MEASUREMENT AND EVALUATION OF PHYSIOLOGICAL COMPONENTS OF PROFESSIONAL SOCCER PLAYERS OF A NORTH AMERICAN SOCCER LEAGUE TEAM

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CHAPTER I

INTRODUCTION

The sport of soccer is a game of total fitness, a game which requires a great deal of intelligence as well as mental and physical toughness on the part of the participants. Soccer is enjoyed by millions of individuals of all ages around the world. The following characteristics of the soccer player make this unique sport the world's favorite. Physical size (height and weight) does not create a problem for a good soccer player; through active participation, physical strength and the development of speed and endurance are achieved. Total body coordination is enhanced through vigorous participation during games as a result of running at different speeds, executing several types of kicking and heading the ball. Full active participation by every player on the field throughout the game is appreciated. Because of full participation by every player, understanding, cooperation, and appreciation of each player's hard work by others are developed among the team members. Although there is enough contact in a game of soccer to satisfy the need for competiton and aggressiveness among participants, there is a minimum of hazard to the life of the player or risk to his physical well being. Soccer is financially economical, and requires little equipment.

A great deal of research effort has been spent in finding the physical and physiological characteristics of competitors in various sports

(1, 2, 3). These studies have tended to concentrate on top-flight performers in order to identify critical requirements for success. Research attempts increase in complexity when team sports rather than individual sports are considered. Great individual differences may be expected and may perhaps be necessary. This will apply particularly in a field-invasive game like soccer. As a result, less attention has been given to superior athletes who compete in sports such as soccer where, in addition to endurance, emphasis is placed on skill and technique. This fact presents a problem to both the coach and the athlete, since there is only limited physiological data available with which to evaluate current training practices and with which to suggest new perspectives for training.

A Brief History of Soccer

History reveals that a ball was being kicked in games or ceremonies among ancient Chinese, Babylonians, Egyptians, Japanese, and others. "The fundamentals of the game are so natural and simple that it is scarcely surprising to find early traces of it in many different cultures" (4).

Different sized and shaped balls were used by different cultures. The Chinese had a stuffed leather ball; Egyptians and Babylonians used one made of bamboo fibers; the Romans introduced the first inflated ball which was the bladder of a freshly killed animal covered with leather. Balls used, the field, goals, and rules have differed considerably over the years.

During the early years of soccer played in China, goal posts were thirty feet high and decorated with silk fabrics. In front was a net, also of silk, with an opening of only one foot through which the players tried to kick the ball. The Japanese used eight-man teams to pass the ball from one to the other on a field sixty feet long with trees planted at each corner. Greeks and Romans used both hands and feet to play on a field four hundred by one hundred-fifty feet. The objective was to pass the ball over a stake that served as a goal. Six referees who sat in stands officiated the games. Colombians used only the right shoulder to hit the ball, while Huitotos used their knees, and Cubans their hips.

At the early Olympic games in ancient Rome, twenty-seven men on a side played soccer so vigorously that two-thirds of them had to be hospitalized after a fifty-minute game. Ireland had no limitations on players or field size. Because of violence associated with British soccer during the early days, participation was discouraged for a few centuries.

In 1681, an English nobleman familiar with Italian soccer introduced a new style of soccer. Because the new style was not as brutal as the Roman style of play and it had official sanction, soccer grew in popularity. English universities drew up a set of rules for "association football" and in 1848 the fourteen "Cambridge rules" including the eleven-man team were adopted. These rules, with the exception of minor changes, have remained in international use.

Sometimes after the founding of the English Football Association, the game had spread to other parts of Europe. Scottish and English coaches traveled around the world to introduce soccer and teach basic skills. The first international contest was played between England and Scotland on November 30, 1872, in Glasgow. European countries--England, Germany, Austria Hungary and Italy--and South American countries--Brazil, Argentine and Peru have been the dominant figures in international competition during the last hundred years (5). In the United States, with the formation of the North American Soccer (professional) League, a rapid increase in elementary, secondary, and collegiate soccer is taking place. For the first time, an amateur U. S. Olympic soccer team will compete in 1984 in the Los Angeles Olympics.

The Federation Internationale de Football Association (FIFA) estimates that in 1972 there were between sixteen and twenty million soccer players in the world. Seventy-six percent of them were registered Europeans. The World Cup games and Olympic Soccer matches take place every four years. In addition to the World Cup games and the Olympic matches, nations sponsor a variety of tournaments. For example, the European Cup brings together the champion league clubs of each member country of the European Union of Football Associations (6).

Soccer styles differ among the countries of the world; each style is unique and adds a different flavor to the sport of soccer. Style of play is determined by such factors as the educational background of players, geographic climatic conditions, available physical facilities, nutrition, temperament, physical and physiological characteristics of the players, and overall coaching philosophy. The English style is to built around hard running, physical contact, long passing, and ability to play for ninety minutes with all-out effort.

The West German and Holland style of play is centered around a more detailed technique and frequent all out sprints, the style that requires players to possess high skills, accept responsibilities well, play with self confidence, and demonstrate high individual play-making abilities. Man-to-man marking has become a popular tactic in West Germany and Holland.

East European countries such as East Germany and the Soviet Union demonstrate a more programmed style of play. The players' physical work rate is high, and players are limited in individual play-making capabilities and self-expression.

The South American soccer style is based on a more positional game plan--more emphasis on fitness rather than physical contact. The overall game pace is slower than the European style of soccer, and the players are permitted more time and space (7).

The sport of soccer is presently experiencing a period of rapid growth and development throughout most of the United States. Characterized by the almost continuous movement of its players, soccer is thought to have a tremendous value as an endurance activity. The fact remains, however, that very few studies have been undertaken to substantiate this thought.

Winning teams play well-organized, aggressive soccer, which requires that players be well prepared physically. Elevated physical capacity helps a player realize his technical-tactical potential. The trend in modern soccer is toward expansion of a player's physiological functions which, in turn, leads to increases in aerobic and anaerobic power.

Based on the above observations, it was the focus of this research to assess cardio-respiratory function of professional soccer players. Such function represents the capacity of the human body to supply and deliver oxygen to the organs and tissues. The heart, the blood vessels, and lungs are the agents of that function.

Maximum Oxygen Consumption

Maximum oxygen consumption, also referred to as maximum aerobic power, is the maximum amount of oxygen a person can utilize while performing a workload (8). When the workload surpasses this oxygen maximum, the anaerobic process (without oxygen) takes over and continues for a brief period before exhaustion occurs and the work must cease.

"Aerobics" is referred to as "with oxygen." An aerobic fitness program is designed to improve one's maximal oxygen intake capacity. Aerobic exercises utilize oxygen without producing an intolerable oxygen debt. Such exercises are based on aerobic activities that stimulate the heart and lungs for a continued and sufficient amount of time to produce beneficial changes in the body (9).

Oxygen uptake increases during the first minutes of exercise to a "steady state" where the oxygen uptake corresponds to the demands of the tissues. When the exercise stops, the oxygen uptake gradually decreases to the resting level; the oxygen debt is paid off. The slow increase in oxygen uptake at the beginning of exercise is explained by the sluggish adjustment of the oxygen-transporting systems to work. The attainment of the steady state coincides with the adaptation of cardiac output, heart rate, and pulmonary ventilation. In light exercise, the energy output during the first minutes of exercise can be delivered aerobically; however, during more severe exercise, anaerobic processes must supply part of the energy during the early phase of exercise, and lactic acid will be produced.

An all-out test is not necessary for the assessment of an individual's maximal aerobic power. Balke and Ware (10) found that a submaximal heart rate of 180 beats per minute was a valid predictor of maximum oxygen uptake. Repeated studies by Balke and others have found that the time taken to reach 180 heart rate is a valid predictor of maximum oxygen uptake for males. It was noted that the submaximal tests avoid much of the discomfort and distress that the subjects are exposed to in an all-out run.

The $\dot{V}O_2$ max depends on pulmonary ventilation, pulmonary diffusion, the oxygen carrying capacity of the blood, cardiac output, and arteriovenous differences in oxygen saturation.

A number of researchers have measured $\dot{V}O_2$ max of professional soccer players. Raven et al. reported an average of 58.4 ml/O_2 kg min, which was above those values reported for sedentary populations of a similar age (11). Williams et al. reported a mean $\dot{V}O_2$ max of 57.77 ml/kg/min for nine British players (12). Using five South Australian soccer players, Whiters et al. reported a mean $\dot{V}O_2$ max of 62 ml/kg/min (13). Superior maximal oxygen uptake values have been reported among national champions and world class competitors in endurance sports. Outstanding distance runners have values exceeding 80 ml/kg/min (14). The $\dot{V}O_2$ max values reported for soccer players are lower than top class athletes; they are greater than the range of 3.10 to 3.69 L/min or 44 to 51 ml/kg/min reported by Astrand for normal males (15).

The trend in modern soccer is toward expansion of a player's physiological functions which, in turnl leads to execution of a greater number of dashes at higher intensity. Godik et al. (16) reported that the total distance of dashes executed at top speed exceeds 1,500 m; the number of such dashes reaches 100 or more during ninety minutes of play. The energy for such work comes from the anaerobic alactate metabolic pathway. Glycolysis (splitting of the glucose molecule into two pyruvic acid molecules) and aerobic reactions are not able to be "switched on" with such sudden increases in every output. Despite the fact that the role of the anaerobic metabolism of work has been studied extensively in normal man (17), much less attention has been given to investigation of its capacity in skeletal muscles of different athlete populations.

As mentioned above, the sport of soccer requires much aerobic and anaerobic work. Therefore, this investigator was interested in the anaerobic threhold of soccer players, and the anaerobic threshold was measured.

Respiratory Functions

Respiratory function tests are frequently used as a measure of the adequacy of the respiratory system. Vital capacity (VC), the volume of gas that can be forcibly expired after a maximum inspiration represents the approximate usable capacity of the lungs. Several authors have reported that vital capacity is higher in athletes than in nonathletic subjects of similar body size (18, 19).

The maximum voluntary ventilation capacity (MVV), the maximum amount of air that can be breathed per minute, must be high in order to furnish the oxygen transport system with necessary supplies for ninety minutes of soccer play. In a review of recent literature, Durusoy and Ozgonul (20) stated that most investigators found the maximum volunary ventilation capacity to be significantly higher in athletes. In their own investigation of soccer referees, all of whom were former athletes, they detected higher MBC values for the athletes, especially in the 40-50 age group. All of the data were corrected for age and body size.

Berglund et al. (21) among others, showed that timid vital capacity (FEV_T, forced expiratory volume) began decreasing at the age of 35. Grimby and Saltin (22) found that forced expiratory volume in one second is higher in athletes than in nonathletes.

The Rest/Work Ratio

Well-conditioned athletes have long cardiac cycles, lower heart rates, and longer diastole than untrained individuals; therefore it is frequently assumed that the athlete's rest/work ratio is somewhat greater. However, investigating physiological differences between variously conditioned groups, Cureton (26) included such an assumption in his research and analyzed data of three groups, track and field champions, swimming champions, and normal young males as control subjects. He could not detect any significant difference among the three groups for the average work time as well as the resting period.

Resting and Exercise Heart Rate

A multitude of factors such as age, sex, body size, intensity of metabolic processes, level of daily physical activity, and level of physical fitness affect resting heart rate (27).

Dawson (28) tested the effect of training upon heart rate, and reported that training slowed the resting rate by an average of nine beats per minute.

Cotton (29) reported on champion swimmers who had a mean of 47.5 (range 40 to 53) beats per minute. His other data showed that normal young men averaged

- with slight experience . . . . 66 beats per minute
- with some experience . . . . 63 beats per minute
- with average experience . . . . 57 beats per minute
- with relatively greater experience . . 53 beats per minute
- Olympic athletes . . . . 50 beats per minute
- Olympic swimmers (aver. 10 yrs training) 47 beats per minute

Costill (30) studied the possibility of predicing performance of a 4.7 mile cross-country run by determining the relationship between sixteen test items and running time. While the maximal oxygen uptake proved to be almost a perfect predictor, he pointed out that the average resting heart rate was lower for the better runners and appeared to be closely related to distance running performance.

Using heart rate as the sole predictor or evaluator of physical fitness can pose a problem. While low heart rates in the absence of any pathology signify good cardiovascular fitness, a high rate does not necessarily mean low fitness.

Resting and Exercise Blood Pressure

Blood pressure is the pressure created against the arteries as blood flows through them. Hypertension (high blood pressure) plays a major role in heart failure, heart attacks, kidney damage, strokes, rupture of major blood vessels, and hardening of the arteries.

Blood pressure varies with age, sex, emotion, ingestion of food, posture, heredity, diurnal variation, and environment.

Exercise tends to lower the blood pressure. Studies have shown that blood pressures are lower in the more active people than in sedentary people, and fitness programs do lower the blood pressure of hypertensive people (31).

Exercise blood pressure depends on the type and intensity of the exercise and the physical condition of the subject (32). In rhythmic exercise that involves moderate to strenuous workloads, the typical response is an elevation of systolic pressure, while diastolic pressure usually rises very little if at all. Systolic pressures are elevated as a result of the larger stroke volumes (33).

Reindell et al. (34) reported that in arterial blood pressure response to exercise in subjects of different ages, the older men had consistently higher systolic and diastolic pressures than the younger men. At rest, the 25-year olds averaged 125/75 mmHg, and during exercise, the pressures were 160 and 80 mm Hg in systole and diastole, respectively. For the 55-year old group, the increase was from 140/86 at rest, up to 180/90 mmHg, the workload being the same. Similar results were reported by Hoolmann and Gerstenblith et al.

Brown et al. (35) studied the effect of eight weeks of pre-season training on university basketball players. The investigators found a 7.2 mmHg drop of the diastolic pressure. Similar results were obtained by Buccola and Stone (36), who measured the effect of jogging and cycling programs on physiological and personality variables in aged men.

Blood Lipids

Fatty substances (lipids) in blood are called cholesterol and triglycerides. A certain amount of cholesterol is essential for good life; it helps the body use fats by moving them through the bloodstream. Abnormal levels of cholesterol and triglyceride increase the risk of disease and premature death. When an excess of these lipids circulates in the blood, some of it is deposited onto the inner walls of the arteries, and this contributes to atheroclerosis.

An increasing level of low density lipoprotein cholesterol (LDL-C) increases the risk of atherosclerotic heart disease; conversely, it decreases with increasing level of high density lipoprotein cholesterol (HDL-C) (37, 38). Total body cholesterol is inversely related to the level of the high density lipoproteins (HDL). Thus, low density lipoproteins (LDL) seem to involve transport to and deposition of cholesterol in the tissues, including blood vessel walls, while the HDLS are responsible for the reverse traffic of cholesterol and remove it from tissues.

High blood fat levels, physical inactivity, and sedentary life style tend to increase the cholesterol levels, whereas exercise decreases the cholesterol levels. Increasing HDL and decreasing LDL levels help blood to dissolve blood clots. One study has shown that substantial amounts of fat can be added to the diet without raising cholesterol levels if the level of physical activity is also increased (39).

Body Composition

Of great concern to the athlete is the amount of body fat which can be carried without hindering performance. Techniques such as densitometry, hydrometry, X-ray and anthropometric measurements including skinfold and isotope detection have been used to assess the body fat of athletes. Unfortunately, no universal constraints have been found which apply equally well to all groups, including male and female athletes. The different methodologies produce differences of five percent or more in measurement of an individual's body fatness.

During inactivity or habitual training, the body weight may remain relatively constant although inactivity often produces a gradual weight gain. During intensive training, the muscle mass and the blood volume increase while the skinfold thickness decreases.

The leanest male athletes appear to be about three percent (which is the approximate value of essential fat) to seven percent fat, and the leanest female athletes about seven percent (which is essential fat plus sex-specific fat) to ten percent fat (40). With few exceptions the suggested upper level of fatness for all males is about 15 percent. For female gymnasts, the placers are less fat than the nonplacers (41). Studies have shown that body fat fluctuates dynamically as a function of the state of physical training.

Statement of the Problem

The problem was to determine the maximum oxygen uptake ($\dot{V}O_2$ max), anaerobic threshold, respiratory function, electrocardiogram components, blood lipids, flexibility, grip strength, anaerobic power, and body composition of professional soccer players who have been playing for a North American Soccer League team. Findings of this research were compared with results of the study conducted by Raven et al. (42).

Subproblems

1. To compare selected fitness variables of American players with other international players on the team.

2. To compare selected fitness variables of players according to different positions (goalkeepers, fullbacks, halfbacks, and forwards).

Hypotheses

1. There will be no significant difference between the maximum oxygen consumption of professional soccer players participating in this study and the maximum oxygen consumption of professional soccer players studied by Raven et al. (42).

2. There will be no significant difference between the vital

capacity of professional soccer players participating in this study and the vital capacity of professional players studied by Raven et al. (42).

3. There will be no significant difference between the body composition of professional soccer players participating in this study and the body composition of professional soccer players studied by Raven et al. (42).

4. There will be no significant differences between the flexibility, hand grip strength, and vertical jump of professional players participating in this study and the flexibility, hand grip strength, and vertical jump of professional players studied by Raven et al. (42).

Limitations

1. There was no attempt to control diet, sleeping, and any activities of subjects prior to testing.

2. Apprehension of subjects due to the unfamiliarity of the testing equipment was anticipated, even though orientation of subjects to the equipment preceded the testing procedure.

Delimitations

1. The subjects for this study consisted of nine professional soccer players who played for the Tulsa Roughneck professional team during the 1982 season.

Assumptions

1. It was assumed that all subjects would follow the pre-test instructions.

2. It was assumed that the subjects were highly motivated and

exerted a maximum effort on all tests.

3. The skill factor did not affect this study significantly, since the only physical requirements were running and breathing.

4. The treadmill protocol used for this study was a valid method of eliciting maximum oxygen intake and anaerobic capacity methodology.

5. The methodologies used to calculate aerobic and anaerobic capacities were valid.

Significance of the Study

Soccer is a dynamic game with ninety minutes of nonstop, fast-paced activity. Players must develop and maintain high levels of endurance through various training methods to meet the game's demands on the cardio-respiratory system. Professional soccer players should reach their maximum cardio-respiratory fitness level prior to the season in order to withstand the intensity of the games once or twice a week. It therefore appears to this researcher that being able to determine players' level of endurance, knowing their physiological limitations will give the coach scientific information to assign his players to different positions according to the player's physiological abilities, and alter training methods if necessary.

