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THE UNIVERSITY OF ALBERTA

HISTOCHEMICAL, BIOCHEMICAL AND PERFORMANCE PROFILES OF CANADIAN INTERCOLLEGIATE FOOTBALL PLAYERS

by

© RAYMOND L. MANZ

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES
AND RESEARCH IN PARTIAL FULFILMENT OF THE
REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

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THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled: "Histochemical, Biochemical and Performance Profiles of Canadian Intercollegiate Football Players", submitted by Raymond L. Manz in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Physical Education.

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Date June 20, 1978

DEDICATION

To my wife, Elaine,
for her patience and encouragement
over the past three years;
for without her love,
this degree
would not have become a realization.

ABSTRACT

Forty-five playing members of the University of Alberta intercollegiate football team were evaluated on twenty-nine physiological variables from data collected during a maximal treadmill run, an endurance stair run, a power stair run, Cybex knee flexion and extension strength, power and endurance tests, underwater weighing, an agility run, sprint tests and a biopsy sample of the vastus lateralis muscle. Correlations were computed between all twenty-nine variables. Pre-season and post-season data on the nineteen variables measured by the Cybex tests, the stair run tests and the VO_2 max test were analyzed by a RMAOV1 to determine whether de-conditioning occurred over the competitive playing season. The football players were grouped by position and the means of the twenty-nine variables for each group were analyzed by an ANOVA1 to determine whether significant differences existed between the groups. The player groupings were: running backs (RB), wide receivers (WR), inside receivers (IR), offensive lineman (OL), defensive lineman (DL), linebackers (LB), defensive backs (DB), and quarterbacks (QB).

Vastus lateralis enzyme activities and % fiber population had low correlations with all non-biopsy variables. The twelve variables generated by the Cybex tests had high correlations with each other but low correlations with all other variables. High correlations were observed between the three power stair run variables and the two sprint run variables.

VO_2 max significantly decreased over the season with DB showing the greatest drop. Freestyle stair run times were significantly faster post season with the WR and IR showing the greatest improvement. Maximal hamstring torque at 30°/s significantly increased post-season with DB showing the greatest improvement. Maximal hamstring torque at 180°/s significantly increased post season with OL, DB and WR displaying the greatest improvements. Maximal quadricep torque at 180°/s significantly increased post season with DB showing the greatest improvement.

For the majority of the twenty-nine variables the following groups had similar physiological profiles: (1) DL, OL and LB (2) DB, WR and QB (3) RB and IR. Generally speaking, the group consisting of DL, OL and LB were the strongest, fatigued the quickest, had the lowest aerobic power, had the highest % body fat, were the slowest and least agile, had the lowest enzyme activities in vastus lateralis muscle and had the lowest % FT fibers in vastus lateralis muscle while the group consisting of DB, WR and QB were at the opposite end of the rankings for the same variables.

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INTRODUCTION

With the advancement of knowledge and techniques in exercise and cellular physiology man is now capable of gathering physiological, histochemical and biochemical data on athletes that will not only aid coaches in their task of selection, deployment and preparation but will also further advance scientific knowledge in these related fields. Unfortunately, not many researchers in exercise and cellular physiology combine all three forms of data collection to give an over-all picture of the athletes abilities, potentials and state of training. Just as unfortunate is the lack of availability of this type of research to the coach and physical educator. There have been a few studies published (Edstrom and Ekblom 72, Gollnick et al. 72, Costill et al. 73, Schreiber 73, Karlsson et al. 75, Prince et al. 76, Costill et al. 76a, Costill et al. 76b, Tesch et al. 76) which report normative data on athletes but it is questionable whether this information has reached the coach or been helpful to the coach. The sample populations for these studies have been relatively small and selective to athletes who participate in individual sports (such as distance runners and weight lifters). The parameters measured have centered around aerobic capacities as well as % muscle fiber type and muscle cross-sectional areas. Performance datum, to give an indication of the caliber of the athletes, were seldom reported. Therefore, datum on physiological profiles of athletes that are available at present are helpful only to those athletes at the two ends of the scale (high aerobic capacity versus high anaerobic power).

