific physical attributes inherent at each position (Gleim, 1984). Profiling has become an integral part in identifying specific athletic characteristics which provides the coach and athlete with a standard by which success can be measured (Nicholas, 1984; Wilmore, 1979). Further insight into performance variables will enable coaches to effectively design training programs which will elicit optimal performance and provide aspiring athletes with a knowledge of the performance characteristics important for success.

Physiological characteristics important for success in football have been divided into the areas of body composition (Olson & Hunter, 1985; Smith & Mansfield, 1984; Wickkiser & Kelly, 1975; Wilmore & Haskell, 1972), somatotype rating (Carter, 1969), cardiovascular function (Gleim, Witman, & Nicholas, 1981; Hoette, Clark, & Wolff, 1986; Novak, Hyatt, & Alexander, 1968; Wilmore et al. 1976), anaerobic work indices (Costill, Hoffman, Kehoe, Miller, & Myers, 1968; Mayhew & Wolfe, 1990), and maximal oxygen uptake rate (Kollias, Buskrik, Howley, & Loomis, 1970; Smith & Byrd, 1976). Each has reviewed football players either prior to the competitive season or during the off-season. On the other hand, changes in body composition and somatotype rating have been reported to occur over the course of the playing season in football players (Bolonchuk & Lukaski, 1987; Thompson, 1958). Presently, no research study simultaneously identifies the causal effects of the playing season on a wide parameter of physiological fitness measures. The need to investigate changes in fitness which occur over the course of a football season remains.

Football is of high-intensity and short intermittent-duration, with 4 to 5 seconds of intense play combined with as much as 30-seconds of rest during the huddle period, so that the energy required to perform the skills have been identified as anaerobic (deVries, 1980; Fox & Mathews, 1981; McArdle, Katch, & Katch, 1986; Wilmore et al., 1972). High anaerobic work indices are favorable adaptations for optimizing football performance (Fox & Mathews, 1981; Wilson & Wagner, 1987). In-season conditioning which exploits the anaerobic processes can effectively enhance anaerobic work indices (deVries, 1980; Marks, 1983; McArdle et al., 1986; Semenick, 1984). However, energy produced through this pathway is rate-limited by the oxygen deficit associated with anaerobic glycolysis and phosphagen metabolism. Lactate production as a bi-product of glycolysis may lead to premature fatigue and to decreases in performance (Karlsson, 1979). A high maximal oxygen uptake rate (VO2max) would contribute to the removal of lactic acid and maintenance of plasma and hydrogen-ion concentration in the muscle, assist in thermoregulation, decrease recovery time, and allow the athlete to work at higher levels of effort more efficiently (Thorland, Johnson, Cisar, Housh, & Tharp, 1987).

Moreover, in-season football training is preoccupied with developing individual and team skills so that some programs neglect to stress the aerobic system as a viable component to over-all work production and neglect increasing oxygen efficiency (Gleim, 1984; Hickson, 1980; Millard-Stafford, Rosskopf, & Sparling, 1989; Ono, Miyashita, & Assomi, 1976; Tesch, 1984). A decrease in aerobic conditioning toward the latter part of the season would attenuate fitness levels, as measured by maximal oxygen uptake rate (Astrand, 1967). Given the length of the playing season, physiological de-conditioning may occur (Hickson, 1980). If the proper stimulus of overload, progression, and movement patterns are not maintained, one can presume that detraining effects may occur during the course of a football season.

The identification of specific physiological variables that change over the course of the competitive season needs to be further investigated so that proper management of fitness can be maintained.

Statement of the Problem

The purpose of this study was to determine the fitness changes in Division I-A college offensive receivers during a 16-week competitive season.

Approach to the Problem

Ten offensive football players in the receiver positions from San Jose State University were measured before and after the playing season to access the following physiological variables: body somatotype ratings of linearity-fatness (X) and muscularity (Y), leg strength (LS), arm strength (AS), shoulder strength (SS), anaerobic power (AP), anaerobic capacity (AC), fatigue index (FI), flexibility, body weight (BW), fat weight (FW), fat-free weight (FFW), musculoskeletal size (FFW/Ht), maximal oxygen uptake rate (VO2max), ventilatory threshold (VAT), and ventilatory threshold relative to maximal oxygen uptake rate (%VO2max).

Null Hypotheses

The null hypotheses included the following statements.

1. There will be no significant differences in bi-dimensional somatotype ratings of linearity-fatness (X) and muscularity (Y) between the pre-season and post-season measures.

2. There will be no significant differences in extension and flexion strength of the arm, shoulder, and leg between pre-season and post-season measures.

3. There will be no significant differences in anaerobic power (AP), anaerobic capacity (AC), and fatigue index (FI) between pre-season and post-season measures.

4. There will be no significant difference in flexibility between pre-season and post-season measures.

5. There will be no significant differences in total body weight (BW), relative fat (RF), fat weight (FW), fat-free weight (FFW), and musculoskeletal size (FFW/Ht) between pre-season and post-season measures.

6. There will be no significant differences in maximal oxygen uptake rate (VO2max), ventilatory threshold (VAT), and ventilatory threshold relative to maximal oxygen uptake rate (%VO2max) between pre-season and
post- season measures.

Assumptions

This research study contained the following assumptions.

1. Each athlete responded similarly to the research environment and experiments.

2. Each subject gave his best effort on the field and in the laboratory.

3. Each subject was highly motivated on the field and in the laboratory.

4. Each subject was directly involved in practice sessions and received similar intensities, frequencies, and durations of practice during practice sessions and received similar amounts of playing time during the 16-week study period.

Delimitations

The following factors were delimited in this study.

1. This study was delimited to 10 Division I-A college offensive-football players who ranged in age from 18 to 24 years in the receiver positions which included slot receivers, wide-receivers, and tight ends.

2. The study was delimited to the 16-week, Fall 1990-91 competitive season.

3. The game statistic variables included total number of receptions in a season, total passing yards in a season, average passing yards per game, and total passing touchdowns in a season.

4. The physiological parameters were restricted to bodybuild characteristics which included the bi-dimensional body somatotype ratings of linearity-fatness (X) and muscularity (Y); muscular strength measures which included extension and flexion strength of the arm, shoulder, and leg; anaerobic work indices which included anaerobic power (AP), anaerobic capacity (AC), and fatigue index

(FI); measurement of flexibility; body composition which included body weight (BW), relative fat (RF), fat weight (FW), fat-free weight (FFW), and musculoskeletal size (FFW/Ht); and aerobic work indices which included maximal oxygen uptake rate (VO2max), ventilatory threshold (VAT), and ventilatory threshold relative to maximal oxygen uptake rate (%VO2max).

Limitations

The factors in this study which were not controlled included.

1. The degree of fitness of each athlete measured prior to pre-season testing.
2. The motivation level of each subject during the testing periods.
3. The genetic make-up of the subject.
4. Sleep loss and improper recovery periods prior to testing.
5. Medications and substances used including alcohol, tobacco, and caffeine consumption prior to each testing period.

Operational Definitions

The following definitions were listed for terms used in this research study.

Anaerobic capacity (AC). Anaerobic capacity reflected the glycolytic (lactic) component and the alactic component of energy release (Tharp, Newhouse, Uffelman, Thorland, & Johnson, 1985).

It represented the total work/time (kgm/30-sec) and was calculated by the following formula: (0.075 kg leg resistance x kg of body weight x 6 x the number of revolutions of the flywheel in a 30-sec period) (Bar-Or, 1978; Tharp et al., 1985).

Anaerobic power (AP). Anaerobic power reflected the alactic phosphagen portion of anaerobic energy release (Tharp et al., 1985). It was calculated as the highest work performed during any 5-sec period (kgm/5-sec) from the following formula: (0.075 kg resistance legs x kg of body weight x 6 x the highest number of revolutions of the flywheel in a 5-sec period) (Bar-Or, 1978; Tharp et al., 1985).

Body density (Db). Body density was the weight of the body per unit of body size (kg/l) and is calculated with the following formula: body density = body weight / body volume (Fox & Mathews, 1981).

Body somatotype ratings (X & Y). Body somatotype ratings were defined by coordinates X and Y. It was composed of a coordinate grid superimposed over a somatochart. Individual coordinate points can be plotted on the chart using the following formulas: X = ectomorphy - endomorphy, and Y = (2 x mesomorphy) - (endomorphy + ectomorphy). Variable X was a descriptive measure of linearity-fatness and variable Y was a descriptive measure of muscularity (Ross & Wilson, 1973).

Body volume (BV). Body volume was the size of the body expressed in liters and was calculated by the formula: body volume

= [(body weight - true underwater weight) / water density] - residual volume (Fox & Mathews, 1981).

Body weight (BW). Body weight was the total weight of all body tissues expressed in kilograms (kg).

Fat weight (FW). Fat weight reflected the portion of body weight consisting of adipose tissue other than essential fat (Brozek, Grande, Anderson, & Keys, 1963). It was calculated with the following formula: fat weight = body weight x relative fat.

Fatigue index (FI). Fatigue index was a reflection of the oxidative capacity of the muscles. A higher FI indicated a greater proportion of fast-twitch fibers and a lower FI indicated a greater proportion of slow twitch fibers in the muscles (Inbar et al., 1979). It was calculated as follows: fatigue index = [(highest 5-sec power for legs - lowest 5-sec power for legs) / highest 5-sec power for legs] x 100 (Bar-Or, 1983).

Fat-free weight (FFW). Fat-free weight was the kg of body weight that was composed of lean tissues plus essential fat (Brozek et al., 1963). It was calculated by the formula: fat-free weight = body weight - fat weight.

Leg strength, arm strength, and shoulder strength (LS, AS, and SS). Leg, arm, and shoulder strength were the absolute peak torque values expressed in ft-lbs for the dominant leg and arm, in full extension and flexion movements at 60 degrees/sec (Isokinetic-joint testing & exercise: A handbook for Cybex II+ and U.B.X.T., 1983).

Maximal oxygen uptake rate (VO2max). Maximal oxygen uptake rate was determined as the greatest volume of oxygen used by the cells of the body per unit of time (l/min) and expressed by body weight (ml/kg/min) (Saltin & Astrand, 1967). In this study VO2max was determined as the highest oxygen uptake rate achieved during a maximal treadmill test when (a) a heart rate was within 10 beats per minute of age predicted maximum heart rate, (b) respiratory quotient (RQ) was 1.0 or greater, and/or (c) a plateau or decrease in oxygen uptake rate was observed when workload increased (Fox & Mathews, 1981).

Musculoskeletal size (FFW/Ht). Musculoskeletal size characterizes body physique based on the ratio of fat-free weight (kg) to height (cm) (Slaughter & Lohman, 1980).

Offensive receiver. An offensive receiver position was located at varying distances away from the ball, but aligned outside each tackle position. A player in this location was eligible to cross the line of scrimmage during a play potentially receiving a forward pass and was referred to as a wide receiver, slot receiver, or tight end (Rasnick, 1990).

Profile/characterization. A profile was a gathering of information about the physical attributes of athletes (Nicholas, 1984).

Relative fat (RF). Relative fat was the portion of total body weight composed of adipose tissue and was calculated from this formula for white athletes: $RF = [(4.57/Db) - 4.142] \times 100$ (Brozek et al., 1963), and for black athletes from this formula: RF = [(4.374/Db) - 3.928] x 100 (Schutte et al., 1984).

Residual lung volume (RLV). Residual lung volume was the volume of air left in the lungs after a maximal exhalation. This volume was taken into account when determining body composition by hydrostatic weighing (Pollock & Wilmore, 1984).

Respiratory quotient (RQ). Respiratory quotient was determined as the ratio of carbon dioxide production rate (VCO2) to oxygen uptake rate (VO2). An RQ value of 1.0 means that only carbohydrate was being burned as fuel and the subject was near maximal oxygen uptake rate (Brooks & Fahey, 1984).

Skill position. A skill position was defined as an offensive position which specializes in receiving the football during a forward pass.

Ventilatory threshold (VAT). Ventilatory threshold was the onset of metabolic acidosis (anaerobic metabolism) and was identified by the oxygen uptake value (l/min) at the point of (a) a nonlinear increase in ventilation (VE), (b) a nonlinear increase in carbon dioxide production (VCO2), and (c) an increase in the fraction of oxygen in the expired air (FEO2) without a concomitant decrease in the fraction of carbon dioxide in the expired air (FECO2) (Wasserman, Whipp, Koyal, & Beaver, 1973). Ventilatory threshold was identified in this study as the last oxygen uptake value fitting a linear trend when ventilation (VE) was plotted against oxygen uptake rate (VO2) (Cisar, Thorland, Johnson, & Housh, 1986). Ventilatory threshold relative to maximal oxygen uptake rate (%VO2max) was identified as the ratio of VAT/VO2max.

Significance of the Problem

Identifying football performance into characteristic profiles has increased over the past few years (Gleim, 1984). By isolating these specific variables before and after the season, seasonal performance traits become evident and translate into heterogeneity within each position. Since the football season requires an athlete to peak in performance weekly, the length of the season necessitates careful manipulation of training to avoid deterioration in performance, especially during the latter part of the season and during the end of the 2nd and 4th quarters when injuries may become more prevalent (Zemper, 1989). This study attempted to isolate those performance parameters that are influenced by the playing season.

CHAPTER II

Review of Literature

Introduction

This chapter focuses on literature reviewing the performance demands of football, the physiological characteristics of offensive receivers and their relationship to other positions, anaerobic performance characteristics, and research studies investigating the physiological effects of a playing season with an emphasis on offensive receivers.

Performance Demands of Football

Football is a series of intense, short-term, and explosive movements interspersed with intermittent recovery periods between plays. Fox and Mathews (1981) suggest that this type of activity is highly anaerobic and produces the greatest energy from a combination of adensoine triphosphate-creatine phosphate (i.e., phosphagen or ATP-PC) and anaerobic glycolytic (i.e., lactic acid or LA) processes. As much as 80% of the relative energy is generated from the anaerobic processes and the remaining 20% from oxidation. Similarly, others have identified the phosphagen-lactic acid system as the predominate energy system for football performance (deVries, 1980; Gleim, 1984; Marks, 1983; Wilmore et al., 1976). However, improvements in football performance come from enhancing the capacity of the phosphagen energy system rather than the anaerobic glycolytic and/or aerobic processes (Kraemer, 1984). Since potential power is relatively greater when utilizing the ATP-PC system and an essential component to football performance, a reliance on aerobic conditioning may impede the ability of the phosphagen energy system and diminish its efficiency (Hickson, 1980; Ono et al., 1976; Tesch, 1984).

In-season conditioning programs would seem appropriate if selective recruitment of muscle fibers that engage large amounts of force per unit of time (i.e., power) were specified in simulated drills during practice. A selective recruitment of muscle tissue would result in an increase in force production, especially since fast-twitch glycolytic fibers have been identified as possessing a high degree of anaerobic characteristics (Astrand, 1987; Costill et al., 1976).

Rather than stress-sustained contractions over a longer period of time, football conditioning develops absolute muscular endurance (AME). Absolute muscular endurance is the ability to maintain a given fixed submaximal force output during work that relies primarily on anaerobic metabolism (Stone, 1984; Tesch, 1984). This characterizes the style of football performance (Goldstein, 1989; Mark, 1983; Semenick, 1984).