Soccer players must sprint with or without the ball quite a few times for distances anywhere from a few yares to fifty or sixty yards continuously. This kind of work puts a great demand on the players. In addition to having high levels of endurance, soccer players must have high levels of anaerobic work capacity. Anaerobic work capacity is important for successful completion of continuous anaerobic work during a soccer match. Anaerobic threshold of professional soccer players has not been determined by previous investigators; therefore this researcher measured anaerobic threshold.

Many authors (43, 44, 45, 46) have reported cases of sudden death or collapse due to cardiovascular conditions, which are oftentimes seen on soccer fields. Myocordial infarction, with or without sudden death on soccer fields can be prevented by administering maximal stress testing, and electrocardiograms to screen persons with high risk factors.

Despite the nationwide popularity of the sport of soccer, comparatively little scientific information is available concerning the physiological characteristics of the professional participant. Success in soccer is dependent upon a variety of factors. These include the physical characteristics and fitness of the players, their level of skill, their degree of motivation, and the tactics employed by them against opposition. Many of these factors are not easily measured objectively. However, some factors can be tested by using standardized testing methods and can provide useful information for coaches.

The Tulsa Roughnecks Professional Soccer team has been successful every season; each season they made the playoffs for the American Soccer Bowl. Finally in the 1983 season, they won most of their matches, made the playoffs, and won the American Soccer Bowl. Seven of the total nine subjects tested for this study took part in the Tulsa Roughnecks winning season.

The main purposes of this research were (1) to find the physical and physiological characteristics of professional soccer players; (2) to compare the findings with those obtained on members of another professional soccer team, and (3) to establish new data for comparison by future investigation.

CHAPTER II

REVIEW OF RELATED LITERATURE

The sport of soccer is a dynamic game with ninety minutes of non-stop, fast-paced physical activity. Evaluations of physiological processes during and after a match indicate that soccer imposes great demands on the cardiovascular system. Players must develop and maintain high levels of cardiovascular fitness (endurance) through training to meet the game's demands on the cardiovascular system.

The review of literature is divided into several different phases: (1) physiological demands of competition in soccer; (2) maximum oxygen consumption of soccer players; (3) resting and maximum heart rate of soccer players; (4) anaerobic threshold and anaerobic power of soccer players; (5) physical characteristics of soccer players, and (6) summary.

Physiological Demands of Competition in Soccer

Soccer is universally played outdoors on natural grass, artificial turf, dirt, rectangular fields with the dimensions anywhere between fifty and seventy-five yards in width and a hundred to a hundred and thirty yards in length. In most countries, soccer seasons last from mid-August to mid-May, with a four to five week recess about the middle of the season. A full soccer match is two forty-five minute halves for a total of nonstop play of ninety minutes, with a fifteen minute break between halves. During an official league match, each team is allowed to make two player changes. Once a player is taken out of the game, that player is not allowed to come back into the game. Most professional teams play one to two matches each week, using the same eleven to fourteen players.

The sport of soccer requires a lot of quick sprints for anywhere from a few yards to forty or fifty yards, many times with an all-out effort. Quick changes in direction are necessary to mark an opponent and follow the ball. A good player needs to be able to start off fast, sprint, change directions, jump high to head the ball, kick forcefully and keep up with the changing pace of the match for at least ninety minutes or longer. As a result of these characteristics, the sport of soccer demands a very high work output from its players. Players must go through a vigorous training regime to increase their cardiovascular fitness and muscular strength during pre-season, and maintain a high level of total fitness throughout the season to be successful and avoid injuries.

Several researchers have attempted to determine the total distance covered during a 90-minute competition. Wade (47) reported a range of 1,600-5,486 meters, 229-1829 meters at walking, and 1,371-3,658 meters at jogging pace. Vinnai (48) determined the total distance covered by Russian players to be up to 17 kn during a match. Zelenka et al. (49) concluded that Czechoslovakian players covered 11.5 km total distance; players run more than 6 km mostly in 5-10 m runs. Since most researchers did not elaborate on how they reached such conclusions, figures for total distance covered should be treated cautiously.

Thomas and Reilly (50) studied work rate during soccer competition. The movements of players were divided into walking, backing, and running; running was subdivided into three intensity levels of jogging, cruising, and sprinting. The distance of each specific movement was estimated in 7-meter units from an elevated position in the stand directly over the half-way line using a number of cues on the playing pitch and along its boundaries. Jumping, tackling, and hiking; the durations of stationary rest pauses, and the distance covered in possession of the ball were also recorded. Researchers validated their methodology by concurrently filming one subject and obtaining distance measures from a film record of one complete game. Results closely corresponded. Thomas and Reilly determined the overall distance covered by outfield players during competition ranged from 7,069 to 10,921 m with a mean of 8,680 m. Of that distance, 36% was covered jogging, 24.8% walking, 20.5% crusing, 11.2% sprinting, and 6.7% backing. Only .26% to 4% of the total distance was covered in possession of the ball by outfield players. More than 900 discrete activities were taken per player during a match. Each player paused 43 times and stood still for a total of 143 seconds during a match. The average distance per discrete activity was 10 m, while activity changed an average of every five seconds. Three walks were observed every minute, and stationary rest pause of 3.8 seconds every two minutes. Players worked significantly higher during the first than in the second half. This might be due partly to fatigue effect or as a result of the usual reduction in uncertainty of the result as the match progresses.

Saltin (51) reported a similar reduction in the distance covered between the first and second periods. The players with the lowest glycogen content in their thigh muscle at the start of the game covered 25% less distance than the other players. Saltin pointed out that the players with low glycogen content covered half of the total distance walking, and 15% at maximal speed compared with 27% walking and 24%

sprinting for the high glycogen players. Saltin concluded that initial muscle glycogen appears to be important in playing soccer.

The intensity of exercise is clearly indicated by the amount of oxygen consumed or energy expended. Maximum oxygen consumption is the best indicator of any individual's ability to withstand different levels of work intensities. A player with a high level of oxygen consumption is more likely to perform better for a long time at a high intensity level whereas a player with a low level of oxygen consumption is more likely to fall apart during a match with high intensity. Therefore, maximum oxygen consumption of each player provides the coach with valuable information about his training regimes.

Maximum Oxygen Consumption Studies in Soccer Players

Maximum oxygen consumption of soccer players was investigated by several researchers through different methods. Whiters et al. (13) reported mean maximum $\dot{V}O_2$ of 62.0 ml/kg/min for five Australian national level soccer players. The same researchers recorded mean maximum $\dot{V}O_2$ of 72.0 ml/kg/minute for the same nation's runners, 64.1 ml/kg/minute for the hockey players, and 58.5 ml/kg/minute for the basketballers.

Williams et al. (52) tested nine English professional soccer players on a bicycle ergometer, and a mean max $\dot{V}O_2$ of 57.77 ml/kg/minute was found.

Reid et al. (53) compared maximum $\dot{V}O_2$ consumption of ten university rugby players, ages 18-24, nine semi-professional soccer players, ages 19-27, and seven university squash players, ages between 21-25 years. The rugby players had a mean max $\dot{V}O_2$ of 51 ml/kg/min with a highest value of 59 ml/kg/min, soccer players a mean max $\dot{V}O_2$ of 53.8 ml/kg/min with a highest value of 61 ml/kg/min. Squash players had a mean max $\dot{V}O_2$ value of 56.1 ml/kg/min, with a highest value of 62 ml/kg/min. Among the groups of athletes tested, soccer players were the oldest. The same researchers reported that all three groups of athletes, soccer players covered slightly more distance during a match with a mean distance of 3,470 yards, squash players 3,304 yards, and rugby players covered a mean distance of 3,224 yards.

Caru et al. (54) reported a mean max $\dot{V}O_2$ intake of 51 ml/kg/min for 16 Italian amateur players ages 14-18.

Israel and Israel (55) studied maximum $\dot{V}O_2$ consumption of 44 East German players who were members of four first-division league teams. Using a maximum treadmill test, four goalkeepers' mean max $\dot{V}O_2$ of 4,308 L/min, twelve players' mean max $\dot{V}O_2$ of 4,380 L/min, eight midfielders' mean max $\dot{V}O_2$ of 4,380 L/min, and twenty forward players' mean max $\dot{V}O_2$ of 4,303 L/min were recorded. Israel and Israel stated that there was no significant difference between the players in different playing positions.

Astrand and Rodahl (56) reported the mean $\dot{V}O_2$ max of 58.6 ml/kg/min for a group of 50 top Swedish soccer players. The highest value reported was 69 ml/k/min. These authors noted that since soccer enables players to pause briefly between bursts of physical effort, the same level of aerobic power is not required in the players as in long-distance runners, cross-country skiers, or athletes in events requiring continuous long-lasting effort of near maximal intensity.

Maximum $\dot{V}O_2$ consumption of Ethiopian national soccer players was studied at the Mexico Olympic games by Reilly (57). Mean $\dot{V}O_2$ values of 3.1 L/min and 43 ml/kg/min were reported, values not representative of highly trained athletic subjects who compete for 90 minutes. Probably these subjects were not representative of top class professional players. It should be noted that measurements were made at a high altitude (Mexico City). Balke (58) stated that high altitude reduces max $\dot{V}O_2$ consumption by more than 10% in athletic subjects.

Reilly (59) in 1975 studied English league players according to different positions in the 4-3-3 team configuration. The midfielders had significantly higher aerobic power values than all other positions; the goalkeepers had significantly lower values than the center backs, and the center back had significantly lower relative values than the other outfield players. The full backs and strikers had intermediate values. Reilly's study points out that the highest capability for endurance performance is possessed by the midfield players, who must act as play makers and linkmen between the defense and the attack. Since goalkeepers stand in the goal most of the time, it is not surprising that they had the lowest of all outfield players.

Raven et al. (42) recently studied a North American Soccer League team with a playing staff of 13 English and five United States nationals (a total of 18) with a mean age of 25.6 years; the oldest was 32 and the youngest was 19 years of age. They found a mean max $\dot{V}O_2$ of 59.6 ml/kg/min for five attacking players, 56.1 ml/kg/min for two midfield players, 59.3 ml/kg/min for nine defensive players, 53.7 ml/kg/min for two goalkeepers. A mean of 58.4 ml/kg/min max $\dot{V}O_2$ value was reported for the eighteen players tested. For the Raven study, a modified Astrand running test on a motordriven treadmill was utilized to determine a max $\dot{V}O_2$ consumption.

In 1975, Cochrane et al. (60) studied max VO_2 consumption of 12 Australian national soccer players using a multistage treadmill test of 7 mph up an increasing grade that gradually elevated oxygen consumption and heart rate to maximal levels. The range of the soccer player's max VO_2 value was 50.0-63.8 ml/kg/min with a mean of 56.1 ml/kg/min.

Research findings indicate that without specific aerobic type training, the aerobic capacity of professional soccer players averages above 56 ml/kg/min with the range being 50.0-66.7 ml/kg/min. These figures fall between the average untrained young man (40-45 ml/kg/min) and the top endurance athlete (3.000 metre runners = 79 ml/kg/min; cyclists - 74 ml/kg/min; cross country skiers = 84 ml/kg/min) reported by Astrand (61). Comparison of the VO_2 max data for other specialized sports showed them to have relatively moderate level endurance capacities.

Unfortunately, there is still a lack of knowledge concerning the role of the endurance capacity in the makeup of a successful soccer team. However, research findings suggest that first team members of professional teams and successful team players do have higher max VO_2 consumption than second team players. All research findings agree that the sport of soccer requires a high degree of cardiorespiratory endurance.

Resting and Maximum Heart Rate of Soccer Players

The heart serves as a pump in the cardiorespiratory system to maintain proper pressure and flow of blood to active muscle tissues. Without the proper function of the heart during rest, exercise muscle tissues cannot be supplied with needed oxygen for muscle function.

The heart rate at rest is different from individual to individual, and also within the same individual from one observation to another under similar situations. Most physiologists agree to consider average resting heart rate to be 78 beats per minute. As low as 40 beats per minute is observed in the highly trained endurance athlete as well as 100 beats per minute by sedentary individuals (62). Heart rate at rest is affected by age, sex, size, posture, ingestion of food, emotion, body temperature, environmental factors, and effects of smoking. Therefore, resting heart rate has very little value for the prediction of just one individual's physical fitness. However, it has some value for indication of groups of individuals' physical fitness. On the other hand, heart rate during exercise and recovery periods serves as a valuable source of information about an individual's cardiovascular fitness.

Research findings show that heart rate increases linearly with increasing workload or $\dot{V}O_2$ in both trained and untrained individuals. At the beginning of an exercise, the heart rate elevates very rapidly. If the workload is light or moderate, a plateau is seen in thirty to sixty seconds, and that heart rate is relatively constant until the end of the exercise. If the workload is heavy (ten or more times the resting metabolic rate), the heart rate keeps increasing until the individual reaches total exhaustion level. During exercise, the heart rate of a trained person is lower at any given $\dot{V}O_2$ than an untrained individual. During the first two to three minutes after the end of exercise, the heart rate decreases very rapidly. After this immediate decrease, the heart rate decreases more slowly at a rate that is roughly related to the intensity and duration of the exercise.

Raven et al. (42) reported a mean resting heart rate of 50 beats per minute for eighteen members of a North American Soccer League team. The same players' mean maximum heart rate was 188 beats per minute with a range of 173-203 beats per minute. The group's mean age was 26 years. Raven's study indicated the following mean maximum HR and range according to players' positions: Two midfield players, ages 32-21, mean age 26.5 years, mean max HR/182 beats/minute, range of 175-190 beats/minute; five attacking players, ages 31-23, mean age 25.6 years, mean max 186 beats/minute, range of 193-194 beats/minute.

Cochrane and Pyke (60) investigated the maximum heart rates of an Australian soccer team utilizing a multistage treadmill test. The following results were reported: Three defenders with a mean age of 25 years, mean maximum HR 190 beats/minute, four midfielders with a mean age of 23.3 years, mean maximum HR of 192 beats/minute, four attackers with a mean age of 23.5 years, mean max HR of 188 beats/minute, and one goalkeeper, 23 years of age, maximum heart rate of 203 beats/minute. Mean group age of the Cochrane and Pyke subjects was 23.8 years and mean maximum HR of 191 beats/minute was stated. This is slightly higher than maximum HR of 188 beats/minute recorded by Raven et al. The study of Cochrane and Pyke (1976) included the degree of strain being exerted on the cardiovascular system. This was estimated from telemetered recordings of heart rate. A Sieman's telemetry system was used to monitor heart rate at two-minute intervals throughout both the training session and practice game. Researchers found that the mean heart rate of each player during the game was higher than that during training. During training, an average of the two players worked at 71% of their maximum heart rate level and 86% of their maximum heart rate level during the game, respectively. The long recovery periods permitted between work bouts in the training session contributed to considerable fluctuation in heart rate; the range was 53-96% of maximum. During the game, heart rate remained between 75% and 96% of its maximum. While it is recognized that heart rate is a gross indicator of aerobic and anaerobic energy release, the heart rate during training and games gives the coach some indication of the type of stress being imposed on the players and enables him to make necessary changes in training methods.

Smodlaka (55) included some previous research findings by Hollman and Hettinger using telemetry during a soccer game, who recorded an average heart rate of 154 beats/minute, ranging from 120 to 170. The rate decreased to 90 beats per minute during halftime. The Israel and Israel study of 44 East German soccer players was also included in Smodlaka's article. Using a maximal stress test, the Israel research compared members of four first league teams in relation to their positions on the team. Maximum heart rates of 188 beats/minute for four goalkeepers, 188 beats/minute for twelve defensive, 187 beats/minute for eight midfield, and 190 beats/minute for twenty forward players were recorded.

Results of research on exercise heart rates of soccer players during training and games indicate the high intensity of the sport. It is obvious that soccer places a high degree of strain on the heart and the oxygen transport system. Appropriate endurance training is needed to meet these high demands placed on the players.

Anaerobic Threshold and Power

The energy sources for the lower levels of work where O_2 demand is matched by O_2 supply are derived from oxidative metabolism. On the other hand, heavy exercise results in the O_2 demand exceeding the circulation's ability to supply O_2. Maintenance of heavy exercise is made possible only by tapping anaerobic energy reserves via glycolytic mechanisms. The onset of anaerobic metabolism during exercise can be discerned from the increase in blood lactate above resting levels.

The amount of energy obtained by the aerobic process during exercise is determined by measuring the oxygen uptake during exercise. The amount of energy obtained by anaerobic processes is approximated by measuring the amount that the metabolism is increased above resting values by following exercise (oxygen debt) and by measuring the difference between blood lactate and the highest value observed during or after exercise.

The term "anaerobic supply" refers to that amount of energy which comes from the breakdown of glycogen or glucose to lactate in the absence of oxygen. This anaerobic energy supply is formed originally by oxidative processes; it can be delivered immediately and should be considered as part of the energy stores of the muscle cell.

The extent to which the various oxidative sources are utilized depends on the intensity and duration of exercise. Dill (63) stated that the oxidative requirement during sprints is met chiefly by credit oxidation, whereas most of the oxidative requirement of distance runners is derived from aerobic sources (atmospheric oxygen). Christensen (64) suggests that alactic oxidative sources must be important during exercise of very short duration since no significant increase in lactate concentration occurs in spite of the presence of an oxygen debt. Wasserman et al. (65) stated that lactate concentration in arterial blood changes very little at moderate work, increases at heavy work, reaching an early plateau concentration, and increases to a greater degree at the very hard work intensities, reaching a later peak value. Oxidative energy from the anaerobic pyruvate-lactate reaction occurs when lactate is produced in excess of its catabolism. This is reflected in the increase in arterial blood lactate concentration. When the concentration of lactate does not change, there will be no net gain in oxidative energy from this mechanism.

Cunningham et al. (66) studied the effect of training on aerobic and anaerobic metabolism during a short exhaustive run. Eight male subjects were tested before and after training. Subjects ran on a treadmill at a speed of eight mph and a grade of 20%. Run times ranged from 36 to 60 seconds. A six week training program of interval sprints of 270 yards of distance runs of two miles were used to stress the capacity for both aerobic and anaerobic metabolism. The training program resulted in a 23% increase in run time for short exhaustive runs. A nine percent increase in oxygen debt and a 17% increase in blood lactate concentration were reported as a training effect. Although very high percentages of sporting and individual athletic endeavors involved a great amount of anaerobic functioning, very little research efforts have been focused on the measurement and meaning of tests of anaerobic functioning. There is still no widely accepted method of estimating anaerobic functioning. Different investigators have chosen to use different criterion scores, including initial or post-exercise glycogen levels, initial levels of muscle phosphagen (ATP and PC), peak exercise muscle or blood lactic acid and/or pyruvate concentrations, one or several glycolytic enzyme concentrations, or even the quantity of post-exercise oxygen uptake (the oxygen debt). All of these different methods suggest that the test used to determine anaerobic functioning must be of maximal intensity for a given individual and must be performed for as long as possible. Katch et al. (67) suggested that a bicycle ergometer test that lasts for approximately 40 seconds at a frictional resistance of 5.0 to 6.0 kp with an all-out cycling cadence can be used to determine maximum aerobic functioning.

Anaerobic Threshold

"The anaerobic threshold is defined as the level of work or oxygen consumption just below that at which metabolic acidosis and associated changes in gas exchange occur." At a level during increasing exercise load, the oxygen demand exceeds the oxygen supply. At this anaerobic threshold level, energy release from anaerobic metabolism increases as a result of lactic acid buildup.

Wasserman et al.(68) developed non-invasive methods for estimating anaerobic threshold by studying the points of (1) nonlinear increase in VE, (2) nonlinear increase in VCO_2, (3) an increase in end-tidal O_2 without a corresponding decrease in end-tital CO_2, and (4) an increase in R, as work rate was increased during an incremental exercise test. Among the above variables studied, R was found least sensitive. The authors investigated the alterations in gas exchange in man during exercise increasing in increments of 15W each minute to determine the non-invasive indicators of the onset of nonaerobic metabolism. Expired airflow and CO_2 and O_2 tensions were continuously monitored with rapidly responding gas analyzers. These measurements were recorded directly as well as processed by an (on-line) minicomputer, to give minute ventilation (VE), CO_2 production (VCO_2), oxygen consumption ($\dot{V}O_2$), and the gas exchange ratio (R), breath by breath. The anaerobic threshold was determined in 85 normal subjects between 17 and 91 years of age by using the above mentioned techniques. The lower limit of normal was 45W, while values for very fit normal adults were as high as 180W. Sixty-one subjects pedaled for four minutes on an unloaded ("0" W) cycle ergometer. After the warmup period, work rates were incremented 15W every minute. For 24 other subjects, 25W rate increases were used.

Using a one-minute incremental work test has the major advantages in measuring the respiratory variables to detect the anaerobic threshold so that it can be determined without blood sampling during the performance of the exercise test. This enables the investigator to determine the exercise soon after the anaerobic threshold is detected. The major disadvantage of Wasserman's technique is that a sophisticated gas analyzer is needed to determine gas exchange measurements of each breath during exercise.

As a result of a 1976 study, Davis and his colleagues (69) concluded that the gas exchange AT is a valid and valuable indirect method for detection of the development of lactic acidosis during incremental exercise. The authors pointed out that AT can be measured using no more laboratory equipment than is normally used for the measurement of VO_2. If only VE is measured, the AT can be defined only in terms of work rate units while inclusion of FEO_2 and $FECO_2$ measurements allow the AT to be expressed as an absolute level of VO_2 or, if maximal work is performed, a percentage of $\dot{V}O_2$ max. The study of Davis supports both the validity and feasibility of the AT measurement. This obviates the need to measure lactate changes via repeated blood sampling or relying on an assumed AT value from other methods.

Anaerobic Power

Anaerobic power is defined as the ability to start moving quickly for four to five seconds to cover short distances with maximal effort. The energy for such tasks is provided by anaerobic energy-releasing mechanisms. The results for anaerobic power are measured in mechanical work output. Units of horsepower and kg-m/kg x sec are commonly used. The anaerobic power increases with age to reach a maximum of 1.5-1.6 kg-m/kg x sec at 20-30 years, and then decreases progressively to a value less than half of about 70 years (70).

Margaria et al. (70) devised a test for the maximum anaerobic power or the maximal work performance in a short burst of maximal activity in man. The test consists of measuring with an electronic clock the vertical component of the maximum speed with the subject running up an ordinary staircase. Mechanical energy is expressed in kg-m kg x second and amounts to 1.6 for young, fit subjects of 20-30 years of age; it decreases with age to about 0.8 at 70 years. The authors determined the efficiency of that exercise to be about 0.25, and therefore the energy requirement amounts to about 50 k cal/kg/hr. The test is easy to administer, does not require a particular skill from either the operator or from the subject, takes a very short period of time, and the only apparatus needed is a watch sensitive to 0.01 second. The authors reported a very high mechanical energy output of 2.8 kgm/kg x sec on an Olympic sprinter capable of covering 200 m in 20.2 seconds. A middle-distance runner capable of covering 3,000 meters in eight minutes two seconds, a lower value of 2.06 kgm/kg x sec was reported for this individual, an exceptionally high value for aerobic power output corresponding to an oxygen consumption of 71 m/kg/min, or 21.3 k cal/kg/hour.

Shave (71) determined anaerobic capacity of thirty untrained college male volunteers 18 to 26 years of age through the administration of the Margaria Test of Anaerobic Power. He correlated the running times of 100 yd, 200 yd, 440 yd, 880 yd, 1-mile run, 2-mile run, 3 mile run. Significant correlations of .05 level between anaerobic power and 100 yd run (-.85), the 220 yd run (-.82) and 440 yd run (-.79). The results of his investigation indicated that the 2 mile and 3 mile runs are good predictors of maximum oxygen intake. The 880 yd run and the 1 mile run should be used with caution. The 100 yd, 220 yd, and 440 yd runs have no predictive value for predicting max VO_2 intake. The performance times of 100 yd, 220 yd, and 440 yd runs were good predictors of anaerobic capacity, while the 880 yd run, the 1 mile, 2 mile and 3 mile runs have had no predictive value for predicting anaerobic capacity.

Withers, Roberts, and Davies (13) determined the anaerobic power of South Australian male athletes according to the procedure outlined by Margaria, Aghemo, and Rovetti (70). The highest mean relative power scores of 1.56 and 1.65 kgm/kg x sec were registed by the hockey and soccer players. The best relative power score of 1.84 kgm/kg x sec was reported for a forward soccer player.

The trend in modern soccer is toward expansion of a player's physiological functions which will enable players to execute a greater number of dashes at high intensity. The energy for such work must come from anaerobic alactate pathways.

Godik and Skomorkhov (72) studied maximum anaerobic power (MAP) of 40 high-level soccer players and six Class II sprinters, utilizing the maximum anaerobic test developed by Margaria et al. Results indicated a close relationship between MAP and AP (aerobic power), (r = 0.823). MAP represents the ability to develop maximum effort, whereas AP reflects the ability to maintain it. Soccer requires a higher ability to develop short-lasting maximum effort, more than ability to maintain it for a long period of time. Godik and Skomorkhov's experiment showed that goalkeepers were superior in MAP, defensive and forward players had identical MAP values, and midfield players had the lowest MAP capacities. When compared with Class II sprinters, soccer players develop relative power of only 0.05 m/sec more than sprinters over a short distance, but over a 10 meter distance, the measurements were identical 1.68 m/sec.

The Sargent Jump Test of anaerobic power can be used to determine anaerobic power of the legs. Leg power is an important factor in soccer to jump, head the ball, or perform fast starts. When using the Sargent Jump Test, body weight and speed in performing the jump should be considered as a part of the measurement along with the vertical jump distance. The Lewis Nomogram can be used to make the Sargent Jump Test more valid as a measure of leg power; the result is expressed in kg/m/sec.

Raven et al (42) reported following mean Sargent Jump Test results according to different playing positions: 21.6 inches for four forwards (range 26-16), 16.0 inches for one midfielder, 21.1 inches (range 25-17) for nine defenders, and 20.2 inches (range 21-19) for two goalkeepers. A total mean of 20.8 inches with a range of 26-16 inches was reported. These results indicated that soccer players ranged from average to excellent in comparison to a normal population. Cochrane and Pyke (60) reported the following mean vertical jump results for Australian soccer players: 48.3 cm for three defenders, 50 cm for four midfielders, 50.3 cm for four attachers, and 52 cm for one goalkeeper; 49.9 cm was reported for the whole squad tested.

Reilly and Thomas (73) measured mean vertical jump test result of 58 cam for 31 English professional soccer players. They found the high est values in two center-back and in two attachers who play as target men during competition because of their ability to win possession of the ball in the air. Results were similar to reported performances of seven-foot high umpers by Kaufmann et al. (74).

When using the Sargent Jump Test as a test of anaerobic power, one should take speed and weight of the subject into consideration as a part of the measurement; otherwise the test result will not represent the true value of anaerobic power.

Komi et al. (75) stated the main parameters describing the anaerobic performance capacity of the whole body (vertical velocity, leg force, blood lactate) is related to muscle fiber composition--specifically, the percentage of fast twitch fibers in the quadriceps. Percentage of fiber compositions or relative area occupied by fast twitch fibers in soccer players have not received much attention by researchers.

Studies Related to Age, Body Size and Composition, Strength, Ability and Flexibility, Lung Capacities, Blood Pressure and Blood Lipids of Soccer Players

Physical characteristics of soccer players were reported by various investigators. Cochrane and Pyke (60) reported the following mean values for twelve members of an Australian soccer squad: 23.8 years of age, 75.8 kg, 178.6 cm, and 10.8% body fat. Among this group of athletes defenders tended to be taller and heavier, and midfield players were below the overall squad mean. Only one attacker, one midfielder and two defenders had more than 12% body fat. It should be indicated that the above measurements were taken two months after the completion of the soccer season, and players probably were not in peak physical condition.

The following results were obtained by Raven et al. (42) on eighteen professional players: age 26 years, height 176 cm, weight 75.5 kg, 9.59% body fat, sit and reach flexibility 20.2 inches, hand grip strength 102 pounds, maximum bench press 161.9 pounds, agility run time of 15.56 seconds, 5.29 liters- BTPS of vital capacity, 1.385- liters BTPS residual volume, 6.735 liters-BTPS of total lung capacity, sitting systolic and diastolic blood pressure readings of 121/77 mm/Hg. After fourteen hours, post-absorptive blood parameters were as follows: total protein 7.15 gm%, hemoglobin 14.6 gm%, hematocrit 41.9%, glucose 94.5 mg% triglycerides 90.8 mg%, and cholesterol 174 mg%. Results indicated that the players studied had a greater percent of body fat than the elite distance runners studied by Pollock et al. (76). The group average of 9.59% body fat was slightly less than the average of 10.65% body fat obtained from 400 Brazilian professional players reported (42). The above study indicates that the percent body fat of soccer players is approximately 10%. Raven et al. (42) found the body fat percentage of soccer players to be equivalent to that of running backs in professional American football.

Studies have shown that the majority of top class soccer players are in their twenties. Hirata (77) concluded from his study of entrants at the Tokyo Olympic Games in 1964 that success in ball games such as soccer, basketball, volleyball, and hockey is accomplished in the period 24-27 years of age, soccer being the earliest of these.

Like in other sports, strength plays an important role in soccer. Among other measurements of strength, grip strength serves as an indicator of gross body strength. Value 50.4 kg of grip strength of 31 English professionals was reported (50). This is similar to results for scuba divers, lawn tennis players, fencers, gymnasts, and swimmers. Raven and others used one repetition maximum bench press as a field test of fitness of professional soccer players and found a mean value of 73 kg (42).

Using cable tensiometry, isometric strength of leg muscles of English professional players was tested (59). No significant limb differences were found. Strength balance between the limbs decreases the likelihood of injuries. The muscle groups of the quadriceps gastrocnemius, and hamstrings are very important for development of the explosive force used in jumping, kicking, and turning. Players should possess a high capacity to sustain a contraction which is required for balance and ball control. Shephard (78) pointed out that isometric strength is important in maintaining a player's balance on a slippery field, and also makes ball control easier. For the goalkeeper, almost all of the body's muscle groups are important. Outfield players hould have strong hip flexors, plantar and dorsi flexors of the ankle, and muscles of the lower trunk.

Current research findings indicate that soccer players are not above average in static muscular strength. The reason for that might be that inadequate attention is being paid to resistance training in training methods.

Since hemoglobin carries oxygen to muscle tissues, blood hemoglobin content is important for endurance sportsmen such as soccer players. Values of hemoglobin concentrations of 14.6 g/dl and 41.9% hematocrit (the proportion of blood volume occupied by the red blood cells which carry hemoglobin) were reported for soccer players by Raven et al. (42). These values fall within normal range. Brotherhood and others (79) reported hemoglobin levels of 14.16 g/dL for nonathletes, and 15.06 g/dL for runners. Athletes taking iron supplements had similar values.

Blood volume and total body hemoglobin were on average 20% higher in the athletes than in the non-athletes.

Summary

A review of the related studies indicated that there is a consistency in the testing procedures and most of the results are closely comparable. Most of the studies have been conducted in England using both amateur and professional soccer players. The average age for professional players was 24 to 28 years, even though there were some older and some younger ages recorded. No attempts were made to determine whether or not any physical and physiological differences existed among younger and older players. However, the literature supports the idea that human subjects' maximum aerobic and anaerobic power decreases with age, and longer periods of training are needed to maintain existing levels of conditioning. Players who continue to play after 28 to 30 years of age use experience for their advantage, work harder, and possess high levels of personal motivation.

Research results agree that soccer is an endurance type of sport which places a high degree of physiological stress on its participants. During an intense competition of 90 minutes, studies indicated that some players covered distances from 7.069 to 10.921 meters by changing directions, speeds, and length of each run.

Physical size, height and weight of professional players are not significantly different from the normal population. In general, defenders tend to be taller and heavier than midfield players, attackers are found to be a heterogeneous group. Goalkeepers are tallest and heaviest among all players. Soccer players are found to have an average of 10%

body fat, which is below the average for adult male population. Vertical jumping ability of goalkeepers and center backs are reported to be better than others. As a group soccer players' jumping ability surpasses normal male population. Agility test results indicated that soccer players had higher scores than normal population.

Lung capacities of soccer players were not significantly higher than non-athletes; however, they did have slightly higher values than the average population. Slower resting heart rate and blood pressure than non-athletes was reported for soccer players. Blood chemistry of soccer players did not differ from the values of the average population. Most studies showed that soccer players had a mean max $\dot{V}O_2$ of over 58 ml/kg/min, which is greater than max $\dot{V}O_2$ values for normal males and lower than values recorded for outstanding orienteers, cross-country skiers, and middle and long distance runners. Most researchers agreed that since soccer permits brief pauses between bursts of physical effort, the same level of aerobic power is not required as for the athletes who participate in events requiring continuous long-lasting effort of near maximal intensity.

Most investigators suggested that running tests had low reliability with professional soccer players when endurance was a factor. If they are used to measure physiological processes, results should be treated with caution. Margaria's maximum anaerobic test is widely used to determine players' maximum anaerobic capacity. Also, a 50-yard running time with a fifteen-yard running start is widely accepted method of measuring anaerobic power.

A review of the literature reveals that not much research has been done on American amateur and professional soccer players. The area of anaerobic threshold and maximum anaerobic power have not received much attention. More longitudinal studies are needed in order to determine development stages of players and to differentiate good players from poor players.

CHAPTER III

METHODS AND PROCEDURES

The purpose of this study was to determine the maximum oxygen consumption (VO_2 max), anaerobic threshold, respiratory function, electrocardiogram components, blood lipids, flexibility, grip strength, anaerobic power and body composition of professional soccer players.

The procedures followed during this course of research were organized under the following headings: (1) selection of subjects; (2) test administration; (3) statistical procedure, and (4) description of instruments.

Selection of Subjects

The subjects for this study consisted of nine Tulsa Roughnecks (a North American Soccer League team), professional soccer players.

Test Administration

The evaluation of subjects was done in the physiology of exercise laboratory in the Colvin Center of Oklahoma State University. Subjects were notified at least two days ahead of the testing date and asked to (1) dress in shorts and running shoes, and (2) avoid strenuous physical activity on the test day. The sequence of events were as follows: (1) resting heart rate, resting EKG, resting blood pressure; (2) measurement of resting oxygen consumption; (3) blood lipids test; (4) height and weight measurements; (5) respiratory function tests (VC, FEV, MVV); (6) measurement of flexibility, grip strength and anaerobic power (vertical high jump); (7) determination of body composition; (8) treadmill best for determination of maximum oxygen consumption and anaerobic threshold, and (9) determination of anaerobic power.

Measurement of Resting Blood Pressure and Resting ECG

Resting heart rate was taken with the subject in the reclining position and relaxed by using the Quinton heart rate meter.

Resting blood pressure was taken while the subject was sitting and relaxed. Blood pressure was measured by using a sphygmomanometer.

Resting EKG tracings were recorded by using a Birtcher electrocardiograph machine. From the ECG tracings, resting heart rate, the amplitude of the R and T waves, intervals (P-R, QRS, and ST), rest/work ratio was calculated according to the method described by Cureton (80).

Blood Chemistry Test

Prior to the blood test, subjects fasted for 14 hours. Fifteen ml blood samples were taken from the antecubital vein by a qualified lab technician. For analysis of total cholesterol and high density proteins, a test was conducted on Spectronic-20 photospectrometer.

Measurement of Flexibility, Grip Strength, and Anaerobic Power (vertical high jump)

Flexibility

The subjects sat with knees fully extended and locked, feet flush against the flexibility box. After sufficient static warmup, the subjects were instructed to bend at the hips and stretch the hands and arms forward as far as possible. This position was held for three seconds. The point where the subject touched on the recording stick was measured as flexibility.

Grip Strength

The Naragansett hand dynamometer was used to measure the force of the hand's muscular contraction. It was placed in the palm of the hand with the dial facing the palm. The subjects were asked to squeeze as tightly as possible with the hand and arm away from the body. The hand or the upper arm did not push against any other object or against any part of the body. Three trials were taken with each hand, and the highest was recorded on the appropriate form (see Appendix, page 99).

Anaerobic Power (vertical jump)

The vertical jump was used to determine explosive leg power. A piece of board marked off in half inches was mounted on a wall and was used for this test. The subject stood straight close to the board, with one foot in front of the other. The index fingers of both hands were chalked with magnesium. The subject reached as high as possible with heels kept on the floor and made a mark on the board with his chalked fingers. Then he executed three jumps from a crouched position, making a mark each time on the board. The distance from the top of the reach mark to the top of the highest jump mark was recorded as his high score. Measurement was taken to the nearest quarter inch.