Interval training has been recommended for football players as a means to achieve increases in anaerobic performance and AME (Wilson & Wagner, 1987). However, a high reliance on anaerobic energy production results in lactate accumulation within the tissues and a concomitant decrease in muscle and blood hydrogen-ion concentrations. This response inhibits the enzymes phosphorylase and phosphofructokinase (PFK) which are important for glycolysis to continue and subsequent regeneration of ATP molecules. An increase in hydrogen ion (H+) concentration as a result of the build-up of lactate acid directly interferes with the actin/myosin cross-bridge formations, and produces a fatigued state and a loss of power output (Astrand, 1987). To counterbalance the accumulating metabolites which result from anaerobic performance, the cardiorespiratory system eliminates lactate through oxidation and delivers oxygen more efficiently to the organism for continued regeneration of ATP and resultant muscle contraction (Stone & Newton, 1984). The onset of fatigue would be delayed if oxygen efficiency were enhanced, thus preventing possible injuries that may occur in the later part of the 2nd and 4th quarters when fatigue is at its highest state (National Athletic Trainers' Association, 1989; Zemper, 1989).

Nevertheless, cardiorespiratory endurance does not play a significant role in determining the efficacy of a receiver's performance and as a result is a neglected training component during the competitive season (Hoette et al., 1986; Parr, Wilmore, Hoover, Bachman, & Kerlan, 1978; Wilmore et al., 1976). A review of literature was conducted to investigate the physiological parameters that characterize football performance with an emphasis on the receiver positions.

Studies Investigating Aerobic Endurance

Aerobic capacity is an indication of cardiorespiratory adaptation to exercise since it is a measure of the maximal amount of oxygen that is supplied and extracted by muscle tissue (Fox & Mathews, 1981). Oxygen uptake rate and the amount of work performed have a linear relationship (Taylor, Buskrik, & Henschel, 1955). Thus, maximal oxygen uptake rate (VO2max) as expressed in ml/kg/min is considered one of the most objective measures by which one can determine the cardiorespiratory fitness of individuals (Astrand, 1967). VO2max was first characterized in competitive athletes from the Swedish National Team which represented 28 different sporting events (Saltin & Astrand, 1967). The highest VO2max recorded was 85.1 (ml/kg/min) in a cross-country skier while the lowest VO2max value recorded was 44.0 (ml/kg/min) in a sedentary individual. The characteristic anaerobic-type sports (i.e., wrestlers, bodybuilders, shot putters, and discus throwers) were categorized as possessing relatively lower VO2max values while the endurance events exhibited a more enhanced aerobic characteristic. Similarly, oxygen uptake rate has been categorized in track and field which ranged from power events to running events (Costill et al., 1976; Costill, Fink, & Pollock, 1976). The strength-trained athletes such as shot putters and discus throwers exhibited lower (55 ml/kg/min) VO2max values than the endurance-trained athletes such as 800-1500m runners (75 ml/kg/min) and long distance runners (77 ml/kg/min). Thus, performance may be characteristically classified based on the predominant energy system being used.

Weight-trained athletes may have aerobic capacities most comparable in physiological parameters to football players. Fahey, Akka, and Rolph (1975) examined VO2max in 30 athletes representing shot putting, discus throwing, bodybuilding, power lifting, wrestling, and Olympic lifting. VO2max was measured during an incremental bicycle ergometer test to exhaustion. When expressed relative to body weight (kg), the highest values were found in the wrestlers (64.0 ml/kg/min) and the lowest in the bodybuilders (41.5 ml/kg/min). Even when expressed in terms of fat-free weight (FFW), the highest values still were recorded in the wrestlers (70.1 ml/kgFFW/min) and the lowest in the bodybuilders (45.0 ml/kgFFW/min). The authors speculated that as the trend for cardiovascular performance increased from typically anaerobic events (e.g., power lifting) to more aerobic events (e.g., wrestling), so did the heterogenenity between groups of athletes in each sport.

In addition, soccer and basketball performance might be comparable to the metabolic energy demands of football players, particularly in the skill positions. Offensive receivers intermittently sprint to a pre-determined zone or specific route either as a primary target for the quarterback or to widen the defensive team, which is then followed by frequent periods of continuous jogging. Although soccer and basketball performance may require periods of intermittent sprinting, the total work over the course of a game is discontinuous. Gettman, Pollock, and Raven (1977) profiled the physiological performance of 18 professional athletes from the Dallas Tornado Soccer Team. VO2max during a progressive treadmill test to exhaustion was measured. The average VO2max value recorded for all subjects was 58.4 ml/kg/min.

On the other hand, Parr et al. (1978) characterized 34 professional basketball players from three positions. Four centers, 15 forwards, and 15 guards had their VO2max measured during a progressive treadmill test to exhaustion. When expressed in terms of body weight, the guards were higher (50.0 ml/kg/min) than the forwards (45.9 ml/kg/min) and centers (41.9 ml/kg/min). Although the guards reflect an enhanced oxygen utilization characteristic of the style of play and the amount of ball handling required for that position, the overall oxygen uptake values for all positions were lower than expected, possibly due to a high ventilatory threshold. Even though ventilatory threshold was not measured, the authors concluded that basketball players are performing at a higher percentage of their maximum capacity than most athletes, and that basketball players rely on skill and execution rather than on cardiovascular endurance.

This literature review found several research studies that attempted to characterize football performance by determining aerobic capacity (see Table 1). Novak et al. (1968) compared the VO2max of 16 college football players to 10 baseball players, 7 swimmers, 9 track men, and 7 gymnasts. The football players on the average were taller and heavier than the other groups and as a result, exhibited the lowest mean maximal oxygen uptake rate values (51.3 ml/kg/min), while the shorter and leaner groups exhibited higher values (i.e., gymnasts = 55.5, swimmers = 62.1, and trackmen = 66.1 ml/kg/min). This suggests that specific metabolic energy demands may play a role in athletic performance, where higher VO2max values are evident in characteristically endurance-trained events.

Kollias et al. (1970) attempted to characterize the difference in VO2max between players in positions typically involved with the ball and those indirectly involved in producing the play. Maximal oxygen uptake rate was determined in 27 members of two 1970 Pennsylvania "Big 33" high school football squads using a progressive treadmill test to exhaustion. The subjects were split into two groups: linemen and linebackers (n = 12); and ends and backs (n = 13). The mean absolute values for the end and back positions

Table 1

Selected Summary Data on Bodybuild Characteristics and Maximal Oxygen Uptake Rate of Offensive Receivers

Author (s)	Level	n		Age (yr)	Height (cm)	Weight (kg)	VO2max (ml/kg/min)
Wilmore et al. (1972)	Pro	10	M =		184.20	91.80	52.40
Wilmore et al. (1976)	Pro	40	M =	24.70	183.80	90.70	52.20
			SD =	3.00	4.10	8.40	5.00
Gleim et al. (1981)	Pro	6	M =	22.50	186.00	104.70	43.40
			SD =	0.50	5.00	13.00	4.30
Hoette et al. (1986)	Pro	16	M =	24.00		84.50	63.00
Novak et al. (1968)	College	16	M =	20.30	184.95	96.40	51.30
			SD =	.92	4.70	10.84	4.30
Smith et al. (1976)	College	5	M =	20.20	181.50	83.10	60.20
			SD =	3.27	10.14	3.24	4.30
Kollias et al. (1970)	H. S.	13	M =	17.70	183.00	83.30	49.90
			SD =	0.60	6.00	8.50	4.40

were significantly ($p \leq .05$) lower (4.14, range 3.30-5.04 l/min) compared to the higher (4.76, range 4.01-5.68 l/min) line and linebacker positions. However, when compared on the basis of body weight, both groups had relatively similar VO2max values (line and linebackers 49.8, range 41.2-61.9 ml/kg/min vs. ends and backs 49.9, range 45.0-59.3 ml/kg/min). The authors speculated that the end and back positions require greater elements of speed, power, and agility, but not neccessarily aerobic capacity when expressed relative to body weight.

Wilmore and Haskell (1972) characterized 15 professional football players for endurance capacity. Subjects were divided into five playing categories: defensive backs, offensive backs and receivers, linebackers, offensive linemen and tight ends, and defensive linemen. When VO2max was expressed in terms of body weight, the offensive backs and receivers had relatively higher VO2max values (52.4 ml/kg/min) than the total mean value for all positions (50.1, range 40.1-60.0 ml/kg/min). The athletes in the receiver position were found to reflect positional characteristics in which a greater functional demand is required where more athletic ability and skills challenge defensive tactics. The authors found no significant difference between positions for endurance capacity and speculated that high VO2max values in football players are not of major significance to performance.

Similarly, Wilmore et al. (1976) investigated the aerobic capacity of 185 professional football players representing 14 teams. Subjects were divided into six positional categories: defensive backs, offensive backs and wide receivers, linebackers, offensive linemen and tight ends, defensive linemen, and quarterbacks and tight ends. Maximal oxygen uptake rate was determined on a motor driven treadmill to exhaustion. In relative terms, the highest average VO2max, in order, was attained by the defensive backs (53.1 ml/kg/min), offensive backs and wide receivers (52.2 ml/kg/min), and linebackers (52.1 ml/kg/min). The defensive linemen (44.9 ml/kg/min), the quarterbacks and kickers (49.0 ml/kg/min), and the offensive linemen and tight ends (49.0 ml/kg/min) recorded the lowest values. The positional demands at the defensive back and offensive back positions may reflect a greater need for a higher functional aerobic capacity.

Likewise, 27 college football players from Florida State University were assessed for aerobic endurance (Smith & Byrd, 1976). VO2max was measured using a continuous multistage treadmill test after 20 days of Spring practice. Subjects were grouped into four categories: offensive backs, defensive backs, offensive linemen, and defensive linemen and linebackers. When expressed in terms of body weight the offensive backs and defensive backs showed the highest VO2max values (60.2 and 59.3 ml/kg/min, respectively). With VO2max expressed in terms of fat-free weight, the offensive back group similarly exhibited the highest (70.0 ml/kgFFW/min) value compared to the defensive backs (65.4 ml/kgFFW/min), offensive linemen (65.4 ml/kgFFW/min), and the lower defensive linemen and linebackers (61.8 ml/kgFFW/min).

Since work and oxygen uptake exhibit a linear relationship, Gleim et al. (1981) attempted to assess indirectly the cardiovascular demands on six professional football players during practice using a telemetric electrocardiographic (ECG) monitor. The purpose of the study was to determine the strength of the relationship between measured aerobic endurance and performance heart rate. VO2max was assessed on a progressive treadmill test to exhaustion. The six players represented a variety of positions including: one defensive back, two running backs, one linebacker, one defensive tackle, and one offensive tackle. The lowest heart rate recorded during the treadmill test was exhibited by the linebacker (172 b/min) and the highest by a running back (195 b/min). The telemetry results for average maximal heart rate (HRmax) during practice was 192.3 $\pm$ 13.5 b/min with the highest value coming from the defensive back (211 b/min) and the lowest from a running back (175 b/min). The reported mean VO2max value was 43.4 ml/kg/min. The authors found that heart rates greater than 140 b/min recorded during telemetry for all subjects were attained less than 48.8 $\pm$ 19.3% of the time. The highest duration of time greater than 140 b/min was achieved by the defensive tackle (71%) and the least amount of time spent above 140 b/min was recorded by a running back (24%). The authors suggested that the higher mean HRmax responses during practice (192.3 $\pm$ 13.5 b/min) when compared to the lower mean HRmax responses on the treadmill test (184.6 $\pm$ 7.8 b/min) were influenced by factors other than workloads. Furthermore, the authors concluded that the total mean VO2max values were at or below normal sedentary populations and that cardiovascular endurance plays an insignificant role in the efficacy of a player's performance during the initial stages of practice, but may become a greater factor than expected during the latter part of practice when the athlete is fatigued and risk of injury is greater.

Hoette et al. (1986) investigated the cardiac function and physical responses of 146 professional football players (aged 22-37 yrs) representing all offensive and defensive positions, prior to the start of the regular season. The purpose of this study was to assess VO2max and dysrhythmia during a graded treadmill exercise test to exhaustion. Subjects were divided into nine categories by positions. With regard to VO2max, the highest VO2max was attained by the quarterbacks (67 ml/kg/min) and the lowest by the offensive linemen (55 ml/kg/min). The flanker position achieved a VO2max value of 63 ml/kg/min. The team average HRmax was 176.22 b/min (range 179-171 b/min). The authors concluded that skill positions that utilize cardiovascular endurance during training may sustain higher performance levels throughout the game with relatively less effort.

To summarize, the literature reported that maximal oxygen uptake rate (VO2max) expressed in ml/kg/min was considered to be the most objective measure of cardiorespiratory fitness. The maximal oxygen uptake rate was found to be the highest in aerobic events such as cross-country skiing, long distance running, and 800 and 1500m running events. The lowest VO2max values were found to be associated with sedentary, inactive individuals. Offensive receivers reported in the literature exhibited similar VO2max values to soccer, wrestling, gymnastic, track and field, and basketball athletes. The mean range in VO2max for college offensive receivers was 51.3 to 60.0 ml/kg/min, while the mean range in VO2max for professional offensive receivers was 43.4 to 63.0 ml/kg/min. In the literature review, both offensive and defensive backs were found to be similar in aerobic capacity to offensive receivers.

Studies Investigating Bodybuild Characteristics

The offensive receiver is a member of a select group of the total football population in regard to body composition and bodybuild. Obtaining a knowledge of physical characteristics of the various types of athletes representing different positions provides information on the structural requirements for success in specific tasks as well as measures of the differences between tasks (Carter, 1970). Selected studies reviewing body weight (BW), fat weight (FW), fat-free weight (FFW), body density (Db), body somatotype ratings and bodybuild characteristics of football players were examined. Studies examining the physical characteristics of offensive receivers are presented in Table 2.

Welham and Behnke (1942) were the first to examine specific gravity in 25 professional football players. The purpose of the study was to demonstrate the difference between overweight and obesity. Their results showed that offensive and defensive backs were lighter in body weight (85.7 kg) in comparison to the heavier offensive and defensive linemen (97.1 kg). The backs as a group averaged lower relative fat (7.1%), fat weight (6.1 kg), and fat-free weight (79.6 kg) when compared to the heavier linemen (relative fat = 14%, fat weight = 14.1 kg, fat-free weight = 83.1 kg). The average values for height (183.1 cm) and body weight (91.2 kg) were attained for all athletes with a total mean body density of 1.080 g/ml (range, 1.051-1.097 g/ml). The authors concluded that the taller and heavier football players were more dense 1.080 g/ml when compared to the average body density of 1.056 g/ml found in relatively ideal body-type Navy personnel.

Carter (1968) described the physical characteristics and body somatotypes of Division I-A college football players by position. Thirty-five San Diego State players representing the positions of offensive back, defensive back, offensive lineman, and defensive lineman were evaluated. When similar positional groups were compared (e.g., offensive backs to defensive backs and the offensive

Table 2

Selected Summary Data on Bodybuild Characteristics and Body Composition of Offensive Receivers

Author (s)	Level	n		HT (cm)	BW (kg)	RF (%)	FW (kg)	FFW (kg)
Wilmore et al. (1972)	Pro	10	M =	184.2	91.80	8.30	7.70	84.10
Wilmore et al. (1976)	Pro	40	M =	183.8	90.70	9.40	8.70	81.90
Gleim (1984)	Pro	146	M =	183.0	90.70	9.60	9.40	81.30
Novak et al. (1968)	College	16	M =	184.9	96.42	13.83	13.84	82.58
Wickkiser et al. (1975)	College	15	M =	179.7	79.80	12.40	10.20	69.60
White et al. (1980)	College	17	M =	179.5	81.85	11.50	9.61	72.24
Smith et al. (1984)	College	14	M =	182.1	89.10	7.80	7.10	82.10
Millard-Stafford et al. (1989)	College	18	M =	183.9	91.60	10.90	11.40	80.20
Kollias et al. (1970)	H.S.	15	M =	183.0	83.30	13.70	6.08	77.22

Note. HT = height, BW = body weight, RF = relative fat, FW = fat weight, FFW = fat-free weight.

linemen to defensive linemen), no significant differences in height, body weight, and somatotype ratings were found; however, the defensive linemen were significantly ($p \leq .05$) shorter (2.66 in) than the offensive linemen. However, when the physical characteristics between dissimilar positions were compared (i.e., backs to the linemen), backs were significantly ($p \leq .05$) shorter in height (-1.82 in) and lower in body weight (-33.06 lb). No significant differences between the backs and the linemen existed for body somatotype ratings. Overall, the results also suggested that major college football players were characterized as endomorphic and mesomorphic. Thus, possession of this type of bodybuild may be the distinguishing factor for selection to Division I-A participation. (Table 3 summarizes the reported data on body somatotype ratings for offensive receivers.)

Body composition was compared between 16 football players and 10 baseball players, 7 swimmers, 9 track men, and 7 gymnasts from the University of Minnesota Intercollegiate Athletic teams (Novak et al., 1968). In comparison, football players were taller and heavier than all groups. The football players, in addition, possessed higher average relative fat (13.83 $\pm$ 6.69%), fat weight (13.84 $\pm$ 8.04 kg), body weight (96.42 $\pm$ 10.84 kg), and fat-free weight (82.58 $\pm$ 6.16 kg) than the swimmers, trackmen, and gymnasts. Also, the percentage of fat-free weight was lowest for the football players. The authors speculated that body composition profiles for football

Table 3

Selected Summary Data on Body Somatotype Ratings of Offensive Receivers

				Somatotype		
Author (s)	Level	n		Endomorphy	Mesomorphy	Ectomorphy
Carter, (1967)	College	12	M	= 4.46	5.46	2.25
Votto, (1975)	College	5	M	= 3.60	4.20	2.80
			SD	= .90	1.20	.80
Wilmore et al. (1976)	Pro	40	M	= 3.50	6.20	1.60
			SD	= 1.60	1.50	.80

players were characteristic of the type of sport and performance demands observed in football, where a great deal of focus during training is to generate explosive power in a limited time.

Body composition profiles between positions were determined from a select group of 32 high school players divided into two groups that included 17 linemen and linebackers, and 15 backs and ends (Kollias et al., 1970). Standard height and weight were measured along with skinfold measurements based on the sum of 10 sites. As a group, the backs and ends were smaller (186 vs. 187 cm), lighter (83.3 vs. 96.0 kg), and leaner (13.7 vs. 17.6%) than the linemen and linebackers. The differences between the measured values for the two groups were significant at $p \leq .05$. The results suggest that body composition characteristics of athletes in the skill position may be a factor underlying successful performance at the high school level.

Wilmore and Haskell (1972) assessed body composition in 44 professional football players representing each offensive and defensive position with the exception of the quarterback, placekicker, and punter. Body composition was assessed by hydrostatic weighing. Residual lung volume was assessed using the closed-circuit oxygen-dilution method. The defensive and offensive backs and receivers were similar in terms of height, body density, and relative fat, although the defensive backs averaged 6.8 kg less body weight and

5.7 kg less fat-free weight than the offensive backs and receivers. The average values for all offensive backs and receivers was 184.2 cm for height, 91.8 kg for body weight, 8.3% for relative fat, 7.7 kg for fat weight, and 84.1 kg for fat-free weight. The higher weights and size values measured for the offensive backs and receivers were in contrast to the lower weights and angularity measured for the defensive backs. The dissimilarities were presumed to distinguish positional characteristics. Offensive receivers rely on considerable power to maintain forward movement and momentum, which necessitates a certain degree of size and speed. Defensive backs must rely on agility, speed, and maneuverability. Excessive body weight would reduce their speed of movement. The defensive back is characterized by his angularity; the offensive back has the same height, but a more powerful build.

Wickkiser and Kelly (1975) investigated the body composition of 65 Division II college football players. Subjects were divided into five categories as follows: defensive backs, offensive backs and receivers, linebackers, offensive linemen and tight ends, and defensive linemen. Body composition was assessed for all subjects by the hydrostatic weighing technique. Residual lung volume was determined by the closed-circuit oxygen-dilution method. Anthropometric measurements were determined by skinfold, diameter, and girth measurements. The mean physical characteristics for the offensive back and receiver positions were

179.7 cm for height, 79.8 kg for body weight, 12.4 kg for relative fat, 1.071 g/ml for body density, 10.2 kg for fat weight, and 69.6 kg for fat-free weight. Analysis of variance was used to determine if the five subgroups were significantly different in their physical characteristics. The mean differences were significant ($p \leq .01$) when comparing the backs with the linemen; however, no significant differences were found between the offensive and defensive backs or between the offensive and defensive linemen. The authors suggested that these differences support the division of football players into at least two groups, backs and linemen. Based on body composition differences between backs and linemen, one regression equation for the prediction of body density from anthropometric measures was developed for the backs and receivers, and a separate equation for the linemen, linebackers, and tight ends. For the backs, a high correlaton ($r = .97$) was found between body density and four independent variables (abdomen, thigh, and tricep skinfolds, and wrist diameter).

Twenty-seven Division I-A football players at Florida State University representing all positions except the kicking specialists were assessed for body composition (Smith & Byrd, 1976). Subjects were divided into four categories: offensive backs, defensive backs, offensive linemen, and defensive linemen and linebackers. Body composition was estimated for all subjects using a multiple regression equation: (FFW = [44.636 + 1.0817(BW) - 0.7396 X]).

FFW is fat-free weight (kg), BW is body weight (kg), and X is the circumference of the abdomen at the level of the iliac crests. The mean $\pm$ SD physical characteristics for the offensive back group were 181.5 $\pm$ 10.14 cm for height, 83.1 $\pm$ 3.24 kg for body weight, 13.8 $\pm$ 5.27% for relative fat, and 71.6 $\pm$ 3.76 kg for fat-free weight. The defensive backs were significantly ($p \leq .05$) leaner than the other three categories of players; however, fat-free weight and total body weight of offensive and defensive backs were similar. The same measurements between the offensive and defensive line positions were also similar, but in comparison to the offensive and defensive back positions, the skill positions were significantly ($p \leq .05$) lower in fat-free weight and total body weight.

One hundred and eighty-five professional football players representing 14 teams were evaluated for body composition (Wilmore et al., 1976). Subjects were categorized into six groups: defensive backs, offensive backs and receivers, linebackers, offensive linemen and tight ends, defensive linemen, and quarterbacks and kickers. Body composition was assessed by hydrostatic weighing. Residual lung volumes were assessed using the nitrogen dilution technique. Defensive backs and offensive backs were relatively similar in height, relative fat, and fat weight. The offensive backs weighed 5.9 kg more and their fat-free weight was 5.4 kg heavier than the defensive back group. In comparison to the other groups, offensive and defensive backs were more muscular and had lower relative fat, both of which are important elements for the positions that require speed, power, agility, and maneuverability.

Somatotype ratings and physical performance characteristics were evaluated in 23 members (age = 18-22 yrs) of the 1975 National Champion, University of Oklahoma football team (Votto, 1976). The athletes were divided into five playing positions as follows: defensive backs, offensive backs and wide receivers, linebackers, offensive linemen and tight ends, and defensive linemen. The physical performance variables assessed were anaerobic power, treadmill run time to exhaustion, trunk flexibility, and body somatotype ratings. The author found no significant differences between positions in height, body weight, flexibility, or body somatotype ratings. All players resembled an endomorphic-mesomorph somatotype rating which appeared to reflect the emphasis in weight training. The offensive backs and wide receivers were similar in endomorphic somatotype compared to their defensive back counterparts (3.6 vs. 3.5); however, the defensive backs were higher in mesomorphic somatotype (5.5 vs. 4.2). Players from both positions were relatively similar in ectomorphy (2.1 vs. 2.8). The total team somatotype was determined to be predominantly endomorphic and mesomorphic (4.2-5.4-1.9). In addition, no significant difference was found between the players from the two positions in flexibility; although the offensive backs and wide receivers were the most flexible (4.3 ± 2.0 in) of all the positions. Only the defensive backs were significantly ($p \leq .05$) different when compared to the offensive linemen and tight ends on treadmill run time to exhaustion (16.36 vs. 12.53 sec). Treadmill run time to exhaustion for the offensive backs and wide receivers was not significantly different when compared to the offensive linemen and tight ends, and ranked third in overall run time to exhaustion behind the linebackers and defensive backs (13.45 vs. 13.92 vs. 16.36 min). Both offensive backs and wide receivers and defensive backs were significantly ($p \leq .05$) lower (2007 and 1965 ft-lb, respectively) in anaerobic power when compared to offensive linemen and tight ends (2330 ft-lb). The author concluded that both the defensive and offensive backs and the wide-receivers reflected significantly higher anaerobic capacities and higher treadmill performance run times than the linemen. Although the skill positions exhibited greater anaerobic capacities, the line positions produced significantly higher amounts of explosive anaerobic power. Thus, a higher anaerobic capacity which is characteristic of the skill positions appears to parallel the greater requirements for mobility and speed. On the other hand, the larger and less agile linemen were capable of producing higher amounts of anaerobic power, but were unable to sustain anaerobic capacity or speed as reflected by their lower treadmill run time to exhaustion values. Therefore, optimizing anaerobic capacity in the receiver positions throughout the season appears warranted for successful performance.

Fifty-eight football players from the 1977 Northeast Missouri State University team were assessed for bodybuild and body composition (White, Mayhew, & Piper, 1980). Body composition was determined by underwater weighing throughout the season on Fridays preceding Saturday's competition. Residual lung volume was estimated as 24% of the vital capacity, measured on a Collins 13-liter spirometer. The athletes were divided into five categories. Significant ($p \leq .05$) differences existed between the offensive and defensive backs and the offensive and defensive linemen for body weight, fat-free weight, relative fat, and body density. No significant differences were either found within the backfield positions or between the line specialties. The offensive backs and defensive backs were similar in height and fat-free weight (179.5 vs. 178.9 cm and 72.24 vs. 72.00 kg, respectively), but the offensive backs weighed more (81.85 and 77.76 kg) and possessed greater relative fat (11.5 and 7.3%, respectively). Defensive backs were greater in body density than offensive backs (1.0844 vs. 1.0736 g/ml, respectively).

Gleim (1984) profiled 51 professional football players in each position from a National Football League roster during the 1979 season. The group was divided into four categorizes: offensive and defensive lines, tight ends and linebackers, offensive backs, and defensive backs and wide receivers. Body composition by hydrostatic weighing and anthropometric data by skinfold, diameter, and circumference measurements were attained. Relative fat determinations were made using an A-scale ultrasound device and by the equation: [0.172567(mmfat) + .046384(wt.lbs.) - 8.5606]. Physical characteristics for the defensive backs and wide receivers were significantly ($p \leq .01$) different from the other three groups. In comparison, the defensive back and wide receiver position tended to be shorter in height, lower in body weight, and lower in relative fat. A high correlation between the total measured millimeters of fat from the thigh skinfold and total leg strength (determined from the cumulative value attained on the Cybex II+ isokinetic dynamometer using leg extension/flexion and hip extension/flexion movement) was obtained ($r = .86$, $p \leq .01$). In addition, a high correlation ($r = .78$, $p \leq .001$) between total millimeters of fat obtained from skinfold measurements and 40-yard sprint time was found. The results support the concept that fatter players are slower. A discriminant analysis was used in an attempt to determine the variables which distinguished statistically the profile of positions within a football team. The best discriminating variables for positional classification of players were height; body weight; total millimeters of fat from eight skinfold measurements; chest, leg, and arm circumferences; and total leg strength. These variables correctly classified 90% of the players. The authors speculated that the differences between the combined defensive back and wide receiver group and the line groups represented opposite ends of the profile spectrum with fatness, strength, and size as discriminating characteristics in each position. Thus, the results indicate some degree of homogeneity by position within the heterogeneous professional football population.

Smith and Mansfeld (1984) determined body composition in 68 Division I-A football players from the University of Alabama (M age = 19.7 yrs). Body composition was measured by hydrostatic weighing. Residual lung volume was determined by the closed-circuit helium-dilution procedure. The physical characteristics for the offensive back positions were 182.1 cm for height, 89.1 kg for body weight, 7.8% for relative fat, 1.081 g/ml for body density, 7.1 kg for fat weight, and 82.1 kg for fat-free weight. In comparison to the defensive backs, offensive backs were similar in height, relative fat, and body density, but 5.9 kg heavier in body weight. In addition, offensive backs were found to carry greater fat-free weight than defensive backs, which would suggest that positional characteristics between these two positions exist. For example, offensive backs require more power off-the-line, forward movement and momentum, and strength, whereas defensive backs rely on speed, agility, and quickness to the ball.

Olson and Hunter (1985) compared 1974 to 1984 college football players to determine if actual differences in size, strength, and speed existed. The purpose of this study was to determine if any physical characteristics had changed during the 10-year period. Strength coaches from 46 Division I-A National Collegiate Athletic

Association Universities provided information on strength, speed, height, and body weight. The 1984 mean values reported for receivers were 189.74 cm for height and 90.42 kg for body weight. In comparison, the 1984 receivers were 3.2 cm taller and 1.47 kg heavier than the 1974 athletes. The ponderal index was utilized to determine the proportional height to body weight relationship between each group. The receivers of 1984 demonstrated a trend away from the more characteristically stocky players of 1974. The ponderal index was found to be higher for the 1984 athletes compared to the 1974 athletes (12.70 vs. 12.55), where a lower ponderal index indicated a player was carrying more body weight for his height. Positive changes in performance variables were as follows: 11% decrease in 40 yard sprint time (sec), 46% increase in the bench press, 56% increase in the squat lift, and a 33% increase in the power clean lift. The improvements in these selected performance variables reflect the advancement of strength and conditioning techniques used in today's programs.

Ninety-five NCAA Division I-A football players (M age = 17.23 yrs) were evaluated for body composition (Millard-Stafford et al., 1989). This investigation attempted to determine the coronary risk factors of football players from each position. The athletes were divided into six playing positions: offensive linemen, defensive linemen, offensive backs, defensive backs, receivers, and linebackers. Body density was determined by hydrostatic weighing and residual lung volume was measured using a closed-circuit rebreathing system. The receivers were 6.6 cm taller than the defensive backs, but 1.8 kg lighter in body weight. In addition, the receivers possessed 0.9 kg more fat-free weight and 1.8% less relative fat than the defensive backs. This study found receivers to be more linear and muscular than all other categories of players.

To summarize, the literature review found the offensive receiver to be unique members of a select group of athletes in comparison to the total football population in regards to body composition and bodybuild characteristics. The college offensive receivers were found to be taller, heavier, and less angular than college defensive backs. The differences were presumed to be related to positional requirements in which offensive backs and receivers rely on power to maintain forward movement and momentum, which necessitates greater muscle mass for force production. On the other hand, defensive backs must rely on agility, speed, and maneuverability, and excessive body weight would hinder their performance. The mean values reported in the literature for college receivers were 181.3 cm for height, 85.58 kg for body weight, 11% for relative fat, 9.57 kg for fat weight, 76.00 kg for fat-free weight, and 42 (kg/cm) for musculoskeletal size. Likewise, the mean values reported for the bi-dimensional scores of linearity-fatness (X) and muscularity (Y) were -1.51 and 3.11, respectively.

Studies Investigating Anaerobic Performance

Power may be defined as the ability to release maximum force in the fastest possible time as exemplified in the power events of track and field such as the high jump, long jump, shot put, discus, and hammer throw (Johnson & Nelson, 1969). Power production is also an important component for success in basketball and soccer where movements against a resistance in a minimum amount of time are indicative of speed (Parr et al., 1978; Wilmore et al., 1976). Moreover, power in football is an essential performance characteristic due to the explosive and intermittent nature of the game. The athletes with the greatest potential for power will have an advantage over their opponents' lack of speed and may anticipate their subsequent reactions. Therefore, offensive receivers who possess speed and power are required to cover a greater distance in a limited amount of time for the purpose of spreading out a defensive team to open up the ensuing running attack and to threaten the defense with the forward pass.