Body Composition

Body composition was determined through the underwater weighing method, according to the procedures outlined by Wilmore and Behnke (41) The subjects were weighed out of water wearing only swim suits. The underwater weighings were conducted in a swimming pool. The subjects sat in a chair placed in the water suspended from a Chatillon Scale. Then a minimum of ten readings was obtained with the subject under water and the air expired. The constant weight of the seat and harness was subtracted from the subject's recorded weight while sitting in the chair to obtain the net underwater weight. Estimated residual volume was used along with the net weight in water plus the weight in air, through a formula to obtain specific gravity and percent body fat of the subjects (see Appendix, page 98).

Treadmill Test for Determination of Maximum Oxygen Consumption and Anaerobic Threshold

All subjects were oriented concerning the testing procedures and provided information pertaining to the study. Each subject signed an informed consent form prior to participation.

Five disposable electrodes were placed on the subjects to monitor leads I, II, II, and V_5. The subjects were then asked to stand up quietly for recordings of pre-exercise ECG. Next, the headgear and nose clip were put on and a one-way valve was placed in the subject's mounth. The researcher explained and demonstrated the proper procedure for mounting and dismounting the treadmill. The subjects were carefully observed until they were comfortable on the treadmill. As soon as that was accomplished, the treadmill speed of 3.4 miles/hr and 10% grade were used to start the test. The subjects walked at 10% grade for three minutes; then the workload was increased 1% of grade each minute. Heart rate and ECG responses were recorded during the last fifteen seconds of each minute.

The first expired air sample was collected in the Tissot tank during the last thirty seconds of the first three minutes; after that, during the last thirty seconds of each minute until the end of the test. After the volume reading was recorded to determine minute ventilation, gas samples were transferred to the Godart Pulmo-Analyzer and Beckman OM14 O_2 analyzer in one-liter rubber bags in order to analyze the expired air for carbon dioxide and oxygen. The analyzers were calibrated at the beginning and at two-minute invervals throughout the test.

A symptoms limited test protocol test was used for all subjects. The subjects were allowed to continue voluntarily until they reached the general exhaustion and fatigue level. Once the subjects indicated that they could not walk any longer, the test was terminated.

After the final minute on the treadmill test, the elevation was decreased to 0% grade, and the subjects continued to walk at a speed of 2.8 miles/hr for two minutes. Then the treadmill was turned off and the subject sat down for third and fifth minute recovery heart rates.

Oxygen uptake was calculated according to the open circuit method as described by Ricci (81). Anaerobic threshold was determined by studying the relationships between workload and VO_2, VE, and percent CO_2 in expired air during exercise, a method suggested by Wasserman et al. (68).

Height and Weight Measurements

All subjects were weighed in pounds on a lever scale weighting machine without footwear and wearing only shorts. Height was measured in inches on a measuring scale fitted with a sliding headpice that was brought down to touch the top of the head. Subjects were asked to stand as erect as possible with their heads poised to look straight ahead. Standing height to the nearest 0.25 inch was recorded.

Respiratory Function Tests

Respiratory function tests were conducted on a Vitalograph machine.

Vital Capacity

The maximum air that can be expired after the largest possible inspiration is called vital capacity. The subjects were given sufficient time to become familiar with the instrument, then inhaled and exhaled as deeply as possible in one continuous effort.

Forced Vital Capacity

The maximum air that can be expired as rapidly as possible is called forced vital capacity. The subjects were instructed to inhale as deeply as possible, then to exhale as forcefully and as rapidly as possible.

FEV_1 and MVV values were also measured by the Vitalograph spirometer while conducting VC and FVC tests.

Grouping and Analysis of Data

General Fitness Variables

1. maximum oxygen uptake

2. anaerobic threshold
3. vital capacity
4. grip strength
5. power (vertical jump)
5. flexibility
7. systolic blood pressure
8. diastolic blood pressure
9. heart rate
10. rest/work ratio
11. T wave amplitude

Directions for Statistical Analysis

1. Compute correlation coefficients between maximum oxygen uptake and other fitness variables.

2. Run t-ratios of general fitness variables between the groups of subjects studied for this research and a group of subjects previously studied by Raven et al. (42).

3. Present descriptive data on all variables--ranges, means, standard deviations for all variables.

A significance level of 0.05 or less was considered necessary for any one test or combination of tests to be accepted as significant correlation for predicting cardiovascular fitness, or providing a basis for further investigations.

CHAPTER IV

RESULTS AND DISCUSSION

Two goalkeepers and seven outfielders, a total of nine professional soccer players who played for a North American Soccer Leage team during the 1982 season, served as subjects. The purpose of the study was to determine aerobic work capacity, anaerobic threshold, respiratory functions, physical characteristics, and blook lipids of professional soccer players by Raven at al. (42). The results were compared with results reported for eighteen Dallas Tornado Professional Soccer Club players during the latter part of the 1975 season. Differences between the physiological and physical characteristics of the present subjects with other groups of soccer, basketball, and field hockey players were studied.

Physical Characteristics

Mean, range, and standard deviation of age, height, weight, and percent body fat of the subjects are presented in Table I. The mean age of the subjects was 28.2 years, which was higher than reported values for other professional soccer players (50, 13, 53, 42, 60, 82). Physical characteristics of other groups of soccer players are summarized in Table II. The subjects were taller than Japanese National players (82) and Aberdeen FC players (53), shorter than the Dallas Tornado players (42), Australian (13), and Czechoslovakian (50) players. The subjects

TABLE I

PHYSICAL CHARACTERISTICS OF (1982) TULSA ROUGHNECK PROFESSIONAL SOCCER PLAYERS

Subjects	Age (years)	Height (cms)	Weight (kgs)	Body Fat %	Professional Playing Experience (years)	Country
Goalkeepers						
WD	27	185.6	86.36	12.2	6	USA
ZB	32	179.3	82.84	15.8	14	Yug
Outfielders						
TS	20	177.5	76.8	14.7	2	USA
BC	28	172.5	78.6	12.0	8	GB
AK	30	172.5	70.5	11.8	10	Pol
ID	30	159.3	64.5	13.0	7	Iran
LA	29	175.6	77.2	12.8	5	GB
SR	20	171.2	76.7	16.0	7	Yug
FG	29	174.3	82.2	13.6	11	Ger
Mean	28.22	174.52	77.31	13.54	8.1	
Range	20-32	159.3-185.6	64.5-86.4	11.8-16	2-17	
SD	3.38	7.43	6.58	1.99	4.25	

TABLE II

COMPARISON OF PHYSICAL CHARACTERISTICS OF (1982) TULSA ROUGHNECK PROFESSIONAL SOCCER PLAYERS WITH DATA REPORTED FOR OTHER SOCCER PLAYERS*

Year	Subjects	N	Age (yrs)	Height (cm)	Weight (kg)	Body Fat (%)
1967	Japanese Nationals 1964	19	-	171.2	66.4	-
1972	Czech Top Players	18	23.5	178.4	74.9	-
1973	Tottenham Hotspur	18	26.4±0.78	-	-	-
1974	Aberdeen FC	9	19-27	174.6-.9	69.4±2.1	12.4±0.73
1976	Australian Nationals 1974	12	23.8	178.6	75.8	10.8
1976	Dallas Tornado	18	25.6±1.9	176.3±1.2	75.7±1.9	9.59±0.73
1977	Southern Australian Representatives	5	24.4±2	178.1±3.6	75.2±2.2	
1983	Present Subjects	9	28.2±1.1	174.5±2.4	77.3±2.1	13.5±.66

*Values are mean ± standard error or mean only.

had a higher mean weight than that reported for the above groups of players.

The t-test analysis (Table III) showed that there was no signifivant difference in age, height, and weight between the present subjects and players tested by Raven et al. (42). The subjects had 13.54 mean percent body fat, which was significantly higher at .05 confidence level than mean percent body fat of players studied by Raven et al. (42).

TABLE III

t-TEST BETWEEN TWO GROUPS OF SOCCER PLAYERS

	Variables*					
Subjects	Age (mean) yrs	Height (cm)	Weight (kg)	Fat (%)	Hand Grip Strength (lb)	Sergant Jump (in)
Dallas Tornado Players	25.6	176.3	75.7	9.59	102	20.8
Present Subjects	28.2	174.5	77.3	13.54	125.1	25.44
t-Value	.96	.85	.55	4.08**	2.81**	.75

*means
**significant at .05 confidence level.

A review of literature indicated that athletes participating in endurance-type sports: long distance running or cross-country skiing, have 8 to 10 percent body fat on the average. The results of other studies conducted on soccer players are in agreement with the review of literature. The present subjects' high percent body fat may be due partly to the testing time. The subjects were tested three months after the 1982 season. It is more likely that during the off-season period, players cut down on their training and as a result gained some extra pounds of fat. Most of the other studies, including those of Raven et al., were conducted toward the end of the playing seasons.

t-Test comparisons (Tables IV and V) showed that the present subjects were significantly older than college basketball players (83) and South Australian field hockey players (13). They were significantly shorter and lighter than college basketball players. The present subjects had significantly lower percent body fat than did the South Australian field hockey players.

TABLE IV

t-TEST RESULTS BETWEEN COLLEGE BASKETBALL AND PRESENT SOCCER PLAYERS

	Variables*			
Subjects	Age (mean) yrs	Height (cm)	Weight (kg)	Fat (%)
Basketball Players	20	194.9	87.13	-
Present Soccer Players	28.2	174.5	77.3	13.54
t-Value	4.85**	5.68**	2.56**	

*means
**significant at .05 confidence level.

The mean, standard deviation, and range of flexibility and muscular strength of subjects are summarized in Table VI. Flexibility was measured by a Sit and Reach Test. The mean flexibility measurement of the subjects was -3.88 inches. Individual players' values ranged from average to excellent when compared with the normal population. Because of sudden stops, takeoffs, turns, and jumps, soccer players need to have a good range of motions at the joints.

TABLE V

t-TEST RESULTS BETWEEN FIELD HOCKEY PLAYERS AND PRESENT SOCCER PLAYERS

	Variables*			
Subjects	Age (mean) yrs	Height (cm)	Weight (kg)	Fat (%)
Field Hockey Players	21.8	174	73.2	16.7
Present Subjects	28.2	174.5	77.3	13.54
t-Value	4**	.15	1.19	2.15**

*means
**significant at .05 confidence level.

Mean grip strength of the subjects was significantly higher than that of players tested by Raven et al. The subjects' mean right hand grip strength was slightly higher than the mean left hand grip strength. Isometric strength measurements obtained by using cable tensiometry indicated no significant control lateral limb differences. However, most subjects had stronger right legs. Strength of quadriceps and

TABLE VI

FLEXIBILITY AND MUSCULAR STRENGTH OF (1982) TULSA ROUGHNECK PROFESSIONAL SOCCER PLAYERS

Subjects	Flexibility Sit and reach (inches)	Grip Strength		Leg Strength		Sergant jump (in)	Lewis Nomogram (kg-m/sec)
		Right hand (lbs)	Left hand (lbs)	Right leg (lbs)	Left leg (lbs)		
Goalkeepers							
WD	-4	150	140			21.5	140.0
ZB	-5	150	152	127.5	126.5	70.0	242.6
Outfielders							
TS	+2	118	98	137.5	130.0	21.0	121.0
BC	-5	141	129	200.0	192.5	20.0	122.0
AK	-2	136	136	135.0	130.0	17.5	104.0
ID	-5	76	95	122.5	137.5	20.0	102.0
LA	-1	117	110	120.0	72.5	20.5	121.0
SR	-4.5	118	117	122.5	137.5	21.5	124.0
FG	-3	120	102	152.5	130.0	17.0	119.0
Mean	-3.88	125.1	119.8	140.2	131.0	25.4	133.28
Range	(-5-1)	150-75	152-95	200-120	192.5-72.5	70-17	242.6-102
SD	1.69	22.95	20.3	24.95	30.0	16.7	43.93

hamstrings of both right and left legs should be equal; strength imbalance between limbs increases the likelihood of injury. For outfielders, strength of the lower part of the body, and for goalkeepers almost all of the total muscle groups is important.

Physiological Measurements of Subjects

Physiological characteristics of the subjects are summarized in Table VII. The subjects' mean resting heart rate of 57.7 beats per minute was lower than values reported for normal young men and higher than values of Olympic athletes (29). Subjects had significantly higher resting and significantly lower maximal heart rates than did soccer players studied by Raven et al. (42). Heart rates of subjects at each workload are presented in Table VIII.

College basketball players, with a mean age of 20 years, had a maximal heart rate of 185 beats per minute, higher than present subjects' mean maximal heart rate of 177.7 beats per minute. Hockey players, with a mean age of 21.8 years, had the highest maximal heart measurements of 191 beats per minute (Table IX). Comparison of physiological measurements of present subjects with other groups of professional soccer players is shown in Table X.

The sport of soccer requires frequent sprints with high intensity during the 90 minutes of play with short rest periods. As a result, quick circulatory recovery from such work is required. Subjects' three- and five-minute recovery heart rates indicated fast circulatory recovery. Mean maximal heart rate of 177.7 beats per minute was decreased to a mean of 115.2 and a mean of 99.8 beats per minute at the end of three- and five-minute recovery periods. Subjects had normal resting systolic and

TABLE VII

AEROBIC POWER CAPACITY OF (1982) TULSA ROUGHNECK PROFESSIONAL SOCCER PLAYERS (N-9)

Subjects	Resting HR Beats/min	Resting Systolic	BP mm Hg Diastolic	Max VO_2 mL/kg/min	Max VE L/min- BTPS	Max HR Beats/min	Max % Grade	3rd min Rec. HR Beats/min	5th min Rec. HR Beats/min
<u>Goalkeepers</u>									
WD	57	150	99	52.0	82.7	186	24	118	104
AB	66	135	88	49.5	86.3	189	23	140	114
<u>Outfielders</u>									
TS	52	135	76	51	68.3	166	24	102	87
BC	49	136	66	54.0	76.7	173	25	113	95
AK	60	122	62	57.4	92.3	190	28	125	115
ID	70	134	84	52.3	64.7	180	24	112	95
LA	53	132	68	53.8	92.3	165	23	105	93
SR	59	126	80	46.4	79.1	178	24	136	116
FG	54	110	68	63.5	118.7	173	28	86	80
Mean	57.7	131.1	76.7	53.3	84.5	177.7	24.7	115.2	99.80
Range	70-49	150-110	99-62	63.5-46.4	118.7-64,7	190-165	28-23	140-86	116-80
SD	6.81	11.0	12.1	4.8	15.9	9.3		16.9	13.0

TABLE VIII

HEART RATE OF (1982) TULSA ROUGHNECK PROFESSIONAL SOCCER PLAYERS DURING EACH WORKLOAD

	Workload %, constant speed of 3.4 MPH HR beats/min																		
Minutes on Treadmill	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Goalkeepers																			
WD	127	131	142	147	152	155	161	164	168	171	173	176	178	182	186				
ZB	132	140	146	152	157	166	168	172	175	180	182	184	186	189					
Outfielders																			
TS	110	117	118	124	127	131	133	140	142	148	152	158	160	164	166				
BC	112	115	120	133	138	141	150	152	155	160	162	167	169	170	172	173			
AK	116	120	123	128	136	142	145	151	157	162	165	168	172	172	177	180	184	185	190
ID	132	138	146	150	152	155	160	167	170	172	175	176	177	178	180				
LA	106	109	113	116	123	131	136	141	148	151	155	162	166	166					
SR	136	138	144	150	152	-	160	162	166	168	171	172	175	177	178				
FG	101	106	110	112	117	122	128	132	137	143	150	155	159	165	165	168	172	173	
Mean	119	123	129	134	139	143	149	153	157	161	165	168	171	173	174	173	178	179	190
Range																			

TABLE IX

MEAN VALUES OF SELECTED PHYSICAL AND PHYSIOLOGICAL MEASUREMENTS FOR THREE TEAM SPORTS PARTICIPANTS

Subjects	N	Age (yrs)	Height (cm)	Weight (kg)	Fat (%)	VE Max L/min	Max HR Beats/min	VO_2 Max ML/kg/min	MVV L/min	Power kg-m/Sec
Basketball Players (83)	13	20	194	87	-	157	185	59	203	-
Hockey Players (13)	9	21.8	174	73.2	16.7	-	191	64	-	115.5
Present Subjects	9	28.2	175.5	77.3	13.5	84.5	177.7	53.3	178.5	133

TABLE X

COMPARISON OF PHYSIOLOGICAL MEASURES OF (1982) TULSA ROUGHNECK PROFESSIONAL SOCCER PLAYERS WITH DATA REPORTED FOR OTHER SOCCER PLAYERS*

Year	Subjects	Resting HR (beats/min)	Maximal HR (beats/min)	Systolic BP mm/Hg	Diastolic BP mm/Hg	VO_2 Max mg/kg/min	VE Max L/min
1974	Aberdeen FC	-	-	-	-	57.8 ± 6.5	108.3 ± 16.9
1975	English League 1st Division	48 ± 1	198 ± 14	120 ± 2.16	70 ± 2.16	66 ± 2.7	-
1976	Australian World Cup Team	-	191	-	-	56.1	-
1976	Dallas Tornado	50 ± 1	188 ± 2	121 ± 1	77 ± 2	58.4 ± 0.83	153.6 ± 4.1
1977	South Australian Team		175 ± 6.9	-	-	62 ± 2.1	-
1983	Present Subjects	57.7 ± 2.2	177.7 ± 5.3	131 ± 3.6	76 ± 4	53.3 ± 1.6	84.5 ± 5.3

*Values are mean ± standard error of mean.

diastolic blood pressures.

Aerobic Power

Aerobic power refers to the ability to carry out relatively heavy workloads for long periods of time, which requires oxygen delivered to working muscles from cardio-respiratory systems. The maximum oxygen consumption ($\dot{V}O_2$ max) is the best indicator of aerobic power. The subjects' $\dot{V}O_2$ max was measured on the treadmill. Oxygen consumption of the subjects at each workload is presented in Table XII. The subjects had a mean $\dot{V}O_2$ max of 53.3 mL/kg/min. This value is higher than non-athletes' mean $\dot{V}O_2$ max. However, the present subjects had a lower mean $\dot{V}O_2$ than values reported for other professional soccer players, college basketball players, and field hockey players. At the time of testing, the subjects had a mean of 13.5 percent body fat, which was higher than that of the other groups of athletes mentioned above. Extra fat reduces oxygen consumption when expressed in mL/kg/min. The high percentage of body fat and the older age of subjects have contributed to lower mean $\dot{V}O_2$ max; $\dot{V}O_2$ max decreases by detraining. These subjects probably lost some of the previous training effect on $\dot{V}O_2$ max during the three months of idle period prior to testing.