Costill et al. (1968) examined the maximum anaerobic power among 72 members from the Ball State University football team (age = 18-24 yrs). The purpose of the study was to determine the anaerobic capabilities by position to pre-selected ability classifications. All athletes were classified as either superior, average, or inferior performers by the coaching staff. They were then divided into five positions as follows: ends, tackles and centers, guards, backs, and inexperienced athletes. Maximum vertical velocity and anaerobic power were determined by run time up 10 steps at a height of 12.6 inches per step from a starting distance of 6.5 feet away from the first step. Vertical velocity was determined as the maximal time achieved while running up the 30 percent incline and anaerobic power was calculated from the subject's body weight, height of incline, and total time to complete the test. Vertical velocity was found to be significantly ($p \leq .05$) lower for the inferior ability group than for either the superior or average athletes. Likewise, significant ($p \leq .05$) differences were found between the three ability levels in weight, vertical velocity, and maximum anaerobic power with the superior ability group obtaining the highest measures. When comparisons were made among players from all five positions, the backs were significantly ($p \leq .05$) faster in vertical velocity than the other four positions. On the other hand, the tackles and centers produced significantly ($p \leq .05$) greater anaerobic power compared to the backs. A one-way analysis of variance was used to compare the players by ability group. Superior players were able to produce greater amounts of anaerobic power in less time than either the average or inferior groups. The authors concluded that leg and trunk power were distinguishing components of successful football performance.

The relationship between certain performance traits and success in football was studied by Wilhelm (1951). Sixty-five football players representing all positions were divided subjectively by the coaching staff into two categories: successful and unsuccessful players. Performance traits that were assessed included strength, power, structure, trunk flexibility, agility, endurance, balance, reaction time, speed, kinesthetic sense, finger dexterity, and mental vision. The author found no significant differences between the successful and unsuccessful players for height, body weight, arm flexion and extension girth, trunk flexion, endurance (cardiovascular), balance, or reaction time. However, significant ($p \leq .05$) differences were found in strength, power, and speed measures. The successful athletes were significantly stronger in right and left grip strength, leg and back lifts, total strength, calf circumference, 40-yard sprint times, vertical jump (power), and agility run times. The results of this study suggest that football players who are stronger in terms of dynamometric strength and possess greater speed and agility may be differentiating factors in the successful performance of football players. Correlational analysis ($r = .81$) revealed that the back lift, calf girth, and speed were the best items for distinguishing between successful and unsuccessful football players.

Power was the distinguishing performance variable which predicted starters from non-starters in 70 football players from the University of South Dakota in a study by Mayhew and Wolfe (1990). All players were measured for strength determined by a 1-RM bench press; power was determined from the power clean lift and vertical jump test; speed was determined from 10- and 40-yard sprint times; agility was determined from the Nebraska agility run; anaerobic capacity was determined as the average time for five 350-yard runs, with a 45 second rest between each run; and cardiovascular recovery time was determined from heart rate during the last 10 seconds of each rest period between runs. No differentiating variable was found between the starters and non-starters in height, body weight, leg strength, total strength, agility time, and 40-yard sprint time. However, the starters were significantly ($p \leq .05$) superior in bench press, power clean, vertical jump, anaerobic capacity, and 10-yard sprint time than non-starters. A stepwise discriminant analysis selected, in order, the power clean, 10-yard sprint time, 40-yard sprint time, body weight, cardiovascular recovery time, and height as predictors of starting performance resulting in proper classification of 77% of the players. The authors suggested that power production is the premium performance variable that provides the greatest differentiation between starters and non-starters on a college football team.

To summarize, strength, speed, and anaerobic power were found to be distinguishing components of successful football performance. Although the literature review found offensive receivers to produce less anaerobic power than offensive linemen, the receivers were able to sustain a higher initial velocity after takeoff, which suggests that anaerobic capacity may be a performance trait specific to the receiver position. More importantly, offensive receivers who desire to be an effective offensive weapon require a great deal of speed as well as power to cover greater distances within a limited amount of time.

Studies Investigating Fitness Changes Over the Playing Season

Studies conducted to determine the anthropomorphic variables to a playing season were reviewed to report the effects a season of play may have on fitness characteristics. Thompson (1958) observed changes in relative fat, estimated from skinfold measurements of 34 varsity college football players during a 12-week playing season (see Table 4). Skinfold measurements at the chest, upper arm, and abdomen were taken with a Vernier caliper. Body composition was determined from estimates of body density by the Brozek (1963) equation and relative fat by the Keys and Brozek (1953) equation. The mean physical characteristics for all subjects were 177.7 cm for height, 88.8 kg for body weight, 8.25% for relative fat, 7.41 kg for fat weight, and 1.0782 g/ml for body density at the beginning of the season and the mean physical characteristics at the end of the playing season were 177.7 cm for height, 87.32 kg for body weight, 6.53% for relative fat, 5.73 kg for fat weight, and 1.0829 g/ml for body density. The mean body weight loss at the completion of the season was 1.49 kg which was not significant. All three skinfold measures

Table 4

Bodybuild Characteristics and Body Compositional Changes During a Season of Football (Thompson, 1958)

Variables			Pre-Season	Post-Season
Height (cm)	M	=	177.68	
	SD	=	5.54	
Body Weight (kg)	M	=	88.81	87.32
	SD	=	8.04	8.53
Relative Fat (%)	M	=	8.25	6.53
Fat Weight (kg)	M	=	7.41	5.73
	SD	=	2.17	1.76
Abdominal Skinfold (mm)	M	=	19.91	14.15 *
	SD	=	6.71	8.11
Chest Skinfold (mm)	M	=	11.88	6.94 *
	SD	=	4.74	2.76
Upper Arm Skinfold (mm)	M	=	11.38	9.94 *
	SD	=	4.64	2.99
Body Density (g/ml)	M	=	1.0782	1.0829
	SD	=	.0172	.0122

* $p \leq .01$

significantly ($p \leq .01$) decreased by the end of the season with the largest skinfold, the abdominal, showing the greatest decrease (5.70 mm) from pre-season measures. As a result of the increase in body density, presumably due to the loss of fat weight and an increase in fat-free weight, the author concluded that body composition changed over the course of the 12-week playing season in the university football players. These results were not significant and only suggest that body compositional changes may be expected over the course of the playing season.

Bolonchuk and Lukaski (1987) investigated the effects of a 13-week season on 79 University of North Dakota football players (see Table 5). The authors determined specific changes in body composition and somatotype ratings over the course of the season. Body composition was determined from estimates of body density by the Durin and Womersley (1974) equation and relative fat by the Siri (1961) equation. Subjects were tested prior to the start of Fall practice (PRS) and immediately after the season (PST). A repeated-measures analysis of variance was used to identify significant ($p \leq .05$) changes over the season. The five skinfold measurements decreased over the season with significant decreases in all measures except the triceps skinfold measure. The biceps circumference decreased significantly from 38.5 to 38.0 cm, but the calf circumference did not change. The humerus width remained relatively unchanged (7.3 vs 7.4 mm), while the femur width

Table 5

Changes in Anthropomorphic, Body Composition, and Somatotype in Football Players Over the Season (Bolonchuk & Lukaski, 1987)

Variables			Pre-Season	Post-Season
Height (cm)	M	=	186.6	186.5
	SD	=	6.2	6.2
Body weight (kg)	M	=	95.4	94.9
	SD	=	12.5	11.2
Relative fat (%)	M	=	13.1	12.4 *
	SD	=	3.9	3.2
Fat-free weight (kg)	M	=	82.5	82.9 *
	SD	=	8.3	8.0
SBIC (mm)	M	=	4.7	4.4 *
	SD	=	1.8	1.4
STRI (mm)	M	=	8.6	8.3
	SD	=	3.2	2.7
SSUB (mm)	M	=	10.5	9.9 *
	SD	=	3.8	3.0
SSUP (mm)	M	=	6.4	5.3 *
	SD	=	3.8	2.4
SCAF (mm)	M	=	10.6	9.9 *
	SD	=	4.3	3.6
CBIC (cm)	M	=	38.5	38.0 *
	SD	=	3.8	2.4

(table continues)

Variables			Pre-Season	Post-Season
CCAF (cm)	M	=	39.8	39.9
	SD	=	2.7	2.5
LHUM (cm)	M	=	7.3	7.4
	SD	=	0.4	0.4
LFEM (cm)	M	=	9.8	10.0 *
	SD	=	0.5	0.5
Endomorphy	M	=	2.5	2.3 *
	SD	=	1.1	0.9
Mesomorphy	M	=	5.3	5.4 *
	SD	=	1.1	1.0
Ectomorphy	M	=	1.5	1.5
	SD	=	0.7	0.7

* $p \leq .05$

Note. SBIC = bicep skinfold, STRI = tricep skinfold, SSUB = subscapular skinfold, SSUP = suprailiac skinfold, SCAF = calf skinfold, CBIC = bicep circumference, CCAF = calf circumference, LHUM = humerus girth, LFEM = femur girth.

increased significantly from 9.8 to 10.0 cm. Body weight did not change significantly (95.4 vs. 94.9 kg) over the13-week season. Fat weight and relative fat decreased significantly from 2.9 to 2.0 kg and 13.1 to 12.4%, respectively. The PRS mean (2.5-5.3-1.5) somatotype ratings were primarily endomorphic and mesomorphic. Comparison of somatotype ratings from PRS to PST resulted in a significant ($p \leq .05$) increase in the mesomorphic rating from 5.3 to 5.4 and a decrease in the endomorphic rating from 2.5 to 2.3. The ectomorphic rating did not change. The PST mean somatotype ratings were 2.3-5.4-1.5, similarly defined as primarily endomorphic and mesomorphic. The changes in endomorphy paralleled the changes in relative fat and the changes in fat-free weight. The authors concluded that even though the changes resulted in significant differences, they were too small to represent a change in somatotype ratings, although the change does reflect a modification of body somatotype over the course of the season.

Fitness changes were measured before and after a 14-week pre-season conditioning program in 53 professional football players which included 18 offensive backs and receivers (Gettman, Storer, & Ward, 1987). Seven fitness variables were measured at the beginning and at the end of the program which included relative fat (%), fat-free weight (kg), treadmill performance run time (min), maximal oxygen uptake rate (VO2max), ventilatory threshold (VAT), vertical jump (VJ), and agility run time (sec) (see Table 6).

Table 6

Mean Changes in Selected Fitness Variables Measured Over a 14-Week Conditioning Program (Gettman et al., 1987)

Variables	Offensive Backs (n = 18)	Team (n = 53)	Team Improvement (%)
Body weight (kg)	0.0	0.0	.00
Relative fat (%)	-0.6	-1.2	.09 *
Fat-free weight (kg)	0.5 *	1.4	.02 *
Treadmill performance run time to exhaustion (min)	0.6 *	0.5	.05 *
Maximal oxygen uptake rate (ml/kg/min)	2.7 **	2.7	.06 *
Ventilatory threshold (ml/kg/min)	0.6	1.7	.08 **
Vertical jump (in)	0.6	1.7	.04
Agility run time (sec)	-0.8 *	-0.9	.03 *

** $p \leq .01$, * $p \leq .05$

Relative fat was estimated from the sum of three skinfold thicknesses at the chest, abdomen, and thigh using a Lange skinfold caliper. VO2max and VAT were obtained using a progressive treadmill walk/run test to exhaustion. The conditioning program consisted of alternate days of sprint and functional strength training exercises with the primary focus on improving aerobic endurance. The effect of training on the mean percentage changes in body composition for the offensive backs and receivers before and after the conditioning program were 0% for body weight (88.44 to 88.44 kg); -0.6% for relative fat (11.0 to 10.4%); and +1.0% for fat-free weight (78.66 to 79.11 kg). Significant changes occurred in three of the seven fitness variables for the offensive backs and receivers after 14-weeks of conditioning: VO2max increased +2.7 ml/kg/min, treadmill performance run time increased +.57 min, and agility run time decreased -0.81 sec. For the team, relative fat decreased -1.2%, fat-free weight increased +1.4 kg, treadmill performance run time increased +0.54 min), VO2max increased +2.7 ml/kg/min, ventilatory threshold increased +1.7, vertical jump increased +0.9 in, and agility run time decreased -0.87 sec, which were significant. The mean team value for VO2max and VAT after training were 49.2 and 21.5 ml/kg/min, respectively, which reflected significant increases of 6% VO2max and 8% for VAT. Based on the total average percentage improvement in all seven fitness variables, the offensive backs and receivers were ranked second to the lowest out of the five positions measured. The authors suggested the offensive backs and receivers had little room for improvement due to their previous condition and concluded that changes in fitness which resulted after a 14-week pre-season conditioning program were greater in individuals who possessed lower pre-test performance measures than in individuals who began the program with a high degree of functional fitness.

To summarize, the literature review reported that fitness measures may change as a result of a play season or pre-season training period. Body weight was reported to remain relatively stable throughout a season. However, body composition and bodybuild characteristics were influenced by the playing season. In the literature, body weight remained unchanged because increases in fat-free weight were found to offset the decreases in fat weight. Body somatotype rating also remained relatively stable and classified offensive receivers as primarily endomorphic and mesomorphic. Training has been shown to improve body composition, aerobic work indices, and agility in offensive receivers. Hence, seasonal conditioning and training may alter a wide variety of physiological parameters. In summary, these changes in fitness over the playing season may translate into a trend for an enhanced functional performance, although more research investigating a wider range of physiological parameters is needed to clarify the effects of a playing season on functional performance.

Summary

This literature review examined the physiological and physical characteristics of offensive receivers. Gathering of data generally occurred either before or after the playing season. Only two studies were found that attempted to identify body compositional changes during a playing season. Tests to determine offensive receiver characteristics included graded stress tests for aerobic endurance, hydrostatic weighing to determine body composition, anthropometric measures for bodybuild characteristics, and flexibility measures. For college offensive receivers, the range of values for these variables were 51.3 to 60.2 ml/kg/min for VO2max, 179.50 to 184.90 cm for height, 79.85 to 96.42 kg for body weight, 7.10 to 13.84 kg for fat weight, 69.60 to 82.58 kg for fat-free weight, 8 to 14% for relative fat, and 4 to 3 endomorphic, 5 to 4 mesomorphic, and 2 to 3 ectomorphic for body somatotype ratings.

The literature review found the physical characteristics to be specific to the offensive receiver position. In comparison to defensive backs, offensive receivers were typically higher in fat-free weight and body density, but similar in body weight, relative fat, and fat weight. Offensive receivers were also characteristically higher in aerobic endurance than defensive backs. Performance characteristics that distinguished success in football identified total body strength, power, speed, and an endomorphic and mesomorphic body somatotype ratings as important characteristics for successful performance in football.

Presently, no research was found that simultaneously integrated these performance measures into a fitness profile for the purpose of identifying the changes that occur over the course of a playing season. A study which investigates the effect of a playing season on fitness parameters may enable coaches and athletes to better understand which variables may separate potential big-play men from those with average playing ability. Therefore, a study investigating the effects of a playing season on a wide variety of physiological parameters in offensive receivers seems to be justified.

CHAPTER III

Methodology

Introduction

This chapter contains information on the subjects, the measurements and methodologies, the experimental design, and the statistical analysis.

Subjects

The subjects for this research study were 10 healthy, young males who ranged in age from 18 to 24 years ($\underline{M}$ = 21.4 $\pm$ 1.07 yrs) and were members of the San Jose State University Division I-A college football team playing as offensive receivers during the 1990-91 season. The group consisted of seven 1st-year transfer students, two incoming freshmen, and one returning player from the 1988-89 team.

Measurements and Methods

The subjects were informed verbally of the procedures of the study at a group meeting prior to testing. At that time, all subjects completed and/or signed, a consent form (Appendix A) and completed a health/medical history questionnaire (Appendix B) which had been approved by the Human Subjects-Institutional Review Board at San Jose State University.

Data collection occurred during the pre-season (August 23rd and 24th, 1990) and post-season (December 10th through 14th, 1990). Subjects were told to report to the laboratory, dressed in the appropriate attire, in a post-absorptive state without having exercised for 12 hours prior to the testing, and not having eaten, drunk, or smoked for 3 to 4 hours prior to test time.

Procedures

Testing instructions and procedures were explained to the subjects prior to each test. The testing for each subject was conducted in the order listed below.

1. Height.
2. Weight.
3. Skinfold measurements.
4. Diameter measurements.
5. Circumference measurements.
6. Residual lung volume.
7. Leg strength.
8. Arm strength.
9. Shoulder strength.
10. Anaerobic work indices.
11. Flexibility.
12. Body composition.
13. Aerobic work indices.

At the completion of each test, the subject was allowed sufficient time to recover and further data collection resumed when each subject verbally agreed and/or until the investigator felt that the subject was fully recovered and capable of giving his best effort. Each subject required approximately 1.5 hours to complete.

Anthropometric measures

Bodybuild characteristics were determined by obtaining anthropometric measurements. Height was measured to the nearest 0.1 cm using a wall scale with a Broca plane. Anthropometric measurements using Lange calipers (10 g/mm^2 constant pressure) determined skinfold thicknesses at the tricep, subscapular, supra-iliac, mid-axillary, abdominal, and calf skinfold sites (Behnke & Wilmore, 1974). The average of two trials within 0.5 mm of each other was used as the representative score. The largest value of three trials obtained from both right and left elbow and knee diameters were recorded along with the largest value obtained from both right and left circumference measurements from the flexed arm and calf. Diameter and circumference measurements were recorded to the nearest 0.1 cm. Diameter measurements were taken with a Layfette anthropometer and circumference measurements were taken with a Lufkin metal tape fitted with a Gullick handle (Behnke & Wilmore, 1974). These measurements were used to calculate musculoskeletal size (FFW/Ht) (Slaughter & Lohman, 1980) and body somatotype ratings described by Heath and Carter (1967). The three component body somatotype ratings (endomorphy, mesomorphy, and ectomorphy) were converted to bi-dimensional scores of linearity-fatness (X) and muscularity (Y) described by Ross and Wilson (1973).

Leg strength

Leg strength was measured on a Cybex II+ isokinetic dynamometer. The subject was seated on an adjustable chair with the thigh, hips, and chest stabilized by velcro straps. The axis of rotation of the dynamometer was aligned with the subject's anatomical axis of rotation at the knee joint and the distal end of the lever arm was strapped to the leg just proximal to the malleoli of the ankle (Isolated-joint testing & exercise: A handbook for using the Cybex II+ and the U.B.X.T., 1983). Leg strength was obtained from the subject's dominant leg (determined by kicking preference) and extension through a 90-degree range of motion that ended at full extension. A warm-up of three to four submaximal trials preceded the actual test. The subject then executed three maximal extensions at 60 degrees/sec. The highest peak torque extension value for knee flexion and knee extension was used as the representative score (Clarkson et al., 1982; Gilliam, Villancci, Freedson, & Sady, 1979; Haymes & Dickinson, 1980).

Arm and shoulder strength

Arm and shoulder strength was measured on a Cybex II+ isokinetic dynamometer utilizing the Upper Body Exercise Table

(U.B.X.T.) attachments. The subject reclined in a supine position on the U.B.X.T. bench with his upper body stabilized by velcro straps. The axis of rotation of the dynamometer was aligned with the subject's anatomical axis of rotation at the elbow and shoulder (Isolated-joint testing & exercise: A handbook for using the Cybex II+ and the U.B.X.T., 1983). Arm and shoulder strength was obtained from the subject's dominant arm (determined by throwing preference) and extension through a 180-degree range of motion. Three to four submaximal trials for proper warm-up preceded the actual test. The subject then executed three maximal extensions at 60 degrees/sec. The highest peak torque extension value for the arm and the shoulder was used as the representative score (Clarkson et al., 1982; Gilliam et al., 1979; Haymes & Dickinson, 1980).

Anaerobic work indices

Anaerobic power, anaerobic capacity, and fatigue index were measured using the Wingate Anaerobic Test (WAnT). Lower body anaerobic work indices were measured on a 650 Monark cycle ergometer. Preceding the start of the test, the seat of the cycle ergometer was adjusted to maintain near full extension of the subject's leg when pedalling. The test began by a standardized warm-up, which was 4 minutes of slow pedaling against zero resistance interspersed with two to three sprints of 4 to 5 seconds duration (Bar-Or, 1978; Inbar & Bar-Or, 1975). After the warm-up, the subject rested for approximately 2 minutes during which time the procedures for the WAnT were reviewed. At the command "GO" the subject began pedalling as fast as possible while the researchers increased the resistance to 0.075 x BW (kg) within the first 2 to 3 seconds (Bar-Or, 1978; Tharp, Johnson, & Thorland, 1984; Tharp et al., 1985). The 30-second test began as soon as the resistance was set during which the subject was verbally encouraged to give a maximal effort. The workload and elapsed time was carefully monitored throughout the time period. Immediately following the 30-second test, a 2 to 4 minute cool-down period followed to prevent dizziness and muscle soreness (Thorland et al., 1987). Anaerobic power was calculated as the highest kgm/ 5-sec work interval and anaerobic capacity as the total kgm/ 30-sec work interval (Bar-Or, 1978; Tharp et al., 1984; Tharp et al., 1985). Fatigue index was calculated as the highest 5-sec peak power minus the lowest 5-sec peak power, divided by the highest peak power, multiplied by 100 (Bar-Or, 1978).

Flexibility

The flexibility test measured trunk flexibility using the sit and reach test (Johnson & Nelson, 1979). The subject was seated on the floor with legs extended and the heels touching the foot stop of the flexibility tester. After a warm-up stretch, the subject reached as far as possible between the feet and passively held for 3 seconds without bending the knees. The subject reached with paralleled hands and did not stretch with a leading hand. The greatest distance from three trials to the nearest 0.25 inches was recorded as the representative score (Golding, Myers, & Sinning, 1982).

Body Composition

Body composition was determined by underwater weighing with correction made for residual lung volume using the helium dilution method (Systems Manual for Collins Residual Volume, Pulmonary Function Testing System, 1983). With the subject seated in a position similar to that assumed during the underwater weighing, residual lung volume was measured using a Collins 10-liter RS Unit and the average of two trials were used as the representative score (Systems Manual for Collins Residual Volume, Pulmonary Function Testing System, 1983). Underwater weighing was performed in a hydrostatic water tank in which a webbed sling was suspended from a Chatillon 9-kg scale. Each subject performed 6 to 10 trials of underwater weighing with the average of the three highest scores being used to represent true underwater weight (Cisar et al., 1986). To determine body composition for white males, relative fat was calculated from the formula of Brozek et al. (1963) where $\% RF = [(4.57/Db) - 4.142] \times 100$, and for black males, relative fat was calculated from the formula of Schutte et al. (1984) where $\% RF = [(4.374/Db) - 3.928] \times 100$. Fat weight (FW) and fat-free weight

(FFW) were calculated from the values for body weight and relative fat. Body weight (BW) was measured to the nearest 0.11 kg (0.25 lb) using a physician's scale (Cisar et al., 1986).

Aerobic work indices

Maximal oxygen uptake rate (VO2max) and ventilatory threshold (VAT) were measured using a modified running protocol on a Quinton model 1860 treadmill (Cisar et al., 1986). Subjects were fitted with headgear which was supported by a Hans-Rudolph respiratory value and mouth piece. Inhaled air was passed through a Parkinson-Cowan CD-4 Dry Test meter and then into the respiratory valve. Expired air was passed out of the Hans-Rudolph value into a mixing chamber and from there into a Wilmore-Costill Spinner Value (WCSV) system.

The sample of expired air from bages on the spinner valve was drawn through a Beckman LB-2 Medical Gas Analyzer, which measured FeCO2 and an Applied Electrochemistry S-3A analyzer, which measured FeO2. The analyzers were calibrated before each test and during every stage (3 minutes) of the test with a standard gas sample. The equipment used to measure VI, FeCO2, and FeO2 were directly interfaced to an Apple II+ computer for data analysis. Expired ventilation rate (VE) was calculated from the inspired ventilation rate (VI). Oxygen uptake (VO2) and carbon dioxide production (VCO2) rates were calculated from VI, fraction of expired oxygen (FeO2), and fraction of expired carbon dioxide (FeCO2) values which were collected every minute of the test.

Heart rate was monitored continuously on a Quinton 623A electrocardiogram (ECG) monitoring system. The ECG was printed out for the last 10 seconds of every minute of the test at the speed of 25 mm/sec. The ECG monitor was used to observe the electrical patterns of the subject's heart throughout the test and to obtain heart rate. Six surface electrodes (right and left arm, right and left leg, sternum, and V5) were used to monitor the electrical patterns of the subject's heart.

The subject began the test by running at 4.0 mph and 0% grade. The work load increments were increased every 3 minutes, first progressing by 1 mph to 9 mph and then 2% grade increases thereafter until voluntary exhaustion (Cisar et al., 1986). Maximal oxygen uptake rate was determined as the highest VO2 value obtained when (a) heart rate was within $\pm$ 10 b/min of age predicted maximal heart rate, (b) respiratory quotient was above 1.0, and/or (c) VO2 plateaued in relation to increasing workloads. The criteria for ventilatory threshold (VAT) was determined by a non-linear increase in VE, a non-linear increase in VCO2, and/or an increase in the fraction of expired oxygen (FeO2) without a corresponding decrease in the fraction of expired carbon dioxide (FeCO2) (Wasserman et al., 1973). Ventilatory threshold was identified in this study as the last oxygen uptake value fitting a linear trend when ventilation (VE) was plotted against oxygen uptake rate (VO2) (Cisar et al., 1986). Ventilatory threshold relative to maximal oxygen uptake rate (%VO2max) was identified as the ratio of VAT/VO2max.

The test was terminated if any of the following situations occurred during the test: (a) a signal from the subject that he wished to stop, (b) failure of heart rate to increase with increasing workloads, (c) pain or fatigue as indicated by decreasing coordination and/or pallor, (d) any abnormalities on the ECG reading, or (e) equipment failure (ACSM, 1986).

A warm-down period followed the maximal treadmill test until the subject's heart rate decreased to or below 120 bpm. A post-exercise ECG strip was obtained immediately after the completion of the test, 1 minute, and 3 minutes during recovery, and prior to removal of the electrodes.

Atmospheric readings (temperature and barometric pressure) were obtained prior to beginning the maximal treadmill test. All maximal treadmill tests were supervised by a qualified Exercise Test Technologist and personnel certified in cardiopulmonary resuscitation (CPR).

Additional information gathered

At the end of each week for the duration of the competitive season information regarding game performance statistics and the accumulative amount of time devoted to conditioning during practice were collected. Game performance statistic measurements included: total number of receptions in a season, total passing yards in a season, average passing yards per game, and total passing touchdowns in a season.

Analysis of Data

Descriptive statistics ($\underline{M} \pm \underline{SD}$) were used to describe the characteristics of all subjects. A total of 10 athletes were tested pre-season and 8 athletes were tested post-season. To calculate the paired dependent $\underline{t}$ tests only those subjects who completed both pre-season and post-season tests were used for data analysis. The Pearson test of skewness and the Hartley homogeneity of variance test were used to determine if the sample population exhibited scores of normal distribution and equal variance. Since the pre-season and post-season scores did not violate the assumptions of homogeneity of variance and normal distribution, dependent $\underline{t}$ tests were used to determine significant differences in fitness. Pearson product-moment correlations were calculated to examine intercorrelations between game performance statistics and all fitness parameters. The computer program SPSSx (SPSSx User's Guide, 1983) was used for statistical analysis of data. An alpha level of $\underline{p} \leq .05$ was established for statistical significance.

CHAPTER IV

Results, Discussion, Summary, Conclusions, and Recommendations

Introduction

Data from this study were analyzed to determine the effects of a playing season on the physical fitness of offensive receivers. The specific issues examined were: (a) bi-dimensional somatotype ratings of linearity-fatness and muscularity, (b) body weight, relative fat, fat weight, fat-free weight, and musculoskeletal size, (c) arm, shoulder, and leg strength during flexion and extension, (d) anaerobic power, anaerobic capacity, and fatigue index, (e) flexibility, and (f) maximal oxygen uptake rate, ventilatory threshold, and ventilatory threshold relative to maximal oxygen uptake rate. This chapter contains the analysis of results, a discussion of the results, summary, conclusions, and recommendations for future study.

Analysis of Results

Hypothesis 1 - There will be no significant differences in bi-dimensional somatotype ratings of linearity-fatness (X) and muscularity (Y) between pre-season and post-measures.

The assumptions of homogeneity of variance and normal distribution were tested using the Pearson test of skewness and the

Hartley homogeneity of variance test and no significant differences were found. Consequently, these assumptions were not violated and parametric statistics were used. Eight athletes measured pre-season and post-season for body somatotype ratings were used to mathematically calculate the following bodybuild classifications: endomorphy, mesomorphy, and ectomorphy, and the converted bi-dimensional scores of X (linearity-fatness) and Y (muscularity). The results are summarized in Table 7. For the endomorphic somatotype rating, the pre-season mean was 2.8 (SD = 1.13) and the post-season mean was 2.6 (SD = 1.30). This difference was not statistically significant. For the mesomorphic somatotype rating, the pre-season mean was 4.9 (SD = 1.38) and the post-season mean was 5.2 (SD = 1.22). This difference was not statistically significant. For the ectomorphic somatotype rating, the pre-season mean was 2.0 (SD = 1.00) and the post-season mean was 2.1 (SD = 1.06). This difference was not statistically significant. The mean overall pre-season body somatotype ratings were 2.8-4.9-2.0 and the mean overall post-season body somatotype ratings were 2.6-5.2-2.1, which classified the offensive receivers in this study as predominantly balanced mesomorphs. Moreover, the overall somatotyping ratings of the offensive receivers remained relatively stable over the course of the playing season.

For the bi-dimensional rating X (linearity-fatness), the pre-season mean was -0.8 (SD = 1.96) and the post-season mean was -0.5

Table 7

Results of Tests Comparing Pre-Season and Post-Season Body Somatotype Ratings

Measure	Pre-Season	Post-Season	Test Statistic	p
Endomorphy				
	M = 2.81 SD = 0.40	M = 2.62 SD = 0.46		
			t = 1.16	.28
Mesomorphy				
	M = 4.88 SD = 0.49	M = 5.23 SD = 0.43		
			t = -0.81	.44
Ectomorphy				
	M = 2.00 SD = 0.35	M = 2.12 SD = 0.37		
			t = -1.00	.35
X (linearity-fatness)				
	M = -0.81 SD = 0.69	M = -0.50 SD = 0.81		
			t = -1.49	.18
Y (muscularity)				
	M = 4.96 SD = 1.11	M = 5.72 SD = 0.94		
			t = -0.83	.43

* $p < .05$, degrees of freedom = 7

(<u>SD</u> = 2.28). This difference was not significant, but indicated a 38% difference between the pre-season and post-season measures. For the bi-dimensional rating Y (muscularity), the pre-season mean was 4.9 (<u>SD</u> = 3.14) and the post-season mean was 5.7 (<u>SD</u> = 2.66). This difference was not significant, but yielded a 14% change in muscularity from pre-season to post-season.