The mean $\dot{V}O_2$ max of 53.5 mL/kg/min for subjects who participated in this study and data reported for other soccer players suggest that soccer players without special training average $\dot{V}O_2$ max levels above 50 mL/kg/min. This indicates that soccer players have relatively moderate levels of endurance capacity. Cross-country skiers and elite distance runners have higher mean $\dot{V}O_2$ max values. Since soccer allows short periods of rest between high intensity physical activity, the same level of aerobic

TABLE XI

OXYGEN CONSUMPTION OF (1982) TULSA ROUGHNECK PROFESSIONAL SOCCER PLAYERS DURING EACH WORKLOAD

	Workload %, constant speed of 3.4 MPH O_2 consumption ML/kg/min																		
Minutes on Treadmill	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Goalkeepers																			
WD	22.9	23.1	25	26.9	30.2	30.9	34.7	35.7	32	38.5	41.5	40.2	47.6	46.3	52				
ZB	26.8	27.6	27.6	29.8	31.2	34.7		42.1	42.9	40.4	42.1	44.7	41.8	49.5					
Outfielders																			
TS	25.2	27.6	27.3	31.3	29.8	32.4	36	35.7	36.6	42.1	44.2	45.4	48	48.9	51				
BC	15.9	24	29	29.9	31.8	28.6	30	35.6	33.8	36.3	43.2	41.9	45	41	49	54			
AK	20.5	26.3	27	30	29.6	35.6	35	38.3	38.8	42	42	45.7	47.6	46.5	47	51.4	51.4	51.6	57.4
ID	26.3	28.7	29.5	36	33	31.5	42	42	41.8	39.8	43.4	44.2	47.4	48.6	52.3				
LA	27.8	25.4	25.8	30.6	32.3	34.4	32.8	37.5	39.4	40.9	43.8	47.6	49.6	53.8					
SR	31	27.4	28.9	27.9	27.3	29.6	31	31.1	36.1	35	40.3	38.6	44.8	40.2	46.4				
FG	29.5	26.6	30.5	27.7	36.6	34.5	32.9	38.2	35.6	39	39	44.8	44.4	50.1	51.1	55.3	51.7	54.1	63.5
Mean	26.2	26.3	27.8	30	31.3	32.4	34.3	37.3	37.4	39.3	42	43.6	46.2	47.2	49.8	53.4	51.5	52.8	60.4

power is not required of the players as in long distance runners, cross-country skiers, or athletes in events requiring continuous long lasting effort of near maximal intensity. It is important that soccer players can carry out their tasks at a higher percentage of $\dot{V}O_2$ max throughout a match. Otherwise they quickly start to work anaerobically and, as a result, lactic acid builds up in working muscles and performance is hindered.

Anaerobic Threshold

The nature of soccer requires a high level of anaerobic work. Hardly any attempts have previously been made to determine anaerobic threshold levels of soccer players. By knowing at what percentage of $\dot{V}O_2$ max or at what heart rates players reach their anaerobic threshold level, precise training methods can be designed. To determine the subjects' anaerobic threshold, volumes of expired air were measured and respiratory gas exchange was analyzed minute by minute.

The individual respiratory gas exchange values of the subjects are presented in Figures 1-9; Figure 10 shows the mean values. The following mean values were measured at anaerobic threshold level: heart rate, 156.4 beats per minute, 50.4 liters of VE, oxygen consumption of 39.3 ml/kg/min, and 75% of VO_2 max (Table XII). This anaerobic threshold at 75% of max $\dot{V}O_2$ was higher when compared to 48% max $\dot{V}O_2$ reported by Bryant et al. (84) for non-athlete, college-age males of 46.5%, 58.6%, and 63.8% $\dot{V}O_2$ max reported by Davis et al. (69) for volunteer college-age males.

The players' mean exercise time after the onset of anaerobic threshold was ten minutes with increasing workload at the end of each minute.

TABLE XII

ANAEROBIC THRESHOLD RESPONSES OF (1982) TULSA ROUGHNECK PROFESSIONAL SOCCER PLAYERS

Subjects	Anaerobic Threshold Heart Rate	% Max VO_2 at Anaerobic Threshold	Exercise Duration After Anaerobic TH (min)
Goalkeepers			
WD	168	78.5	6
ZB	166	73.5	7
Outfielders			
TS	148	78.5	6
BC	160	80	6
AK	157	70	10
ID	155	69	9
LA	136	77	7
SR	168	81	5
FG	150	76	8
Mean	156.4	78.1	7.1
Range	136-168	69-81	5-10
SD	10.6	4.2	1.6

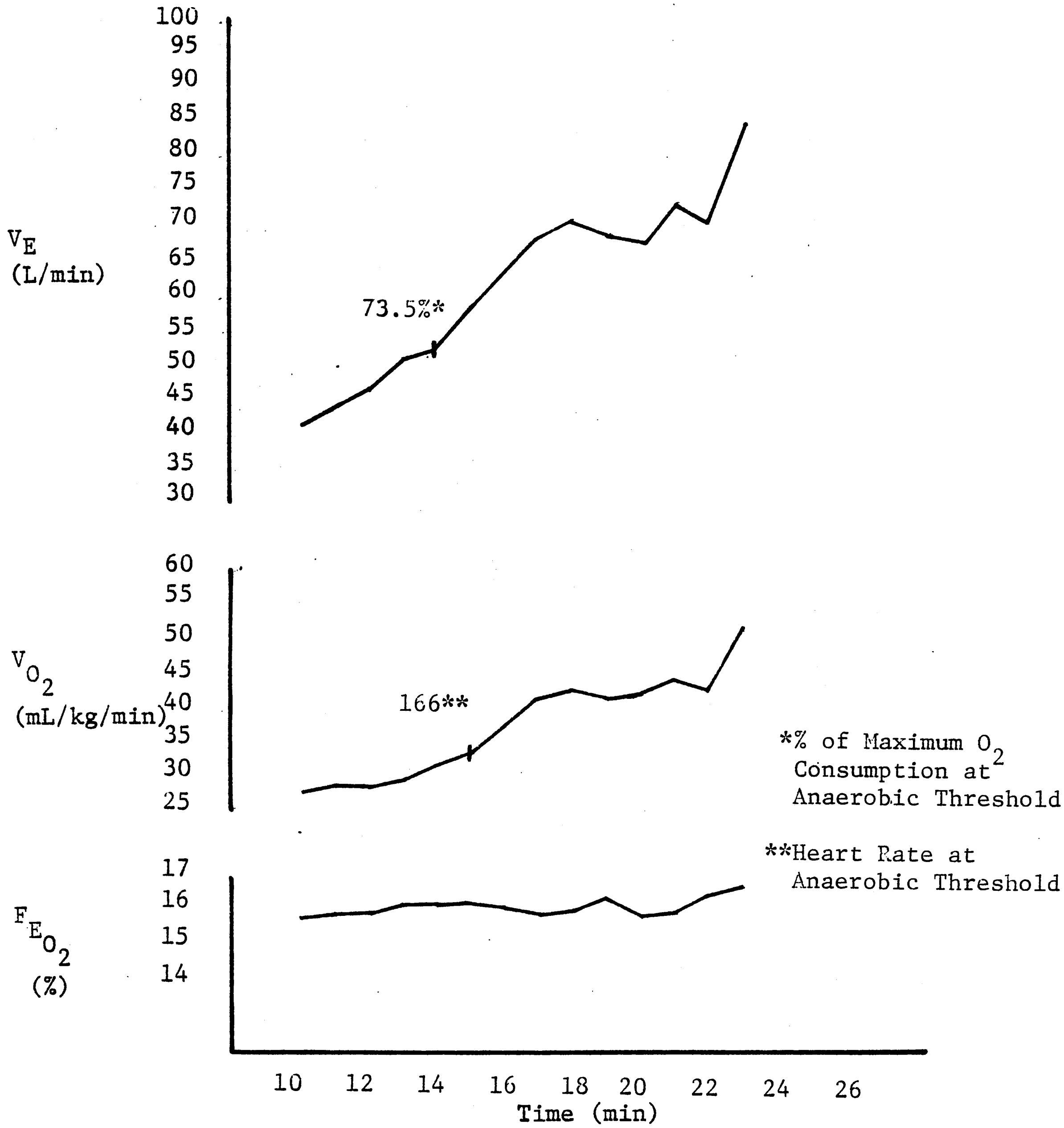

Figure 1. Respiratory Gas Exchange During Incremental Treadmill Test. Subject (ZB) is a Goalkeeper

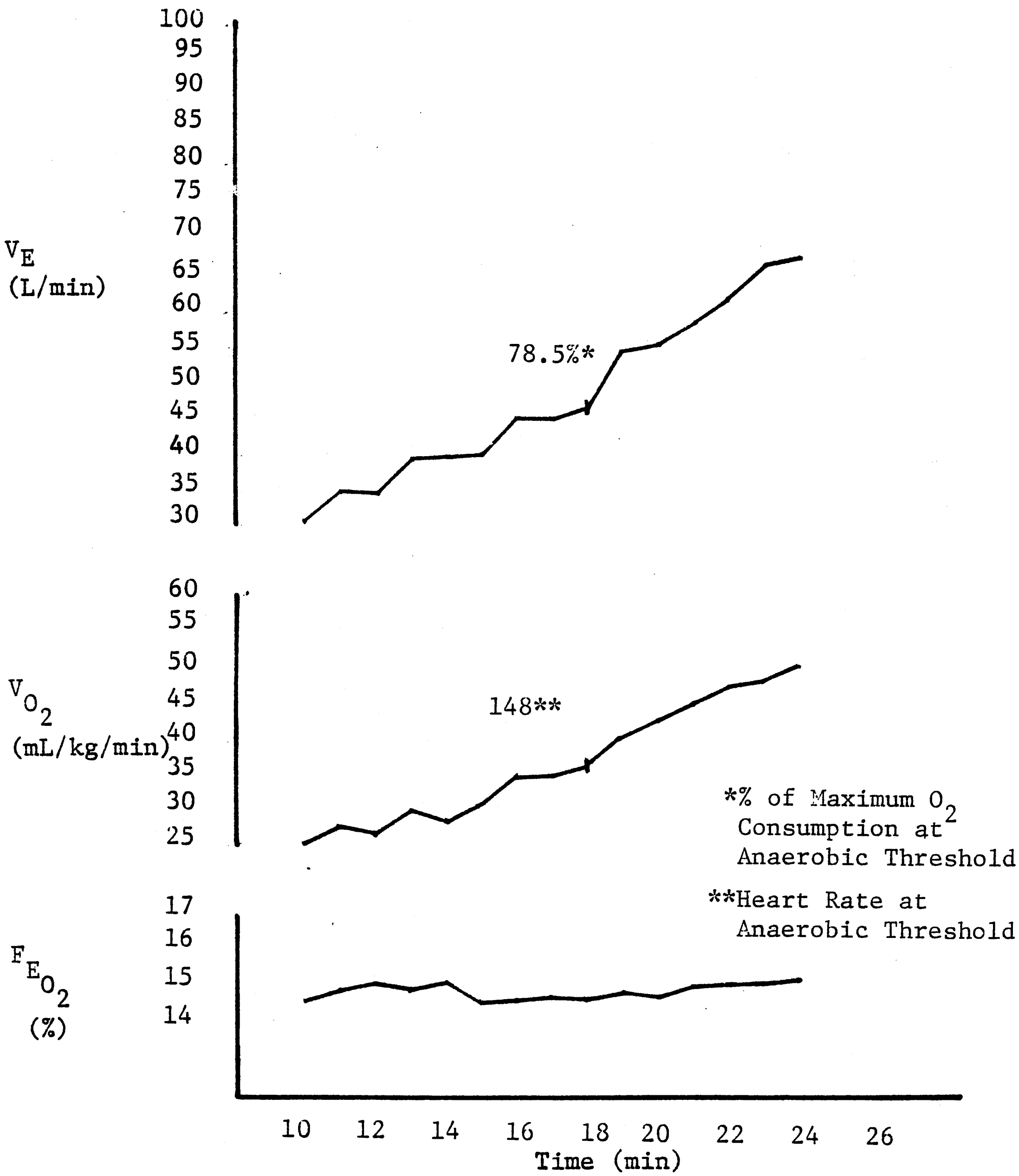

Figure 2. Respiratory Gas Exchange During Incremental Treadmill Test. Subject (TS) is an Outfielder

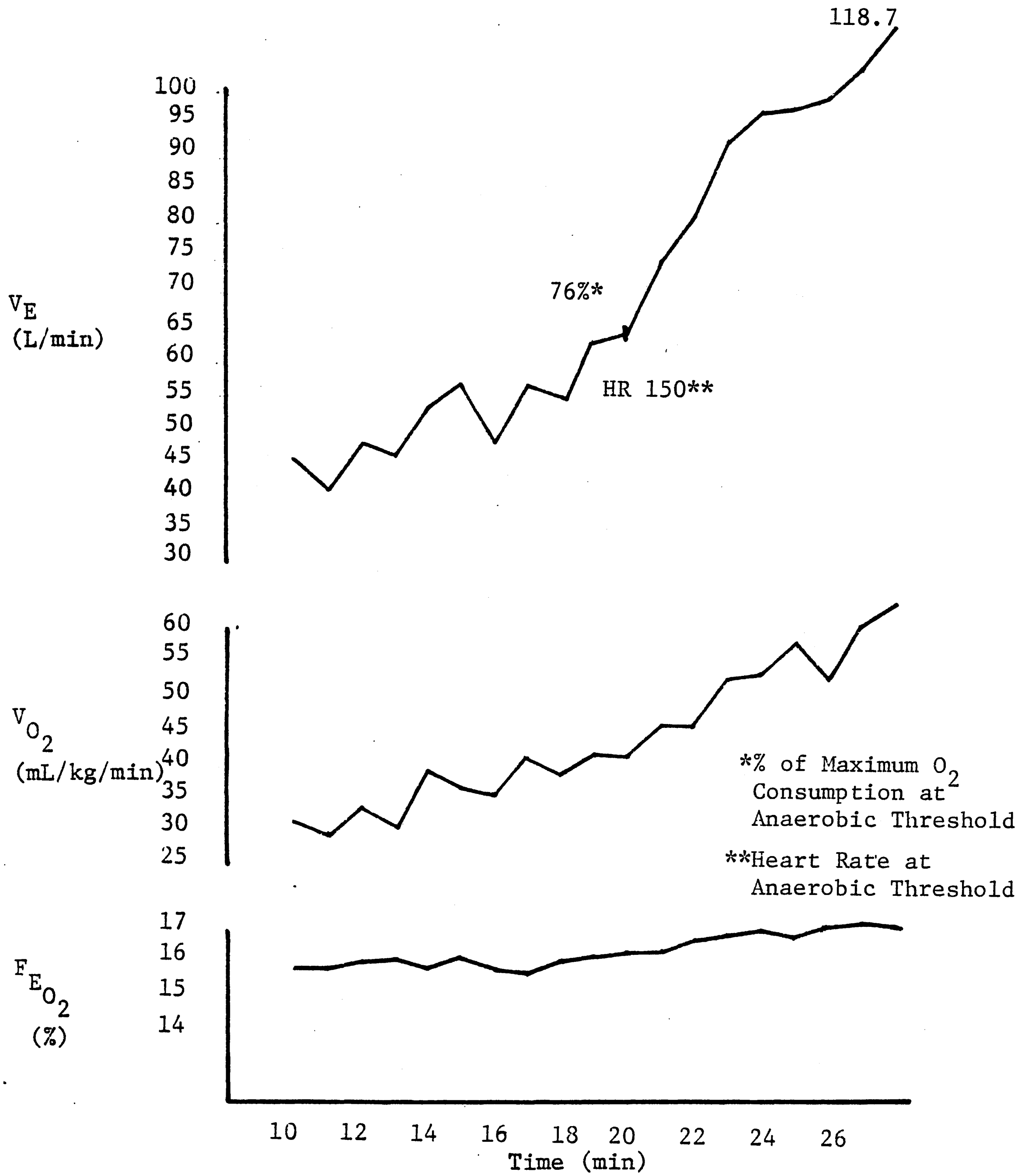

Figure 3. Respiratory Gas Exchange During Incremental Treadmill Test. Subject (FG) is an Outfielder