<u>Hypothesis 2</u> - There will be no significant differences in extension and flexion strength of the arm, shoulder, and leg between pre-season and post-season measures.

The assumptions of homogeneity of variance and normal distribution were tested using the Pearson test of skewness and the Hartley homogeneity of variance test and no significant differences were found. Consequently, these assumptions were not violated and parametric statistics were used. Muscular strength measures for eight athletes who completed the test pre-season and post-season appear in Table 8.

For arm strength (AS), the pre-season mean for arm flexion was 54.75 ft-lb (<u>SD</u> = 7.40) and the post-season mean was 50.50 ft-lb (<u>SD</u> = 7.19). This represented a 8% reduction in arm flexion strength, but this difference was not significant. The pre-season mean for arm extension was 54.63 ft-lb (<u>SD</u> = 8.94) and the post-season mean was 56.75 ft-lb (<u>SD</u> = 13.35). This difference was not significant, but reflected a 4% increase. For shoulder strength (SS), the pre-season mean for shoulder flexion was 82.63 ft-lb

Table 8

Results of Tests Comparing Pre-Season and Post-Season Fitness Characteristics of Arm, Shoulder, and Leg Strength

Measure	Pre-Season	Post-Season	Test Statistic	p
Arm Flexion (ft-lb)				
	M = 54.75 SD = 7.40	M = 50.50 SD = 7.19		
			t = 1.76	.12
Arm Extension (ft-lb)				
	M = 54.63 SD = 8.94	M = 56.75 SD = 13.35		
			t = -1.02	.34
Shoulder Flexion (ft-lb)				
	M = 82.63 SD = 10.58	M = 68.63 SD = 9.29		
			t = 3.80	.006 *

(table continues)

Measure	Pre-Season	Post-Season	Test Statistic	p
Shoulder Extension (ft-lb)				
	M = 67.75 SD = 24.63	M = 92.75 SD = 11.54		
			t = -3.46	.01 *
Leg Flexion (ft-lb)				
	M = 108.13 SD = 28.57	M = 114.38 SD = 13.24		
			t = -0.54	.60
Leg Extension (ft-lb)				
	M = 167.50 SD = 37.29	M = 166.38 SD = 27.97		
			t = 0.11	.92

* $p \leq .05$, degrees of freedom = 7

(SD = 10.58) and the post-season mean was 68.63 ft-lb (SD = 9.29). Shoulder flexion strength decreased 17% and was statistically significant. The pre-season mean for shoulder extension was 67.75 ft-lb (SD = 24.63) and the

post-season mean was 92.75 ft-lb (SD = 11.54). This difference represented a 27% increase and was also statistically significant. For leg strength (LS), the pre-season mean for leg flexion was 108.13 ft-lb (SD = 28.57) and the post-season mean was 114.38 ft-lb (SD = 13.24). The post-season measurements were only 5% greater than pre-season measurements and, consequently, were not significant. The pre-season mean for leg extension was 167.50 ft-lb (SD = 37.29) and the post-season mean was 166.38 ft-lb (SD = 27.97). This small difference was also not significant.

Hypothesis 3 - There will be no significant differences in anaerobic power (AP), anaerobic capacity (AC), and fatigue index (FI) between pre-season and post-season measures.

The assumptions of homogeneity of variance and normal distribution were tested using the Pearson test of skewness and the Hartley homogeneity of variance test and no significant differences were found. Consequently, these assumptions were not violated and parametric statistics were used. A dependent t test was also used to compare six athletes who completed both pre-season and post-season tests. The results are summarized in Table 9.

For anaerobic power (AP), the pre-season mean was 433.42 kgm/

Table 9

Results of the Tests Comparing Pre-Season and Post-Season Fitness Characteristics of Anaerobic Power, Anaerobic Capacity, and Fatigue Index

Measure	Pre-Season	Post-Season	Test Statistic	p
Anaerobic Power (kgm/ 5-sec)				
	M = 433.42 SD = 66.49	M = 400.25 SD = 60.01		
			t = 1.58	.17
Anaerobic Capacity (kgm/ 30-sec)				
	M = 2116.78 SD = 216.22	M = 1919.25 SD = 298.05		
			t = 3.51	.01 *
Fatigue Index (%)				
	M = 42.89 SD = 10.21	M = 41.41 SD = 6.02		
			t = 0.37	.72

*$p \leq .05$, degrees of freedom = 5

5-sec (SD = 66.49) and the post-season mean was 400.25 kgm/ 5-sec (SD = 50.01). This resulted in a 8% reduction in anaerobic power and was not statistically significant. For anaerobic capacity (AC), the pre-season mean was 2116.78 kgm/ 30-sec (SD = 216.22) and the post-season mean was 1919.25 kgm/ 30-sec (SD = 298.05). This also resulted in a 9% reduction in anaerobic capacity performance which was statistically significant ($p \leq .05$). For the fatigue index (FI), the pre-season mean was 43% (SD = 10.21) and the post-season mean was 41% (SD = 6.02). This difference was not significant, although it reflected a 5% decrease between pre-season and post-season measures.

Hypothesis 4 - There will be no significant difference in flexibility between pre-season and post-season measures.

The assumptions of homogeneity of variance and normal distribution were tested using the Pearson test of skewness and the Hartley homogeneity of variance test and no significant differences were found. Consequently, these assumptions were not violated and parametric statistics were used. Flexibility was measured in eight athletes before and after the season and the results are listed in Table 10. The pre-season mean was 10.19 in (SD = 1.75) and the post-season mean was 10.83 in (SD = 2.27). This represented a 6% increase during the season, but was not significant.

Table 10

Results of the Test Comparing Pre-Season and Post-Season Flexibility

Measure	Pre-Season	Post-Season	Test Statistic	p
Flexibility (in)				
	M = 10.19 SD = 1.74	M = 10.83 SD = 2.27		
			t = -1.26	.25

* $p \leq .05$, degrees of freedom = 7

Hypothesis 5 - There will be no significant differences in total body weight (BW), relative fat (RF), fat weight (FW), fat-free weight (FFW), and musculoskeletal size (FFW/Ht) between pre-season and post-season measures.

The assumptions of homogeneity of variance and normal distribution were tested using the Pearson test of skewness and the Hartley homogeneity of variance test and no significant differences were found. Consequently, these assumptions were not violated and parametric statistics were used. Eight athletes measured pre-season and post-season were used to mathematically compare differences in bodybuild characteristics. The results are presented in Table 11. For body weight (BW), the pre-season mean was 82.05 kg (SD = 10.71) and the post-season mean was 82.24 kg (SD = 13.17). This difference represented a nominal change and was not statistically significant. For relative fat (RF), the pre-season mean was 12% kg (SD = 3.30) and post-season mean was 10% kg (SD = 3.24). This difference was not significant, but represented a 12% decrease from pre-season measures. For fat weight (FW), the pre-season mean was 9.80 kg (SD = 3.22) and the post-season mean was 8.91 kg (SD = 3.89). This difference was not significant, although it reflected a 10% decrease from pre-season measures. For fat-free weight (FFW), the pre-season mean was 73.39 kg (SD = 9.54) and the post-season mean was 74.56 kg (SD = 10.66). The increase in fat-free weight was 2%, but the difference was not

Table 11

Results of the Tests Comparing Pre-Season and Post-Season Body Composition and Bodybuild Characteristics

Measure	Pre-Season	Post-Season	Test Statistic	p
Body Weight (kg)				
	M = 82.05 SD = 10.71	M = 82.24 SD = 13.17		
			t = -0.1	.90
Relative Fat (%)				
	M = 11.73 SD = 3.30	M = 10.42 SD = 3.24		
			t = 1.77	.12
Fat Weight (kg)				
	M = 9.80 SD = 3.22	M = 8.91 SD = 3.89		
			t = 1.66	.14
Fat-Free Weight (kg)				
	M = 73.39 SD = 9.54	M = 74.56 SD = 10.66		
			t = -0.64	.54
Musculoskeletal size (FFW/Ht) (kg/cm)				
	M = 41.10 SD = 0.50	M = 41.20 SD = 0.50		
			t = -0.66	.54

* $p \leq .05$, degrees of freedom = 7

significant. For height (HT), both the pre-season and the post-season means were 180.49 cm (SD = 6.88). For musculoskeletal size (FFW/Ht), the pre-season mean (40 kg/cm) was similar to the post-season mean (41 kg/cm). Thus, musculoskeletal size did not change over the course of the playing season.

Hypothesis 6 - There will be no significant differences in maximal oxygen uptake rate (VO2max), ventilatory threshold (VAT), and ventilatory threshold relative to maximal oxygen uptake rate (%VO2max) between pre-season and post-season measures.

The assumptions of homogeneity of variance and normal distribution were tested using the Pearson test of skewness and the Hartley homogeneity of variance test and no significant differences were found. Consequently, these assumptions were not violated and parametric statistics were used. The hypotheses were tested by mathematically comparing the VO2max, VAT, and %VO2max values from pre-season and post-season testing. The testing was completed by eight athletes pre-season and by five of the athletes post-season. The dependent t tests were computed on the five athletes who had both pre-season and post-season scores (see Table 12). The mean VO2max pre-season was 47.58 ml/kg/min (SD = 5.12) and the post-season mean was 46.63 ml/kg/min (SD = 4.01). This difference was not significant, but reflected a 2% reduction in VO2max from pre-season to post-season measures. The

Table 12

Results of the Tests Comparing Pre-Season and Post-Season Fitness Characteristics of VO2max, VAT, and %VO2max

Measure	Pre-Season	Post-Season	Test Statistic	p
VO2max (ml/kg/min)				
	M = 47.58 SD = 5.12	M = 46.63 SD = 4.01		
			t = 0.37	.73
VAT (ml/kg/min)				
	M = 37.29 SD = 3.73	M = 38.26 SD = 4.50		
			t = -0.39	.72
%VO2max				
	M = 78.46 SD = 2.78	M = 81.93 SD = 5.17		
			t = -2.17	.09

* $p \leq .05$, degrees of freedom = 4

pre-season mean VAT was 37.29 ml/kg/min (SD = 3.73) and the post-season mean was 38.26 ml/kg/min (SD = 4.50). This difference reflected a 3% increase, but was not significant. The pre-season mean %VO2max was 78% and the post-season mean was 82%. This difference was also not significant, although a 5% increase in %VO2max was observed between pre-season and post-season values.

Table 13 represents the total mean game-statistics collected for the offensive receivers over the 16-week playing season. The game-statistics include total number of receptions in a season, average yards per reception in a season, total passing yards in a season, and total number of passing touchdowns in a season. Of the 10 offensive receivers who participated in this study, one athlete red-shirted and did not play during the season. Another athlete played, but did not receive any receptions throughout the season. Thus, the data presented in Table 13 were averaged for the eight offensive receivers who had received at least one reception during the playing season.

Table 14 represents the zero-order correlation between the physiological parameters and the game-statistic measures collected throughout the playing season. The intercorrelation coefficients between actual performance variables gathered over the course of the season and the fitness variables measured in this study demonstrated a wide range of values (r = -.84 to .68). Because some athletes did not test all measures completely at post-season, only

Table 13

Game-Statistics for Offensive Receivers During the 1990-91 Playing Season (12 Games)

Game-Statistics	Season Totals	M, SD, Range
Total number of receptions in a season	262	M = 22.37 SD = 14.33 Range = 42 - 1
Total passing yards in a season	3650	M = 345.75 SD = 234.69 Range = 649 - 7
Average passing yards per game	304	M = 14.25 SD = 3.49 Range = 18.88 - 7.0
Total passing touchdowns in a season	21	M = 3.50 SD = 2.70 Range = 7 - 0

Table 14

Correlation Matrix for the Descriptive Characteristics of the Offensive Receivers (N = 10)

Physiological Variable	Game-Statistics	Correlation Pre-Season (n)	Correlation Post-Season (n)
VO2max (ml/kg/min)			
	TDSEASN	-.63 (7)	-.17 (5)
VAT (ml/kg/min)			
	TDSEASN	-.65 (7)	.23 (5)
Leg Flexion Strength (ft-lb)			
	TTNBREC	-.27 (10)	-.71 * (8)
	AYRDREC	-.24 (10)	-.72 * (8)
	TYRDSEA	-.04 (10)	-.79 * (8)
	TDSEASN	-.27 (10)	-.63 * (8)
Anaerobic Power (kgm/ 5-sec)			
	TTNBREC	-.01 (9)	-.82 * (6)
	AYRDREC	.07 (9)	-.83 * (6)
	TYRDSEA	.07 (9)	-.84 (6)
	TDSEASN	.18 (9)	-.66 * (6)

(table continues)

Physiological Variable	Game-Statistics	Correlation Pre-Season (n)	Post-Season (n)
Anaerobic Capacity (kgm/ 30-sec)			
	TTNBREC	-.13 (9)	-.70 (6)
	AYRDREC	-.02 (9)	-.71 (6)
	TYRDSEA	.09 (9)	-.64 (6)
	TDSEASN	.09 (9)	-.65 (6)
%VO2max			
	TTNBREC	-.42 (7)	.68 (5)
	AYRDREC	-.47 (7)	.65 (5)
Fat-Free Weight to Height Ratio (kg/cm)			
	TTNBREC	-.22 (10)	-.64 (7)
	AYRDREC	-.11 (10)	-.65 (7)

* $p \leq .05$

Note. TTNBREC = Total number of receptions in a season, AYRDREC = Average number of yards per reception, TYRDSEA = Total passing yards in a season, TDSEASN = Total number of passing touchdowns in a season.

those scores which were paired and greater than $r = \pm .60$ were used for the correlational analysis. As a result, correlations moderately related were presented, but were not significant. For instance, moderately-negative correlations were found for the pre-season maximal oxygen uptake rate and ventilatory threshold measures for the total number of passing touchdowns in a season. Similar post-season measures failed to reach correlational significance. The post-season measures for leg flexion strength and anaerobic power exhibited significantly high to moderately-negative correlations with all four game-statistics. Ventilatory threshold relative to maximal oxygen uptake rate was the fitness measure to exhibit the highest positive correlation with the total number of receptions in a season ($r = .68$) and the average yards per reception ($r = .65$), but the correlations were not significant.

Discussion of Results

The purpose of this research study was to determine the effects of a playing season on selected fitness variables in offensive receivers. A review of literature was conducted and revealed no study which had investigated the effects of a competitive season on fitness in offensive receivers. Two previous research studies were found that only examined body compositional changes over the playing season.

The bi-dimensional somatotype scores X (linearity-fatness) and Y (muscularity) slightly changed over the season which reflect the changes found in individual body somatotype ratings. Although the changes were not significant, these athletes became relatively more linear in relation to body fatness as the X rating reflected a less higher ectomorphic rating and a lower endomorphic rating. The positive change in the Y component indicates that muscular development occurred during the season. An increase in fat-free weight combined with the increases in the mesomorphic somatotype rating and rating of muscluarity (Y) supports the theory that additional muscle tissue was gained over the course of the season. Due to the small sample size and the specific position selected, minimal changes were found in body somatotype ratings. This may reflect prior coaching preference for a particular body type where a premium on aesthetic qualities rather than on actual bodybuild characteristics may have influenced player recruitment.

Body somatotyping ratings for offensive receivers found in this study were predominantly balanced mesomorphs (2-5-2). The endomorphic somatotype was lower and the mesomorphic and ectomorphic somatotypes found in this study were similar both before and after the season to somatotype ratings reported by other researchers (Carter, 1967; Votto, 1976; and Wilmore et al., 1976). Likewise, body somatotype ratings did not change from pre-season to post-season in this study, which were in contrast to the significant increase in mesomorphy and a significant decrease in endomorphy reported by Bolonchuk et al. (1987). In this study, the body somatotypes, mesomorphy and ectomorphy, slightly increased while the endomorphic component decreased slightly, but these changes were not significant. Even though the somatotypes were modified, the changes were favorable as the receivers became more muscular and leaner over the season. This is in agreement to Bolonchuk et al. (1987) who found similar, but significant changes in body somatotype ratings as a result of the playing season.

Furthermore, the somatochart distribution of the offensive receivers in this study both before and after the season was primarily balanced mesomorphs, which corresponds to the somatochart distribution for football players reported by Carter (1967). Even though this study exhibited trends in body composition and bodybuild as a result of the competitive season similar to those reported by other studies, they were not significant. Year round training and a highly conditioned state of football preparedness prior to the start of the season may, in part, explain why dramatic changes were not observed in the body composition and bodybuild characteristics of these offensive receivers.

A significant increase (27%) was found in shoulder extension strength while shoulder flexion strength significantly decreased (17%). Arm flexion strength slightly increased and arm extension strength slightly decreased, but the changes were not significant. Leg flexion strength slightly increased while leg extension strength slightly decreased, but the changes were not significant. The reduction in arm and shoulder flexion strength may suggest a reduced ability to execute natural arm raising and flexing motions, when receiving a football. On the other hand, the increases in arm and shoulder extension strength may be attributed to performance adaptations while receiving a forward pass. The proper technique to receive a forward pass requires the arms to be extended and the shoulders flexed in front of the body in order to receive the football, which is followed immediately by "pulling" the ball into the body by extending the shoulders and flexing the arms. The significant increase in shoulder extension strength is difficult to explain in light of the other observed decreases in muscular strength. In general, the trend toward decreased strength contradicts the increases found in fat-free weight and the bi-dimensional somatotype score Y (muscularity). Since the mechanics of receiving a football require muscular work, the loss in arm strength during both extension and flexion movements may result in an earlier onset of upper body fatigue and hence decreased performance over the course of the playing season. Likewise, a significant increase in leg flexion suggests greater strength increases in the quadriceps occurred as a result of the playing season and may indicate an adaptation to the type of running required for the receiver positions. In other words, performance specificity to the receiver positions may have occurred over the course of the season.

In the literature, measurements of power have been assessed by a variety of tests that include the Margaria step-test, vertical jump, 10- and 40-yard sprints, power clean, and bench press. This study investigated anaerobic work indices using the Wingate 30-second cycle ergometer test and found an 8% decrease in anaerobic power, a 9% decrease in anaerobic capacity, and a 5% decrease in the fatigue index. However, only the decrease in anaerobic capacity from pre-season to post-season was found statistically significant. These findings suggest that anaerobic work indices at the beginning of the season were higher than at the end of the season, which may, in part, have been due to strength gains induced by the summer lifting program, or by a decrease in the alactic component of anaerobic metabolism over the course of the season. In consideration with the conditioning program implemented during the season by the strength coach (see Appendix C), a certain degree of training specificity may have occurred which modified positional performances from a short-term, explosive skill to a more muscular-endurance type of performance. Votto (1976) reported anaerobic power in offensive receivers to be significantly lower (2007 ft-lb) than offensive lineman (2330 ft-lb), who require immediate, short-term explosion. Costill et al. (1968) similarly found offensive receivers to be significantly lower in anaerobic power, but were significantly faster in initial vertical velocity than all other positions. The loss in anaerobic capacity may translate to slower speeds of movement during the later stages of the game, particularly during the latter stages of the season. The decrease in anaerobic capacity may contradict the theories that speed and power are discriminating performance traits for success in football and hence, greater emphasis on speed-specific training may be needed throughout the season.

Although flexibility did not significantly change from pre-season to post-season, the mean post-season flexibility measure for the offensive receivers in this study was 6.3 in greater than the college offensive receivers reported by Votto (1976). On the other hand, the offensive receivers in this study were 7.7 in less flexible than the professional offensive receivers measured by Gettman et al. (1976). In addition, Gleim (1984) reported that offensive receivers exhibit greater flexibility than any other position in football. Other literature (Gettman et al., 1987; Gleim, 1984; Mayhew et al., 1990; Votto, 1976) suggest that a high degree of flexibility was associated with better running economy and success at the skill positions. A relatively greater amount of running opportunities would indicate that offensive receivers might be more in tune with the importance of stretching as compared to down linemen. Although other positions were not measured in this study nor was the amount of time spent stretching measured, the flexibility results reported in this study are similar to results of other research.

Body composition and bodybuild characteristics of offensive receivers reported in this study were similar to previous research (see Table 2). Height measures of the athletes reported in this study were within the range of similar college offensive receivers (range, 179.50 to 184.95 cm), but were 3.3 cm shorter than the professional offensive receivers. Body weight, relative fat, fat weight, and fat-free weight both before and after the season were within the mean ranges reported for college offensive receivers by other profile studies (Millard-Stafford et al., 1989; Smith et al., 1984; White et al., 1980; and Wickkiser et al., 1975). Body weight did not change over the playing season and this lack of change was comparable to previous studies (Bolonchuk et al., 1987; Gettman et al., 1987; Thompson et al., 1958). Although relative fat decreased by 12% over the course of the season, the change was not significant. This change was 15% greater than the decreases in relative fat reported after a 14-week conditioning program by Gettman et al. (1987). This decrease may, in part, be due to the increase in fat-free weight and a decrease in fat weight. These changes were not significant, but did reflect similar modifications in body composition over the course of the playing season as reported in other studies (Bolonchuk et al., 1987; Gettman et al., 1987; Thompson et al., 1958). A change toward a leaner physique with less relative fat and fat weight and greater fat-free weight occurred over the course of the playing season. The observed increase in fat-free weight appears to be primarily related to an increase in muscle mass. The present study followed a trend similar to Gettman et al. (1987) and Bolonchuk et al. (1987), where significant decreases in relative fat and significant increases in fat-free weight in offensive receivers were reported after a playing season.

Maximal oxygen uptake rates (VO2max) measured pre-season and post-season were found to be lower than college offensive receivers reported in other research studies (Novak et al., 1968; Smith et al., 1976). The highest reported VO2max in the literature for a professional offensive receiver was 63.0 ml/kg/min by Hoette et al. (1986). However, the VO2max reported was a predicted value based on a graded treadmill test without direct assessment of oxygen uptake rate, so actual values may have been lower than reported. The lowest reported VO2max was 43.4 ml/kg/min, which was also found in a professional offensive receiver by Gleim et al. (1981). A similar graded treadmill test was administered, but the protocol consisted of three 3-minute stages. The first two stages were performed at a submaximal intensity while the third stage at maximal intensity, which was terminated regardless of fatigue or voluntary exhaustion. The VO2max values may have been higher, had the athletes run until exhaustion. The mean VO2max values reported in the present study were 47.6 ml/kg/min for the pre-season and 46.6 ml/kg/min for the post-season, which were located toward the lower range for maximum oxygen uptake rates reported for offensive receivers (range, 43.4 to 63.0 ml/kg/min) by other researchers (see Table 1). In comparison, the mean post-season VO2max values found in this study were similar to untrained individuals (44 ml/kg/min) reported by Astrand (1987). It is apparent from the cardiovascular measures taken pre-season and post-season that these athletes are not endurance-trained individuals, which indicates that aerobic fitness is not an important component of football performance. In addition, seven of the eight athletes in this study were Junior College transfers who were recruited for their receiver skills and talents and hence, factors other than cardiovascular fitness may have contributed to their high degree of success in football.

Gettman et al. (1989) reported a 8% increase in VAT and a 6% increase in VO2max after a 14-week pre-season conditioning program. The present study found a 3% increase in VAT and a 2% decrease in VO2max from pre-season to post-season. In addition, the mean VAT (37.8 ml/kg/min) reported for offensive receivers in this study was 40% higher than the total mean VAT (21.5 ml/kg/min) reported by Gettman et al. (1989). This demonstrates an increase in the onset of anaerobic metabolism with a concomitant reduction in maximal aerobic power, but neither changes were significant. An enhancement of submaximal work capacity may appear to exist toward the end of the season. The 5% increase in %VO2max during the season may support the theory that the receivers measured in this study performed at a higher workload at the end of the season than at the beginning of the season.

The 1990-91 San Jose State University football team was highly successful winning the Big West Conference title with a record of 9-2-1. San Jose State University football team was ranked second in the Big West Conference for passing offense (e.g., 294.6 yrds/game) and eighth in the nation. In addition, they were ranked first in the Big West Conference for total offense (e.g., 465.1 yrds/game) and seventh in the nation, which reflects the success of the passing style of offense adopted at San Jose State University.

VO2max and VAT, measured during the pre-season, moderately correlated with the total number of passing touchdowns in a season. The negative correlation associated with these variables to the game-statistics indicate that other measures not investigated in this study (i.e., coaching and quarterback throwing preference, offensive strategy, skill, agility, coordination, savvy, and speed) may, in part, play a role in whether a receiver is directly involved in each pass play. This was in contrast to the positive low correlations found for the similar post-season measures, which supports the theory that aerobic work indices are not discriminating performance traits of football receivers. In other words, athletes with a relatively high maximal oxygen uptake rate and a high ventilatory threshold prior to the season are not necessarily guaranteed success at the receiver position. On the other hand, the moderately-positive correlation demonstrated by the post-season %VO2max measure to the total number of receptions in a season and to the average yards gained per reception suggests that those athletes with higher %VO2max values may have achieved some measureable degree of success. Significant moderately-negative correlations were found for the post-season measures of leg flexion strength and anaerobic power, which suggest that success for the receiver may be more related to specific performance traits achieved over the course of the playing season, rather than fitness dependent. Nevertheless, these performance traits appear to be centralized in the lower body regions, which are difficult to interpret based on the small sample size and, in part, due to the motivation of the athletes at the end of the season.

The results found in this study combined with the success of the 1990-91 San Jose State University football team leads the author to speculate as to the lack of significant changes in fitness over the course of the season. The results found indicate that these athletes were: (a) already in a high state of football preparedness prior to the study and maintained that level over the course of the season, (b) these athletes were less motivated at the end of the season and therefore probably did not give a true maximal effort, and (c) that fitness is a small component to the success in the receiver position and perhaps, psychological as well as sociological influences play a more important role than previously thought.

Summary of Results

Slight improvements in the bi-dimensional body somatotype rating of X (linearity-fatness) were found due to a slight increase in linearity (ectomorphic rating) and a slight decrease in fatness (endomorphic rating). Similarly, the bi-dimensional body somatotype rating of Y (muscularity) increased over the course of the playing season, which reflected an increase in muscle tissue as indicated by the increase in the mesomorphic somatotype rating. However, these changes were not statistically significant.

A significant ($p \leq .05$) decrease was found in shoulder flexion strength, while a significant ($p \leq .05$) increase was found in shoulder extension strength. This discrepancy in shoulder strength is opposite the typical movement patterns when receiving a forward pass and may indicate the onset of fatigue during the later stages of the season. Slight decreases were found in arm flexion and leg extension strength, as well as slight increases in arm extension and leg flexion strength over the course of the season, but these changes were not statistically significant.

Furthermore, anaerobic capacity significantly ($p \leq .05$) decreased over the course of the season which indicate a decrease in the endurance characteristics of muscle fibers occurred. Combined with the observed decrease in anaerobic power, while not significant, appears that a loss in explosive leg power as well as anaerobic characteristics within the muscle tissues of the legs occurred over the season.

Flexibility measures changed over the course of the playing season, which resulted in a slight increase in trunk flexibility, although the difference was not significant. The increase in the range of motion at the trunk is indicative of greater abdominal and hamstring muscle flexibility over the course of the season.

Body weight and fat-free weight to height ratio (musculoskeletal size) remained unchanged from pre-season to post-season, but other body composition and bodybuild characteristics tended to change during the season. Relative fat and fat weight decreased 12 and 10%, respectively, but these changes were not significant. Body weight remained relatively stable due to a slight increase in fat-free weight, which offset the changes in relative fat and fat weight.

Ventilatory threshold slightly increased and maximal oxygen uptake rate slightly decreased during the season. Hence, ventilatory threshold relative to maximal oxygen uptake rate (%VO2max) increased over the course of the season. No significant changes were observed in any of these measures. Since the VO2max values found prior to the beginning of the season were similar to untrained young men of similar age, these athletes appeared to be less fit at the end of the season than when they reported in the beginning of Fall camp. Therefore, cardiovascular fitness may have decreased as a result of the season.

Zero-order correlations found significant negative intercorrelations (r = -.68 to -.84) between selected game-statistics and the post-season fitness measures for leg flexion strength and anaerobic power. The pre-season measures for maximal oxygen uptake rate and ventilatory threshold exhibited a moderately-negative correlation with the total number of passing touchdowns in a season. Although, not significant, this suggests that an athlete with a high maximal oxygen uptake rate is not neccesarily guaranteed success at the receiver position. Likewise, ventilatory threshold relative to maximal oxygen uptake rate measured post-season exhibited a moderately-positive correlation with the total number of receptions in a season and with the average yards per reception in a season. This finding suggests that the onset of anaerobic threshold may play a role in the performance of a receiver during the later stages of the season.

Conclusions

Within the boundaries of this study the following conclusions were made.

1. A decrease in shoulder flexion strength occurred in offensive receivers during the 16-week playing season. The anterior deltoid muscle which is primarily involved in shoulder flexion appears to lose its capacity for strength and may attenuate injury since the deltoid muscle protects and surrounds the upper body region.

2. Anaerobic capacity which is a reflection of speed and endurance characteristics should be a specific training objective maintained throughout the playing season, particularly since this physiological variable declined toward the later part of the season.

3. Maximal oxygen uptake rate and ventilatory threshold had little influence on a receiver's performance, but ventilatory threshold relative to maximal oxygen uptake rate might a better discriminating factor of success in the receiver position. Maximal oxygen uptake rate relative of ventilatory threshold was the only physiological variable to positively correlate with game-statistic measures and maybe a better indicator of a receiver's true work capacity.

4. Body composition and bodybuild characteristics exhibited a positive trend toward improvement during the playing season and consequently, should be monitored regularly for proper weight loss and for optimal muscle growth.

5. Factors other than fitness (i.e., psychological, motivational, and sociological) may, in fact, influence a receiver's performance.

Recommendations for Future Study

The following recommendations for future studies are presented.

1. Fitness studies which compare playing season effects on less fit athletes should be investigated, such as offensive and defensive linemen.

2. Fitness studies comparing two complimentary positions, such as the defensive backs and offensive backs to determine positional profiles, should be undertaken.

4. Fitness studies involving larger sample sizes and mid-season measurements to better track trends in fitness changes should be performed.

5. Fitness studies which take into account practical field measures and the influence a playing season has on the athlete's performance in these field measures should be completed.

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A STUDY TO INVESTIGATE THE FITNESS CHANGES IN DIVISION I-A COLLEGE FOOTBALL PLAYERS DURING THE COMPETITIVE SEASON

STATEMENT OF INFORMED CONSENT - - FOR ANAEROBIC CAPACITY, BODY COMPOSITION AND SIZE, MUSCULAR STRENGTH, FLEXIBILITY, AND CARDIORESPIRATORY ENDURANCE

Invitation to Participate

You are invited to participate in a study investigating the fitness changes that result during the competitive season. Changes in anaerobic work indices, body composition and size, muscular strength, flexibility, and cardiorespiratory endurance measurements will be determined during the Fall 1990 season. This study will be conducted at San Jose State University under the direction of the Department of Human Performance.