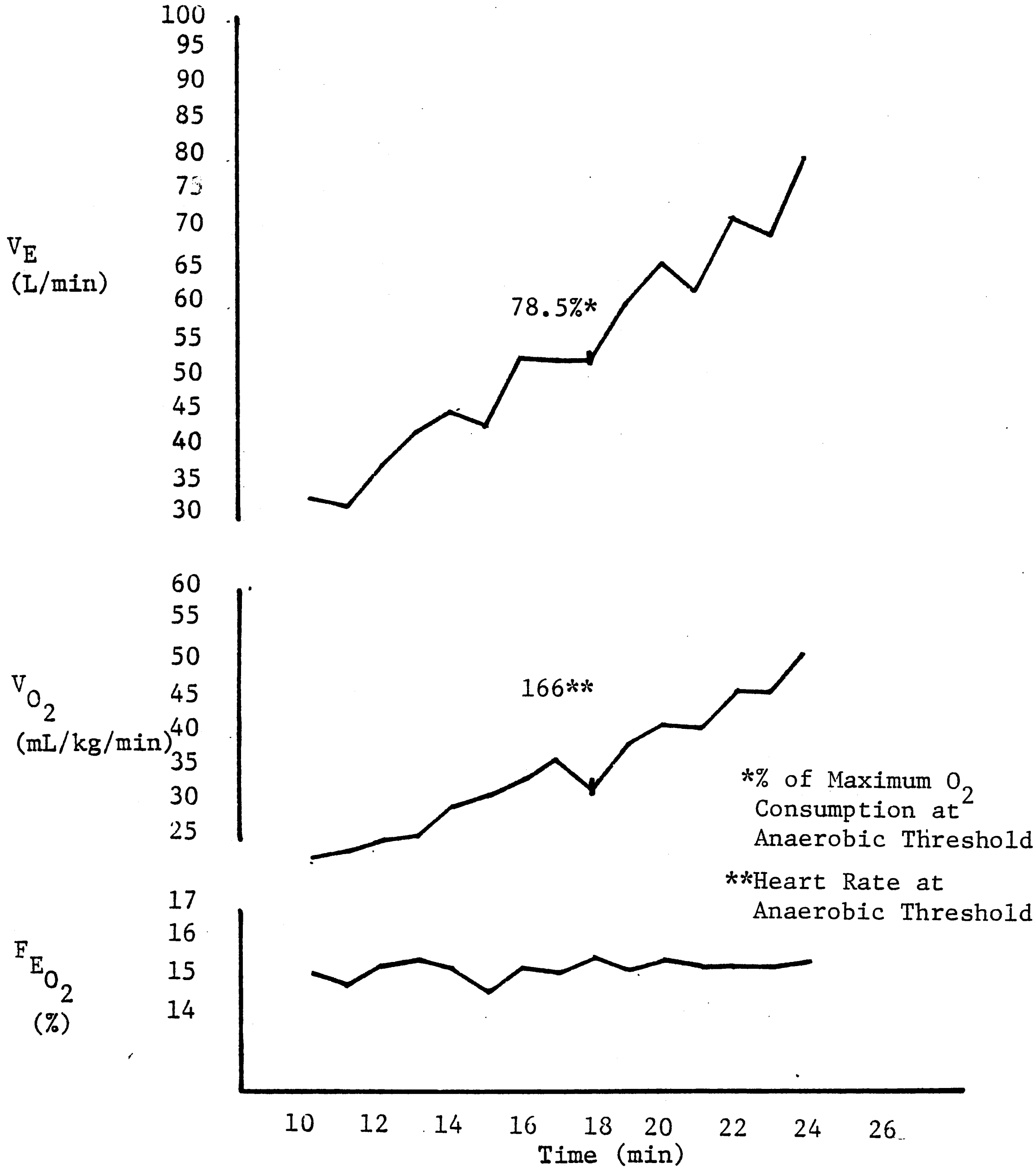

Figure 4. Respiratory Gas Exchange During Incremental Treadmill Test. Subject (WD) is a Goalkeeper

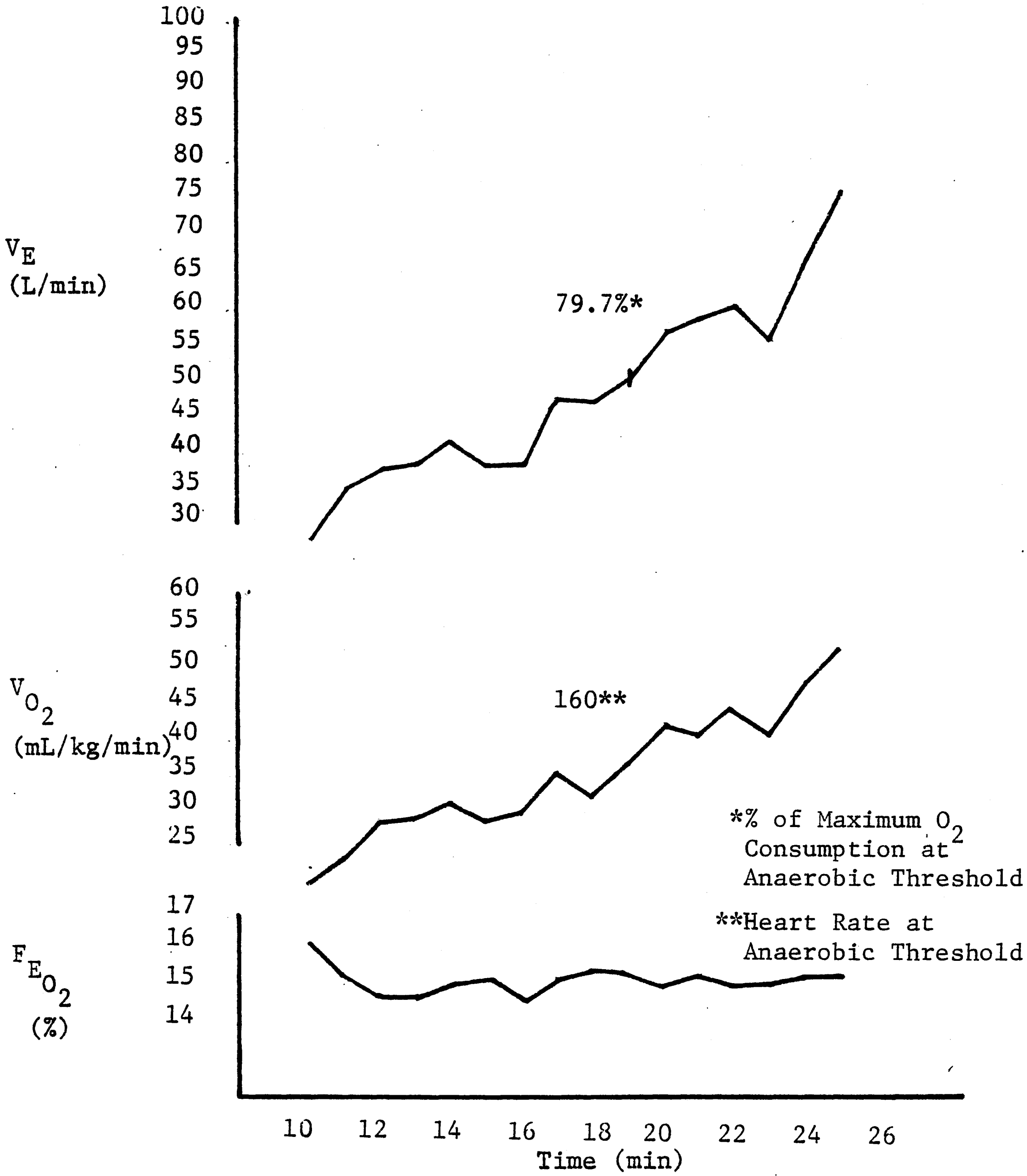

Figure 5. Respiratory Gas Exchange During Incremental Treadmill Test. Subject (BC) is an Outfielder

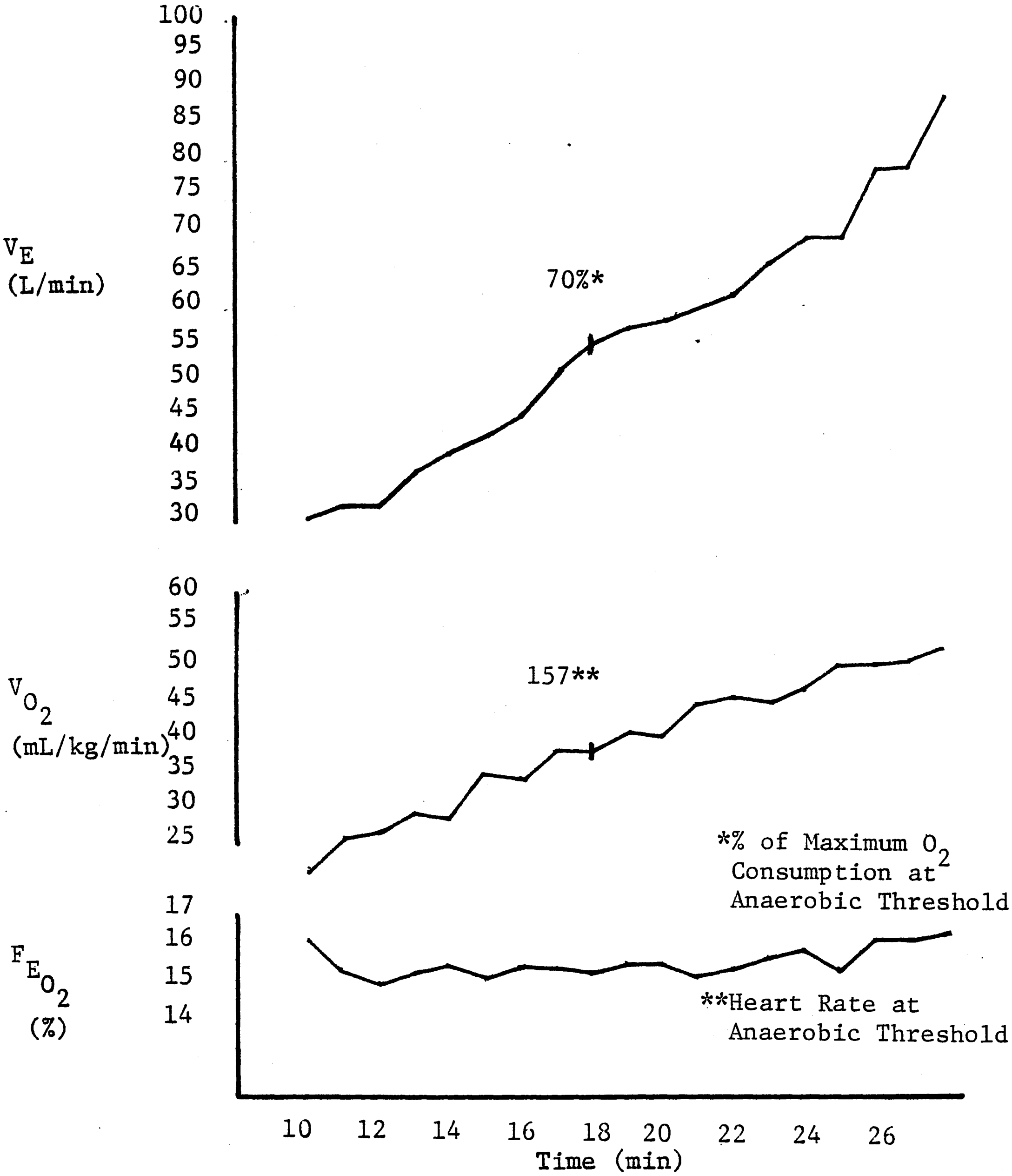

Figure 6. Respiratory Gas Exchange During Incremental Treadmill Test. Subject (KA) is an Outfielder

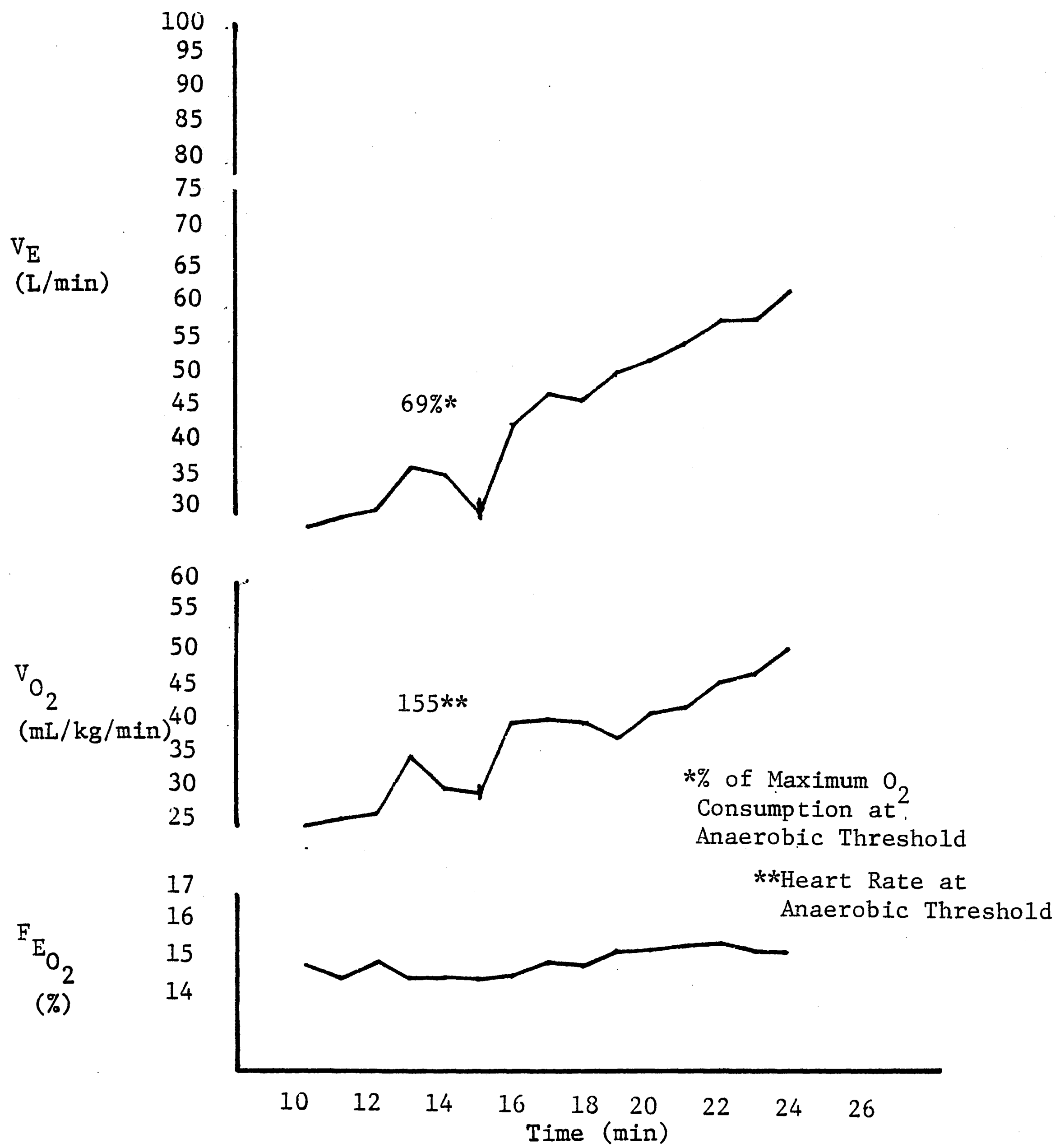

Figure 7. Respiratory Gas Exchange During Incremental Treadmill Test. Subject (ID) is an Outfielder

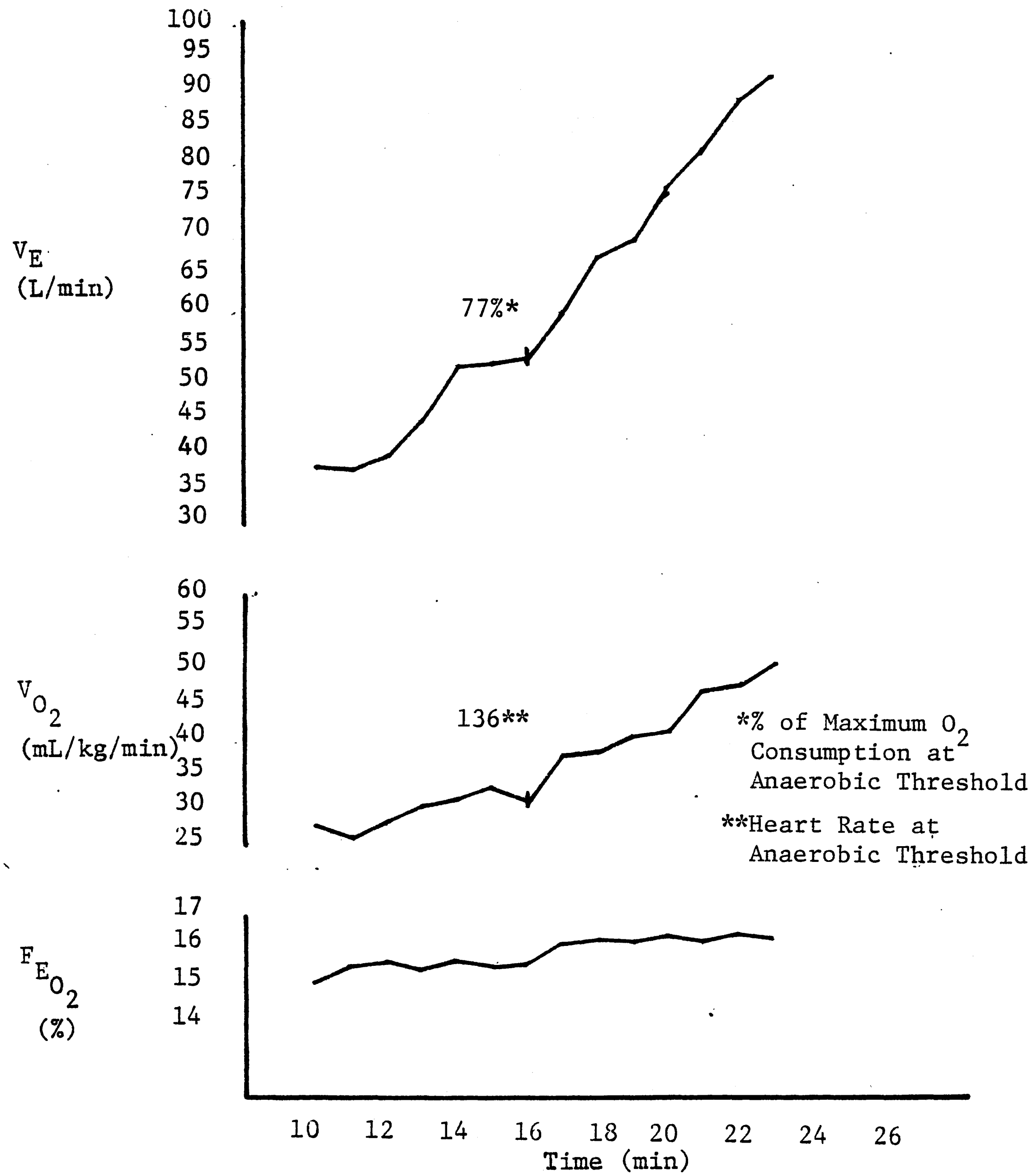

Figure 8. Respiratory Gas Exchange During Incremental Treadmill Test. Subject (LA) is an Outfielder

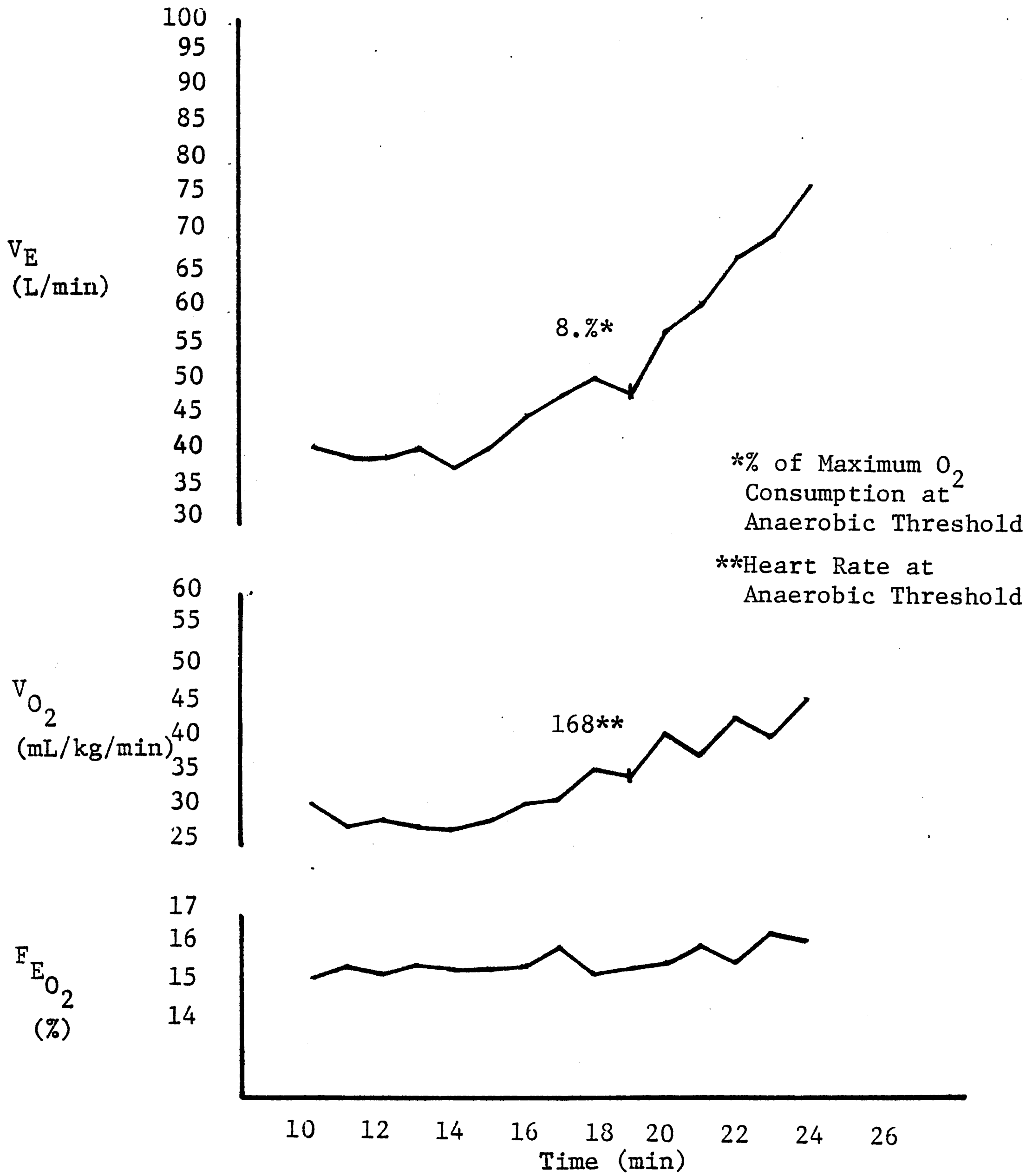

Figure 9. Respiratory Gas Exchange During Incremental Treadmill Test. Subject (SR) is an Outfielder

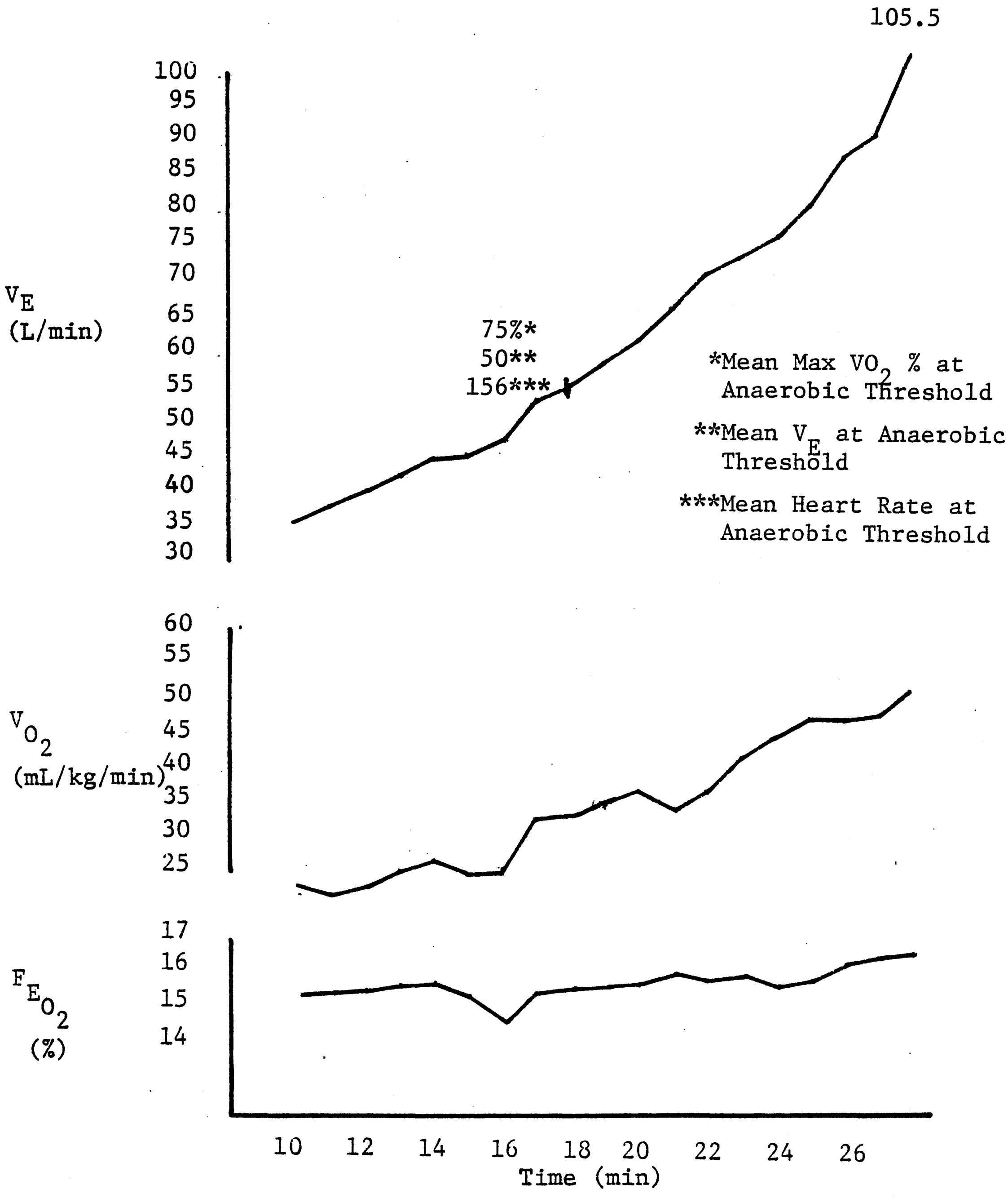

Figure 10. Mean VO_2, FEO_2 and V_E During Incremental Treadmill Test. Subjects: Tulsa Roughneck Soccer Players

Anaerobic Power

The Sargent Jump test was used to determine anaerobic power. Since the jump itself does not take body weight into consideration, the Lewis Nomogram was used. Results of the Sargent Jump in inches and the Lewis Nomogram in kg/m x sec are included in Table VI. The subjects had a higher mean of 25.4 inches than a mean of 20.8 inches of players studied by Raven et al. The subjects' mean anaerobic power of 133.28 kg/m x sec was higher than a mean of 115.54 kg/m x sec reported for field hockey players (13). The highest value of 242.6 kg/m x sec was measured for one of the goalkeepers tested for this research.

It is not surprising that soccer players have high anaerobic power. Explosive leg strength is important to jump high for heading and fast takeoffs.

Lung Capacities

Vital capacity (VC), forced vital capacity (FVC), timed force vital capacity (FEV_1) and maximum breating capacity (MVV) were measured. The results are summarized in Table XIII. The results of lung capacities of the subjects were higher than for players tested by Raven et al. Since height and weight are highly correlated with lung capacities, college basketball players had significantly higher MVV, max VE, slightly higher FVC and FEV_1. The subjects had higher VC, FEV_1, and MVV values than that predicted for their eight and age. Minute by minute measurement of ventilation for all subjects is presented in Table XIV; 118 L/min and 64.7 L/min of VE were highest and lowest values.

TABLE XIII

LUNG CAPACITIES OF (1982) TULSA ROUGHNECK PROFESSIONAL SOCCER PLAYERS

Subjects (N=9)	Vital Capacity (liters)	Predicted Values* (%)	FEV_1 Liters	Predicted Values (%)	MVV L/min	Predicted Values (%)
Goalkeepers						
WD	6.74	141.8	5.26	111.6	197.0	100.0
ZB	6.29	143.4	4.67	105.0	182.0	96.0
Outfielders						
TS	4.96	110.0	4.36	119.7	164.0	85.4
BC	6.41	152.0	6.19	154.0	232.0	131.0
AK	5.34	127.3	4.82	121.6	181.0	104.0
ID	4.23	109.0	3.87	116.9	145.0	92.3
LA	5.14	119.7	4.10	106.2	179.0	86.0
SR	5.04	121.5	4.34	110.0	163.0	93.6
FT	5.78	136.0	5.25	112.9	197.0	110.0
Mean	5.54		4.75		178.66	
Range	(4.23-6.74)		(3.87-6.19)		(145-282)	
SD	.81		.71		26.78	

*Values determined by Vitalograph LTD Buckingham MK18 1SW. U.K. 1979.

TABLE XIV

VOLUME OF VENTILATION OF (1982) TULSA ROUGHNECK PROFESSIONAL SOCCER PLAYERS DURING EACH WORKLOAD

	Workload %, constant speed of 3.4 MPH VE L/min																		
Minutes on Treadmill	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28
Goalkeepers																			
WD	34.8	33.6	38.4	43.2	45.5	43.2	53.9	52.7	52.7	61.1	67.1	63.5	74.3	70.7	82.7				
ZB	41.9	44.4	45.5	50.3	52.7	58.7		69.5	71.9	69.5	68.3	74.3	71.9	86.3					
Outfielders																			
TS	32.3	36	36	40.7	40.7	40.7	45.5	45.5	46.7	55.1	56.3	60	64.7	65.9	68.3				
BC	28.7	36	38	39.5	43	38	39.6	49	47.9	52.7	58.7	60	63.5	57.5	69.5	76.7			
AK	32.3	34.7	33.5	38.3	40.7	44.3	46.7	53.9	50.3	58.7	59.9	52.7	64.7	67.1	71.9	71.9	81.5	81.5	92.3
ID	30	31.2	33.6	38.4	36	32.4	45.5	49	48	50.3	54	56	60	60	64.7				
LA	37	37	39.5	44	50.3	50.3	50.3	59.9	65.9	68.3	75.5	80.3	89.9	92.8					
SR	41.9	40	40	42	38.3	41.9	45.5	49.1	50.3	49	58.7	62.3	69.5	73	79				
FG	44.3	39.6	46.7	44.3	53.9	55	46.7	55	53.9	61	63.5	74.3	80.3	92.3	95.9	95.9	97.1	104	118.7
Mean	35.9	36.9	39	42.3	44.5	46.9	46.7	53.7	54.7	58.4	62.4	64.8	80.9	73.9	76	81.5	89.3	92.7	105.5
Range																			

Blood Lipids

The mean standard error of hemoglobin, hematocrit, glucose, cholesterol, HDL, and HDL percent are summarized in Table XV. The t-tests showed that these subjects had significantly higher levels of hemoglobin and hematocrit and significantly lower glucose concentration and slightly higher total cholesterol concentration than did the subjects in the Raven study (Table XVI). The above values fall within the normal range.

Descriptive Analysis of Resting ECG

Resting ECG responses are summarized in Table XVII; .4 mm of mean P-R interval, .06 mm of P, 1.08 mm of R, and .25 mm of T amplitude were measured. A mean QRS time of .08 seconds, .33 second of work time, and .69 second of rest time were calculated. Rest/work ratio of 2.07 is an indication of efficient pumping ability of a subject's heart. The subjects had a mean electrical axis of $+71^{o}$, which is in the normal range.

Correlations Between Variables

Correlation coefficients between variables were calculated at the Oklahoma State University Computer Center. Coefficients of .5 and above are presented in Table XVIII. Because of the small number of subjects, correlations should be treated with caution. There is a high correlation between the following variables: height-weight, weight-eight hand grip strength, weight-FVC, years played-Sargent Jump Test, right hand grip strength-lung capacities, left leg strength-lung capacities, hemoglobin-resting heart rate, hematocrit-recovery heart rates,

TABLE XV

12-HOUR POST-ABSORPTIVE BLOOD PARAMETERS OF (1982) TULSA ROUGHNECK PROFESSIONAL SOCCER PLAYERS

Subjects	Hemoglobin (gm%)	Hemotocrit (%)	Glucose (mg%)	Cholesterol (mg%)	HDL	HDL%
Goalkeepers						
WD	17.3	51	76.9	152.6	57.4	37.6
ZB	17.6	53	80.8	192.1	67.2	36.5
Outfielders						
TS	16.5	49	73.1	157.9	49.0	31.0
BC	14.4	43	80.8	157.9	67.2	42.5
AK	17.3	50	84.6	215.8	79.8	36.9
ID	17.3	49	96.2	184.2	67.2	36.5
LA	165	48	78.0	163.2	39.2	24.0
SR	17.5	50	76.9	200.0	65.8	32.9
FG	16.4	46	75.0	163.6	39.2	24.0
Mean	16.75	48.7	80.2	176.36	58.64	33.13
Range	17.6-14.4	53-43	96.2-73.1	215.8-152.6	79.8-39.2	42.5-24
SD	.99	2.9	6.89	22.37	13.76	6.17

TABLE XVI

COMPARISON OF 12-HOUR POST-ABSORPTIVE BLOOD TEST RESULTS OF (1982) TULSA ROUGHNECK PROFESSIONAL SOCCER PLAYERS*

Year	Subjects	N	Total Protein (gm %)	HBG (gm %)	HCT (%)	Glu (mg %)	Triglycerides (mg %)	HDL	HDL%	Chol. (mm %)
1976	Dallas Tornado Players	18	$7.15 \pm .08$	14.6 ± 0.2	41.9 ± 0.5	94.5 ± 1.2	90.8 ± 53	-	-	174.8 ± 6.9
1983	Present Study	9	-	16.7 ± 0.33	48.7 ± 0.96	80 ± 2.2	-	58.6 ± 4.5	33 ± 2	176.3 ± 7.5
			t	6.47**	.624**	5.62**				.153

*Values are mean ± standard error.
**Significant at .05 confidence level.

TABLE XVII

RESTING ECG RESPONSES OF (1982) TULSA ROUGHNECK PROFESSIONAL SOCCER PLAYERS

Subjects	P-R Interval (mm)	P Amp (mm)	R Amp (mm)	T Amp (mm)	QRS (sec)	Work Time (sec)	Rest Time (sec)	Rest/Work (ratio)	Axis
Goalkeepers									
WD	.16	.04	1.16	.28	.08	.32	.80	2.60	$+39^{o}$
ZB	.08	.04	.84	.20	.04	.36	.56	1.50	$+79^{o}$
Outfielders									
TS	.16	.08	1.44	.32	.08	.32	.80	2.50	$+93^{o}$
BC	.08	.04	1.08	.28	.08	.32	.76	2.37	$+89^{o}$
AK	.12	.12	1.24	.24	.08	.32	.72	2.25	$+98^{o}$
ID	.12	.04	.80	.08	.08	.28	.72	2.57	$+39^{o}$
LA	.2	.04	1.20	.24	.08	.36	.48	1.33	$+92^{o}$
SR	.2	.08	1.04	.20	.08	.32	.52	1.62	$+94^{o}$
FG	.16	.08	1.00	.48	.12	.40	.80	2.00	$+21^{o}$
Mean	.14	.06	1.08	.25	.08	.33	.69	2.07	$+71^{o}$
Range	(.2-.08)	(.12-.04)	(1.4-.8)	(.48-.08)	(.12-.04)	(.4-.28)	(.8-.48)	(2.57-1.5)	(+94-+21)

TABLE XVIII

.5 AND HIGHER CORRELATIONS BETWEEN VARIABLES STUDIED ON 1982 TULSA ROUGHNECK SOCCER PLAYERS

Age:	-.56 Tricep, -72 Bicep, -.59 Thigh, -.5 Flex, .53 Chol, .55 RHR
HT:	.88 WT, .8 Chest, .84 RHND, .6 LHND, .56 LNON, -.5 Flex, .7 ANTHVE
WT:	.76 Chest, .76 RHND, .5 LNON, .69 Fuc, .52 Fev_1, .52 MVV, -.7 Glu
Prys:	.75 Age, .58 Tricep, -66 Thigh, -6 LHND, .75 Sjump, .67 FVC, .63 MHR, .5 ANTHVE
Tricep:	.5 WT, .67 Thigh, -.7 Chol, .57 RSYT, .5 RDS, .8 Exdue, .7 Max Panth
Back:	.5 WT, .69 ABD, -.5 Glu, .56 HDL, .57 MAXVE, .62 Anthve
Chest:	.56 RHND, 5 PRYR, .6 Tricep, .57 H_2O, -.64 RHND, .58 ANTHVE
ABD:	-.56 Chol, .5 Chest, .64 PRYR, .68 Tricep, .5 H_2O, .5 RDS, -.7 RWRAT
Thigh:	.6 PRYR, -.52 RHND, -.5 MHR, .6 MAX PANTH, -.6 Chol
RHND:	.85 LHND, .5 LNON, .89 VC, .88 FVC, .65 FEV_1, .65 MVV, -53 Glu, .7 ANTHVE
LHND:	.6 Sjump, .65 LNON, .7 VC, .87 FVC, .7 MHR, .6 ANTHHR, .5 ANTHVE, .6 HR3, .7 HRS
RLEG:	.76 LLeg, .57 VC, .9 FEV_1, 9 MVV, -.8 HB6, -.75 HCT
LLEG:	-.6 Flex, .65 FEVI, .6 MVV, -5 HB6, .5 HDL, .7 HDLP, .5 RWRAT, .5 ANTHHR
Sjump:	.97 LNON, .58 FVC, .56 HCT, .57 HR_3
LNON:	.5 VC, .68 FVC, .5 HCT, .5 HR3
Flex:	-.51 HDLP, -.76 ANTHHR
VC:	.92 FVC, .8 FEV1, .8 MVV, .75 ANTHVE
FVC:	.68 FEV1, .68 MVV, .74 ANTHVE
FEV1:	.99 MVV, -.67 HBG, -.54 HCT, -.54 RHR, .57 ANTHVE
MVV:	-.67 HBG, -.5 HCT, .55 RHR, .58 ANTHVE
HBG:	.9 HCT, .55 Chol, .73 RHR, .52 RDS, .55 MHR, .53 HR5
HCT:	.65 RHR, .63 RDS, .59 MHR, .6 HR3, .63 HR5
GLU:	.56 HDL, .73 RHR, -.69 ANTHVE, -.77 MaxPANTH, .6 EXDUR, -.5 Tricep
Chol:	.68 HDL, .6 RHR, .6 MHR, -63 MaxPANTH, .64 HR3, .74 HR5, -.5 WT
HDL:	.8 HDLP, .7 MHR, .6 ANTHHR, .7 HR3, .73HR5
HDLP:	.59 RWRAT, -.59 MaxVE, .64 ANTHHR
RHR:	.6 Chol, .64 MHR, -72 MaxPANTH
RSYT:	.69 RDS, -.66 MaxVE, -.6 $MaxVO_2$
RDS:	-.55 $MaxVO_2$, .57 ANTHHR, .56 Chest
MHR:	.73 ANTHHR, .67 HR3, .74 HR5, .56 Age
MaxVE:	.74 $MaxVO_2$, .74 ANTHVE
$MaxVO_2$:	.58 Exdur, -.71 HR2, -55 HR5, -.6 ABD
ANTHHR:	.7 HR3, .6 HRS
MaxPANTH:	.7 HR3, .67 HRS
HR3:	.95 HR5, .5 ABD

cholesterol-recovery heart rates, HDL-resting heart rates, VO_2 max exercise duration after anaerobic threshold.