Basis for Selection

You have been selected as a participant because you are a healthy male age 18 to 24 years old who is directly involved as an offensive scoring threat and because of the positional requirements unique to the receiver. Should you decide to participate, your response to a health history questionnaire will be reviewed by an exercise physiologist and, if satisfactory, you will be asked to participate in the tests described below.

Purpose of the Study

The purpose of this research study is to determine the fitness changes associated with the receiver position during the competitive season in college football.

Explanation of Procedures

The testing procedures will be supervised by Craig Cisar, Ph.D., Exercise Test Technologist, and Scott Setterlund. Additional cardiopulmonary resuscitation certified personnel will be present during testing that involve stressing the cardiorespiratory system.

Body Composition and Size Test

The body composition and size test will involve two testing techniques: anthropometry and underwater weighing. Anthropometry involves measuring height, circumferences, diameters, and skinfold thicknesses at specific body locations. Underwater weighing involves three measures: body weight, body weight while underwater, and residual lung volume (the amount of air left in your lungs after you have fully exhaled). For this test you will be seated in a chair breathing room air through a mouthpiece. At the end of a normal expiration a valve will be turned so you will breathe a mixture of helium and room air from the spirometer. Oxygen will be added to the sprìometer as needed. After breathing this mixture for several minutes you will be asked to inhale fully and then exhale fully. The whole procedure will be repeated as necessary. To obtain body weight while underwater, you will be sitting in a 4 inch wide canvas sling which will be suspended from a scale so that you are about neck deep in water. The water will be about 88 degrees F. You will then tuck your knees up and bend your head forward so that you are completely submerged and blow as much air from your lungs as possible. You must try to remain in this position for 5 to 10 seconds before raising your head, to allow a scale reading to be made. These procedures will be repeated 6 to 10 times with rest intervals between each.

(approximately 30 minutes)

Muscular Strength Tests

The muscular strength tests will involve measuring the maximal strength for extension of your dominant leg at the knee joint and dominant arm at the shoulder and elbow joints using a Cybex II+ isokinetic strength machine. The Cybex II+ will not generate any resistance at slower speeds of leg or arm movement. At faster speeds of movement the resistance will match the force you produce. For the leg strength test, you will be in a sitting position on a bench and secured at the thigh with a velcro strap for stabilization. Your leg will be attached to a lever arm of the machine by a velcro strap at the ankle. For the arm strength test, you will be stabilized in a reclined position on a bench with velcro straps and your hand around a hand grip. Both leg and arm strength tests will begin with three to four warm-up trials, followed by three consecutive maximal extension trials at a moderate speed of movement for determination of leg and arm strength.

(approximately 20 minutes)

Anaerobic Capacity Test

The anaerobic test will consist of pedaling simultaneously on a stationary cycle ergometer against resistance as fast as possible for 30 seconds. A warm-up period will precede the test and will be followed by a cool-down period. The cycle is fitted with an adjustable seat to assure individual comfort and toe-clips to reduce the risk of slipping off the pedals and provide additional stability during test. You will begin pedalling against a light resistance and on the command "GO" will begin pedalling as fast as possible. The resistance will be increased to the appropriate level (based on your body weight) within the first 2-3 seconds of the test. Verbal encouragement will be given to motivate you to give a maximal effort.

(approximately 10 minutes)

Flexibility

The flexibility test will involve sitting with your legs extended so your heels touch the foot stop of the flexibility tester. You will then passively reach as far as possible between your feet to the point you can reach and hold for 3 seconds without bending your knees. The highest of three trails will be recorded.

(approximately 5 minutes)

Cardiorespiratory Endurance Test

The cardiorespiratory test determines your maximal oxygen consumption and ventilatory threshold and involves running on a treadmill with incremental changes in grades and speed to exhaustion. Following the measurement of a resting heart rate and blood pressure you will begin running at 4.0 mph and at 0% grade. Every three minutes the work load will increase in speed, first progressing by 1 mph to 9 mph and then 2% grade increases thereafter until you can no longer continue. The test will end when you indicate you can no longer continue, or physical responses (heart function, respiration, and/or physical appearance) indicate that you should not continue, or you have reached your maximal effort, and/or any equipment fails. It is anticipated the test will last 15 - 20 minutes. Following the completion of this test, the speed and grade will be reduced so that you can recover comfortably. The cool down period will continue until your heart rate is less than or equal to 120 b/min.

(approximately 40 minutes)

Additional Information To Be Gathered:

Field measurements will be gathered at the end of each week for the duration of the season regarding the amount of time you spend in conditioning periods, playing time during the games, and weekly depth chart ratings.

Discomforts and Risks

Flexibility:

Some individuals may strain muscles in the hamstrings and lower back region from too vigorous and jerky movement when performing the test. This is unlikely because a pre-stretch warm-up period will precede the test to insure that a passive sit and reach method will be performed.

Underwater Weighing:

The water quality in the tank is maintained daily; however, there is the possibility of certain types of infections. This is very unlikely due to the daily chemical treatments and filtering of the water. Chlorine irritation to the eyes, swallowing water, and choking are all possible risks as in any pool situation. There may be some discomfort associated with being submerged underwater.

Residual Lung Volume:

Some individuals experience faintness and/or dizziness when performing this breathing test. The discomfort associated with this test may come from breathing through a mouthpiece with a nose clip in place. Some persons may experience discomfort when performing the maximal inhalation and the maximal exhalation.

Skinfold Measurements:

You may develop small bruises from these measurements, although this is very unlikely. The pinching sensation from skinfold measurements may cause some discomfort. You may also feel uncomfortable standing still for these measurements as you will be wearing either just your shorts or swimsuit.

Anaerobic Capacity and Muscular Strength Responses:

You may experience some muscle soreness and fatigue following this test as well as increased heart rate, increased breathing rate, elevated body temperature, sweating, and fatigue during the test. After the maximum anaerobic test you may feel faintness and/or dizziness and possibly slight nausea.

Cardiorespiratory Endurance:

You may experience some discomfort and dryness in the mouth, throat, and chest as a result of the restricted breathing apparatus. You may feel lightheaded, fatigued, and slightly nauseous for a short time following this test. Also, you will experience the discomforts commonly associated with exercise: sweating, increased heart rate, increased breathing rate, and elevated body temperature. Before the test some of the hair on your chest may be shaved off for placement of the EKG electrodes. When you are at or near maximal exercise you may experience abnormal blood pressure, fainting and/or dizziness, muscle fatigue or cramps, and abnormalities in heart beat. If abnormalities are detected in pulmonary function or electrocardiographic recordings, the test will be stopped and you will be excluded from this investigation.

Benefits from Participation in the Study

You will benefit from this study by receiving information regarding body composition (% body fat, lean body mass); anaerobic capacity and fatigue index; flexibility, upper and lower strength; body build; and cardiorespiratory endurance (maximal oxygen uptake and ventilatory threshold). You will also receive information regarding fitness changes that occur during the competitive season. The results from this research will quantify aspects of your fitness that may decrease throughout the competitive season and enable college coaches, particularly at the Division I-A level, to establish training standards, and to identify certain physiological characteristics that may be important to maintain as the season progresses. Results from this research may influence current training methods and improve the quality of instruction and provide a better understanding of the positional requirements which in turn may enhance the quality of the position.

Assurance of Confidentiality

The data generated from this research study may be used for medical and/or scientific purposes, including publication and presentation at professional meetings. Your identity or individual test results will not be revealed in published or presented papers without your written consent. However, test results may be shared with your football coaches at San Jose State University only after the completion of the season and will not be shared during the season.

Withdrawal of Consent

You may withdraw your consent and discontinue participation in the project at any time (including during the testing) without prejudicing your relationship with the Department of Human Performance, San Jose State University, or SJSU Department of Intercollegiate Athletics. You are free to decline to answer any question or item on the health history questionnaire or other questionnaire(s).

If you have any questions regarding the investigation at this time or during the test, please feel free to ask. For questions or complaints, that may come up later or in the case of an emergency, call: Scott Setterlund (408) 741-1239 or Dr. James Bryant, Department of Human Performance Chairperson (408) 924-3010. For questions or complaints about research subject's rights, or in the event of research related injury, contact Dr. Serena Stanford, Associate Academic Vice President of Graduate Studies and Research, (408) 924-2480.

Consent

Having read the above, I agree:

(a) that my consent is given voluntarily without being coerced,

(b) that to participate in the study, procedures will be verbally explained to me, knowing that there are some discomforts and/or risks,

(c) that I understand I can withdraw from the study at any time,

(d) that I understand the data are confidential but may be published or presented without revealing my identity except with my express consent.

MY SIGNATURE INDICATES THAT I HAVE DECIDED TO PARTICIPATE IN THIS STUDY HAVING READ THE INFORMATION PROVIDED ABOVE AND THAT I HAVE RECEIVED A COPY OF THIS CONSENT FORM FOR MY LIFE.

SIGNATURE______________________________ DATE________

PRINT
NAME____

SIGNATURE OF
WITNESS____

SIGNATURE OF
INVESTIGATOR______________________________________

Appendix B

SAN JOSE STATE UNIVERSITY
DEPARTMENT OF HUMAN PERFORMANCE

PRE-EXCERISE TESTING
HEALTH STATUS QUESTIONNAIRE

POSITION ____________________________ DATE____________________

NAME ______________________________YEAR IN SCHOOL_________

CAMPUS ADDRESS ______________________CAMPUS PHONE________

HOME ADDRESS ________________________HOME PHONE___________

AGE ___ yrs. HEIGHT ___ ft./in. WEIGHT ____ lbs.

DOES THE ABOVE WEIGHT INDICATE: A GAIN___, A LOSS__, NO CHANGE __, IN THE PAST TWO WEEKS?___ HOW MANY POUNDS?____

A. **JOINT - MUSCLE STATUS** (Check areas which you currently have problems)

Joint Areas

( ) Wrists
( ) Elbows
( ) Shoulders
( ) Upper Spine and Neck
( ) Lower Spine
( ) Hips
( ) Knees
( ) Ankles
( ) Feet
( ) Other________________
____

Muscle Areas

( ) Arms
( ) Shoulders
( ) Chest
( ) Upper Back and Neck
( ) Abdominal Regions
( ) Lower Back
( ) Buttocks
( ) Thighs
( ) Lower Leg
( ) Feet
( ) Other________________

B. HEALTH STATUS (Check if you previously or currently have any of the following conditions)

( ) High Blood Pressure
( ) Heart Disease or Dysfunction
( ) Peripheral Circulatory Disorder
( ) Lung Disease or Dysfunction
( ) Arthritis or Gout
( ) Edema
( ) Epilepsy
( ) Multiple Sclerosis
( ) High Blood Cholesterol or Triglyceride levels
( ) Acute Infection
( ) Diabetes or Blood Sugar Level Abnormality

( ) Anemia
( ) Hernias
( ) Thyroid Dysfunction
( ) Pancreas Dysfunction
( ) Liver Dysfunction
( ) Kidney Dysfunction
( ) Neural Dysfunction
( ) Others that you feel we should know about:______
____
____

C. PHYSICAL EXAMINATION HISTORY

When was your last physical exam ______________________________
Any physical problems noted at that time ___________________________

When was the last time your resting electrocardiogram was evaluated?____
Was it normal? Yes ( ) No ( ) If no, what was abnormal about it?____

When was the last time your had your electrocardiogram evaluated during an exercise stress test?____
What heart rate did you reach during this exercise?_____________________
Was the electrocardiogram normal? Yes ( ) No ( ) If no, what was abnormal about it?____

Has a physician ever made any recommendations relative to limiting your levels of physical exertion? Yes ( ) No ( ) If yes, what limitations were recommended?____

D. **CURRENT MEDICATION USAGE** (List the drug name and the condition being managed)

Medication	Condition
____________________	____________________
____________________	____________________
____________________	____________________
____________________	____________________

E. **PHYSICAL PERCEPTIONS** - Indicate any unusual sensations or perceptions. (Check if you have recently experienced any of the following perceptions during or soon after physical activity (PA); or during sedentary periods (SED).

PA	SED		PA	SED	
( )	( )	Chest pain	( )	( )	Light headedness
( )	( )	Heart palpitations	( )	( )	Loss of balance
( )	( )	Unusually rapid breathing	( )	( )	Loss of condition
( )	( )	Overheating	( )	( )	Extreme weakness
( )	( )	Muscle cramping	( )	( )	Numbness
( )	( )	Joint pain	( )	( )	Mental confusion
( )	( )	Nausea	( )	( )	Other____________ ____________

F. **FAMILY HISTORY** (Check if any of your blood relatives - parents, brothers, sisters, aunts, uncles, and/or grandparents - have or had any of the following)

( ) Heart disease
( ) Heart attacks or strokes prior to age 50
( ) Elevated blood cholesterol or triglyerides level
( ) Diabetes

G. CURRENT HABITS (Check any of the following if they are characteristic of your current habits)

Do you smoke? Yes ( ) No ( ) If so, how many per day? ________________

How often do you consume alcohol? Every day?____ Once a week?____
If so, how much? Less than 12 oz. ___, more than 12oz. ____

How often do you consume coffee? Every day? ____ Once a week? _____
If so, how much? Less than 12 oz. ___, more than 12 oz. _____.

How do you feel about your diet? excellent ___, good __, bad __, poor __

Do you consider your state of fitness as: excellent __, good __, bad __, poor ___

Do you feel abnormally exhausted after each workout? Yes ( ) No ( )

Do you feel emotionally stress-out after each workout? Yes ( ) No ( )

What was your primary means of conditioning during the pre-season prior to reporting to camp? (Check more than one if they apply)

( ) Summer conditioning program provided by Coach Frederico
( ) Self administered program
( ) Group training
( ) Personal trainer
( ) Exercise physiologist
( ) Other _______________

Thank you for your cooperation.

Appendix C

IN-SEASON CONDITIONING SCHEDULE

Lifting program

All players were required to lift twice a week throughout the 16-week playing season. A Monday-Wednesday or a Tuesday-Thursday cyclic program was selected by each athlete. A high repetition program and moderate loads were implemented at the beginning of the season, which progressed into a low repetition program and high loads at the end of the season. The objective of the lifting program was to maintain strength gains achieved during the summer program and, as the season progressed, a cyclic routine was implemented for power development. The total volume of work remained unchanged throughout the season and included:

Heavy day (90% of 1 RM)

Leg press or squats
Hang cleans
Incline bench press or supine bench press
Push press
Lat. pull-down
Tricep push-down
Crunches
Neck

Light day (70% of 1 RM)

Leg extensions and leg curl
Upright rows
Shoulder shruggs
Supine bench press or incline bench press
Lat. pull-down
Tricep push-down
Crunches
Neck

Conditioning program

The conditioning program preceded the regular practice schedule and conducted four days a week on Mondays, Tuesdays, Wednesdays, and Thursdays. The objective of the conditioning program was to increase progressively the volume of work and concomitantly decrease in recovery time.

Monday, Wednesday, and Thursday Conditioning

Entire team, six group rotation

1 to 6 weeks: 12 X 110 yard strides (.16 sec) with 30 second rest
6 to 9 weeks: 12 X 110 yard strides (.16 sec) with 25 second rest
9 to 16 weeks: 12 X 110 yard strides (.16 sec) with 20 second rest

Tuesday Conditioning Only

Entire team, six group rotation

Gassers: sideline to hash at 1/2 (50%) speed;
hash to hash at 3/4 (75%) speed;
hash to sideline at full (100%) speed.

1 to 8 weeks: 10 repetitions, 25 second rest
9 to 16 weeks: 12 repetitions, 25 second rest

Friday Conditioning Only

Entire team
Pre-game practice, special teams, 1 X 800 yard slow jog no time

Saturday Game; No Conditioning.

Sunday Rest; No Conditioning.