Subproblems

1. A subproblem of this study was to compare selected fitness variables of American players with the international players on the team. Since only two American players were tested, this subproblem was not investigated.

2. Another subproblem was to compare selected fitness variables of players according to different positions: goalkeepers, fullback, halfbacks, and forwards. The goalkeepers scored higher on the Sargent Jump Test, had higher values of grip strength; they were taller than outfielders. There were no significant differences between goalkeepers and fielders. Since the author was able to test only seven outfielders, no attempt was made to study differences among the outfield players according to different playing positions.

Summary of Results

The main purpose of this study was to determine the physical and physiological characteristics of professional players and compare the results of this research with the results of a study conducted by Raven et al. (42).

Nine Tulsa Roughneck professional soccer players were tested three months after completion of the 1982 North American Soccer League season. The subjects were older, heavier, and taller than most other groups of soccer and field hockey players who were tested by other researchers. The subjects had a greater percent of body fat than did athletes who participated in long distance running and cross-country skiing. The subjects scored higher on muscular strength tests than other groups of soccer players and field hockey players. There were no muscular strength differences between the limbs. Resting heart rates were low, but when compared with other athletes who participate in endurance-type sports, these values were high. The subjects' mean maximal heart rate, VO_2 max, lung capacities, and maximal VE were higher than those of a normal population. The results revealed that soccer does not require as high aerobic work capacity as other continuous endurance-type sports such as long distance running and cross-country skiing. The subjects reached their anaerobic threshold level at a mean heart rate of 156.4 beats per minute, 50.4 liters of VE, and oxygen consumption of 39.3 mL/kg/min. The subjects started to do anaerobic work and continued the graded exercise test for ten minutes on the average after the onset of anaerobic work.

The results of anaerobic power tests indicated that these soccer players had high values. Explosive power in the legs is required of soccer players.

Analysis of blood lipids and resting ECG recordings showed that values were in normal ranges when compared with the normal population.

t-test analysis showed that these subjects had significantly higher resting heart rate, systolic blood pressure, grip strength, percent of body fat, hemoglobin and hematocrit values, significantly lower max HR, max VE, VC and glucose values than did players tested by Raven et al. Max $\dot{V}O_2$ was slightly lower, and total cholesterol and anaerobic power of the subjects were slightly higher.

The subjects had significantly lower $\dot{V}O_2$ max and lung capacities than college basketball players. Differences in $\dot{V}O_2$ max, anaerobic power between these subjects and field hockey players were not statistically signifivant.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

Most coaches are concerned about the physical and physiological characteristics of their athletes, their levels of physical fitness as well as skill levels. Coaches of highly conditioned individual athletes who specialize in endurace events have advantages over coaches of team sports, including soccer. Most researchers concentrate their efforts on studying top class individual athletes who participate in endurance events. Less attention has been given to athletes who compete in team sports such as soccer where, in addition to endurance, emphasis is placed on anaerobic work, skill, and technique. Obviously coaches and such athletes have problems as a result of only limited physiological data available with which to evaluate current training procedures and with which to suggest new methods for training.

With these observations and the continuous growth and development of soccer throughout the United States, the present research was undertaken to determine physical and physiological characteristics of professional soccer players. Due to some unfortunate circumstances, only nine players were able to take part in this research. The results were compared with the existing data from professional soccer players by using the t-Test, correlations between variables, and descriptive statistical analysis.

Conclusions

Within the scope of this study based on the null hypotheses stated, the following conclusions were made:

Hypothesis 1:

There will be no significant difference between the maximum oxygen consumption of professional soccer players participating in this study and the maximum oxygen consumption of professional soccer players studied by Raven et al. (42).

This null hypothesis was accepted. The differences in the means of VO_2 max were not statistically significant at the .05 confidence level.

Hypothesis 2:

There will be no significant difference between the vital capacity of professional soccer players participating in this study and the vital capacity of professional players studied by Raven et al. (42).

Subjects tested by Raven et al. (42) had significantly higher mean vital capacity than the present subjects at the .05 confidence level. The null hypothesis was rejected.

Hypothesis 3:

There will be no significant difference between the body composition of professional soccer players participating in this study and the body composition of professional soccer players studied by Raven et al. (42).

The present subjects had significantly higher mean percent body fat at the .05 confidence level than did players tested by Raven et al. (42). The null hypothesis was rejected.

Hypothesis 4:

There will not be significant differences between the flexibility, hand grip strength, and vertical jump of professional players participating in this study and the flexibility, hand grip strength, and vertical jump of professional players studied by Raven et al. (42).

Present subjects had significantly higher mean hand grip strength at the .05 confidence level. However, there was no significant difference in mean flexibility and vertical jump results of the two groups. This null hypothesis was rejected in relation to hand grip strength and accepted in relation to flexibility and vertical jump.

The subjects in this study were generally in as better condition than the general population, but not in as good condition as other professional soccer players reported in the literature.

The players in this study had an anaerobic threshold of 39.3 mL/kg/min, which is 75% of their maximal $\dot{V}O_2$

Recommendations

In order to obtain valid results and make an accurate comparison of the physical and physiological characteristics of soccer players with other groups of athletes, the following recommendations are made with regard to further study:

1. More research using college and professional soccer players to determine aerobic work capacity, oxygen debt, blood chemistry, lung capacities, and muscular strength is needed.

2. Since soccer puts high demands on the anaerobic processes of energy release, further research is needed to determine the anaerobic threshold level of soccer players. Training methods for increasing

anaerobic work capacity should be studied with carefully designed research techniques.

3. Effects of pre-season training on maximal aerobic work capacity, anaerobic power, muscular strength should be studied. Physiological status of players at the beginning, in the middle, and at the end of the season should be studied.

4. More college and professional coaches should be interviewed, and research topics related to the concerns of coaches should be designed and carried out.

5. Physiological differences between older and younger players should be studied. Also physical and physiological characteristics of top class soccer players should be examined.

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APPENDIX

LABORATORY SOFTWARE

Treadmill Results

NAME ______________________ AGE ________ SEX ________ DATE ____________

Resting: Heart Rate Blood Pressure Cat. ______________

Supine __________ ______ ______/______

Standing ______________ ______/______

3.4 mph

Grade	METS / 02		Heart Rate	BP	EKG Comments
0	3.4	11.2			
2	4.2	14.5			
3	4.7	16.5			
4	5.1	18.0			
5	5.7	20.0			
6	6.1	21.5			
7	6.6	23.0			
8	7.1	24.5			
9	7.5	26.5			
10	8.0	28.0			
11	8.5	29.5			
12	9.0	31.5			
13	9.4	33.9			
14	9.9	34.5			
15	10.3	36.0			
16	10.8	37.5			
17	11.2	39.0			
18	11.7	41.0			
19	12.2	43.0			
20	12.7	44.5			

21-32 cont. on back

Recovery: HR BP

3 min. ____________ __________/__________

5 min. ____________ __________/__________

8 min. ____________ __________/__________

Reasons for Stopping: Anxiety ☐ Dyspnea ☐ Nausea ☐ Dizziness ☐ Chest Pain ☐
Leg Weakness ☐ Claudication ☐ Gen. Fatigue ☐
Hypotension ☐ EKG Changes ☐ Hypertension ☐
Other ______________________________

Treadmill Results (Continued)

Grade	METS / 02		Heart Rate	BP	EKG Comments
21	13.2	46.0			
22	13.6	47.0			
23	14.0	49.0			
24	14.9	51.9			
25	15.3	53.6			
26	15.8	55.7			
27	16.3	56.9			
28	16.7	58.5			
29	17.2	60.2			
30	17.7	61.8			
31	18.13	63.5			
32	18.6	65.1			

Cooper's Fitness Classification: Men

Category	Measure O^2ml/kg/min	Age 13-19	20-29	30-39	40-49	50-59	60+
I. Very Poor		< 35.0	< 33.0	< 31.5	< 30.2	< 26.1	< 20.5
II. Poor		35.0-38.3	33.0-36.4	31.5-35.4	30.2-33.5	26.1-30.9	20.5-26.0
III. Fair		38.4-45.1	36.5-42.4	35.5-40.9	33.6-38.9	31.0-35.7	26.1-32.2
IV. Good		45.2-50.9	42.5-46.4	41.0-44.9	39.0-43.7	35.8-40.9	32.2-36.4
V. Excellent		51.0-55.9	46.5-52.4	45.0-49.4	43.8-48.0	41.0-45.3	36.5-44.2
VI. Superior		> 56.0	> 52.5	> 49.5	> 48.1	> 45.4	> 44.3

Coopers Fitness Classification: Women

Category	Measure O^2ml/kg/min	Age 13-19	20-29	30-39	40-49	50-59	60+
I. Very Poor		< 25.0	< 23.6	< 22.8	< 21.0	< 20.2	< 17.5
II. Poor		25.0-30.9	23.6-28.9	22.8-26.9	21.0-26.4	20.2-22..	17.5-20.3
III. Fair		31.0-34.9	29.0-32.9	27.0-31.4	24.5-28.9	22.8-26.9	20.2-24.4
IV. Good		35.0-38.9	33.0-36.9	31.5-35.6	29.0-32.8	27.0-31.4	24.5-30.2
V. Excellent		39.0-41.9	37.0-40.9	35.7-40.0	32.9-36.9	31.5-35.7	30.3-31.4
VI. Superior		> 42.0	> 41.0	> 40.1	> 37.0	> 35.8	> 31.5

LABORATORY METABOLIC CALCULATION SHEET

Subject________________________ Date__________ Age______ Surface Area________________ Sq.M.

Temp.____________ degrees C. Barometric Pressure__________ mm Hg. Corr. Factor________

SITTING (Non basasl)

1. Oxygen %_______ CO_2%_______ True O_2_______ R.Q._______ (from nomogram)
2. Ventilation/min. = $\frac{\_\_\_\_\_\_\_\_\_\_}{10}$ Kym mm. = __________ x 1.332 = __________ l/Min
3. Corr. Vent. = Vent. x Corr. Factor = __________ x __________ = __________ L/Min
4. Oxygen Intake = $\frac{\text{Corr. Vent. x True } O_2}{100}$ = $\frac{\text{x}}{100}$ = __________ L/Min
5. S.M.R. = $\frac{\text{x5 x60}}{\text{sq. M. S.A.}}$ = ________________ Cal/Hr. Sq. M.

EXERCISE:

SPEED_______________ HEIGHT_______________ TIME_______________

1. Oxygen %________ CO_2%________ True O_2________ RQ________ (from nomogram)
2. Ventilation/min. = $\frac{\_\_\_\_\_\_\_\_\_\_}{10}$ KYM mm. = __________ x 1.332 = __________ L/Min
3. Corr. Vent. = Vent. x Corr. Factor = __________ x + __________ = __________ L/Min
4. Oxygen Intake = $\frac{\text{Corr. Vent. x True } O_2}{100}$ = $\frac{\text{x}}{100}$ = __________ L/min
5. EMR = $\frac{\text{x5 x60}}{\text{Sq. M. SA}}$ = _______________ Cal. hr/ Sq. N.

EXERCISE:

SPEED_______________ HEIGHT_______________ TIME_______________

1. Oxygen %_________ CO_2%_________ True O_2_________ RQ_________ (from nomogram)
2. Ventilation/Min. = $\frac{\_\_\_\_\_\_\_\_\_\_}{10}$ kym mm. = __________ x 1.332 = __________ L/min
3. Corr. Vent. = Vent. x Corr. Factor = __________ x __________ = __________ L/min
4. Oxygen Intake = $\frac{\text{Corr. Vent. x True } O_2}{100}$ = $\frac{\text{x}}{100}$ = __________ L/min.
5. EMR = $\frac{\text{x5 x60}}{\text{Sq. M. SA}}$ = _______________ Cal/ hr. / Sq. M.

EXERCISE:

SPEED_______________ HEIGHT_______________ TIME_______________

1. Oxygen % _________ CO_2%_________ True O_2_________ RQ_________ (from nomogram)
2. Ventilation/min. = $\frac{\_\_\_\_\_\_\_\_\_\_}{10}$ kym mm = __________ x 1.332 = __________ L/min.
3. Corr. Vent. = Vent. x Corr. Factor = __________ x __________ = __________ L/min.
4. Oxygen Intake = $\frac{\text{Corr. Vent. x True } O_2}{100}$ = $\frac{\text{x}}{100}$ = ____________ L/min.
5. EMR = $\frac{\text{x5 x60}}{\text{Sq. M. SA}}$ = _______________ Cal/ hr./ Sq. M.

OKLAHOMA STATE UNIVERSITY

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Underwater Weighing Record

Name: ______________________________

Date: ______________________________ Ht.: __________ Age: __________

Nude Weight: __________lbs. __________oz. oz.=tenths of lb.__________

A. Scale reading with seat and harness

Subject's weight readings in water:

1.
2.
3.
4.
5.
6.
7.
8.
9.
10.

B. Highest reading obtained at least two times __________

C. Underwater Weight (UW) - difference between A and B __________

D. Net weight in water = UW + 2.86 (2.2 for females) __________

E. Specific Gravity (SG) = $\frac{\text{Wt. in air}}{\text{Wt. in air-net wt. in water}}$ __________

F. Percent of Body Fat = 100 (4.201/SG---3.813) __________

OKLAHOMA STATE UNIVERSITY

HEALTH AND FITNESS CENTER

Name______________________ Age________ Sex________

Date______________________

Anthropometric:

Ht. ______in. ______cm. Wt. ______lbs. ______kg. B.S.A. ____________sq. m.

Skinfold Measures:

Tri ______	Chest ______		Σ 3 % Fat	______
Bi ______	Abd ______		Σ 4 % Fat	______
Ill ______	Thigh ______		Nomogram %	______
Back ______			% Fat Used	______
Σ 4 Total ______	Σ 3 Total (Men) ______		% Fat Residual $\pm$	______
			Pounds Fat Residual $\pm$	______
			Suggested Ideal Weight	______

Motor Area:

Grip Strength: Rt. 1. ______ Lt. 1. ______ Strong______

2. ______ 2. ______ Weak______

Flexibility: ______________

Pulmonary Function:

	Predicted Value	Measured Value	% of Pred.	
VC	______		______	VC
FVC	______		______	FVC
MVV	______		______	MVV
FEF 25%-75%	______		______	FEF 25%-75%
FEF 75%-85%	______		______	FEF 75%-85%

BLOOD SURVEY RESULTS NAME______________________

BLOOD TEST		HEMOGLOBIN GM/100 ML	HEMATOCRIT %	GLUCOSE MG/100 ML Plasma/Whole Blood	CHOLESTEROL MG/100 ML	HDL-C	
						MG/100 ML	% OF CHOLESTEROL
YOUR RESULTS							
NORMAL VALUES		13-18 (M) 11-16 (F)	39-54 (M) 33-48 (F)	Plasma 60-110 Whole Blood 50-90	133-318 (M) 133-295 (F)	29-72 (M) 35-80 (F)	≥ 21 (M) ≥ 25 (F)
VALUE SCALE	MALE	15-17 Good 13-15 & 17-18 Fair < 13 & > 18 Poor	45-51 Good 39-45 & 51-54 Fair < 39 & > 54 Poor	Plasma 70-100 Good 60-70&100-110 Fair < 60 & > 110 Poor	< 170 Excellent 171-200 Good 201-249 Fair > 249 Poor	NOT APPLICABLE	> 26 Excellent 23-26 Good 19-22 Fair < 19 Poor
	FEMALE	13-15 Good 11-13 & 15-16 Fair < 11 & > 16 Poor	39-45 Good 33-39 & 45-48 Fair < 33 & > 48 Poor	Whole Blood 60-80 Good 50-60 & 80-90 Fair < 50 & > 90 Poor	< 155 Excellent 156-185 Good 186-230 Fair > 230 Poor	NOT APPLICABLE	> 31 Excellent 27-31 Good 23-26 Fair < 23 Poor

COMMENTS: All measurements are in units depicted and apply to the methods and equipment we use. (M) refers to Male and (F) refers to Female. < means less than while > means greater than. ≥ means equal to or greater than. Normal values are those routinely used by the medical profession to distinguish between states of sickness and health when used in conjunction with patient history and medical examination. The value scale is an attempt by the O.S.U. Health and Fitness Center to distinguish levels most desirable - from a holistic health concept when used in conjunction with other findings and history as collected by Center personnel.

VITA 2

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