Generally speaking, team sport athletes are quite different from the high aerobic capacity and high anaerobic power type athletes. Athletes partaking in team sports need to possess more than one physical trait or fitness component to be successful in their sport whereas the athlete who has a high aerobic capacity and who can utilize a high percentage of this capacity without having to generate energy anaerobically can be a very successful long distance runner. Likewise, the strong and powerful weight lifter does not need a high aerobic capacity to be a successful competitor. Therefore, when attempting to establish physiological profiles for a team sport all components of physical fitness which contribute to successful performance should be measured. Football, which involves a large number of players per team as well as many positions where possible physiological differences could exist, should be a good example of a team sport where many of the physical fitness components need to be developed to a high degree to produce successful performance. These fitness components would include:

1. Cardio-respiratory efficiency - aerobic capacity,
2. Muscular strength,
3. Muscular power,
4. Muscular endurance,
5. Energy production - anaerobically and aerobically.

Many football players spend months of intense training in preparation for the season and two-a-day training camp practices. However, once the season has commenced most discontinue their rigorous weight training and running programs with the belief that further training will be detrimental to their performance. Most football players also consider two hours of on the field practice sufficient to maintain their fitness level. Coaches also foster this belief by devoting minimal time to physical fitness training during practice situations. It is the contention of many exercise and cellular physiologists that if athletes are highly trained prior to in-season practices a de-conditioning process will occur over the duration of the season resulting in lower levels of physical condition at the end of the season.

Theoretically, all football players should possess the ability to rapidly contract muscle, to develope large amounts of muscle force and to rapidly resynthesize adenosine triphosphate (ATP) both anaerobically and aerobically. The degree to which they are capable of displaying these abilities will vary by position and is dependent upon their genetic endowment (Klissouras 72, Klissouras 73, Komi et al. 73, Leitch et al. 75, Weber et al. 76) and level of training (Keissling et al. 74, Thorstensson et al. 75, Saltin et al. 76, Thorstensson et al. 76a, Thorstensson and Karlsson 76b, Andersen and Henricksson 77, Byland et al. 77, Henriksson and Reitman 77).

Running speed, which is an essential quality needed by football players, is dependent upon stride frequency and stride length. Stride frequency is correlated to the contractile speed of the muscles involved whereas stride length is correlated to the force generated by the leg muscles through the foot to the ground. The contractile speed of a muscle has been correlated to its myosin adenosine triphosphatase (ATPase) activity (Barany 67). This enzyme catalyzes the breakdown of ATP to produce energy for muscular contraction. The amount of tension a muscle is capable of developing is correlated to its content of contractile protein or crossbridges (Gordon et al. 67, Jaweed et al. 74). Fast contracting muscle fibers (FT) possess high concentrations of myofibrillar ATPase (Close 72, Burke and Edgerton 75, Essen et al. 75, Thorstensson et al. 77a), a faster reaction velocity of myofibrillar ATPase (Sreter 69, Close 72, Burke and Edgerton 75) and greater contractile protein content (Goldspink 70, Close 72, Burke and Edgerton 75) than slow contracting fibers (ST). Therefore, successful football players would be expected to possess a percentage of FT muscle fibers greater than that of ~~ST~~. This percentage FT population would likely vary by position but the top player at each position might well be the one with the greatest percentage of FT muscle fibers. To test this hypothesis muscle fiber populations will be determined histochemically, myofibrillar ATPase activity will be determined biochemically and these results will be cross-correlated with running times and measures of leg power and dynamic leg strength.

Football, regardless of position, is an explosive activity requiring the immediate production of energy for maximal muscular contraction. The average time of sustained maximal effort during one play would be approximately five seconds. Between plays, the recovery time would be approximately thirty-five seconds. A sustained march resulting in a change-over of possession of the ball could require as many as fifteen plays.

The hydrolysis of ATP causes shortening of the contractile structures and is the direct energy source for mechanical work. This phenomenon was observed by Davis et al. (59) who upon poisoning isolated muscle with 1 - Fluor - 2, 4 - dinitrobenzene (FDNB), a chemical which inhibits creatine kinase and myokinase and prevents the resynthesis of ATP from oxidative phosphorylation or glycolysis, induced muscular contraction resulting in a decrease in ATP, an increase in inorganic phosphate and no change in creatine phosphate (CP) or creatine content. However, under these conditions the muscle was only capable of contracting a few times. Therefore, for muscular contraction to continue ATP must be resynthesized.

The resynthesis of ATP occurs through different metabolic pathways but in a specific order. Creatine phosphate is an energy source found in the muscle cell which is capable of immediately resynthesizing ATP. This energy source can be sustained for approximately 10 s and has a recovery half time of approximately 30 s (Fox and Mathews, 74). Glycogen is an energy substrate that is stored in muscle and liver. During high intensity exercise this stored carbohydrate will generate ATP in a matter of seconds, via anaerobic glycolysis (Scopes, 74). Lactic acid is an end product of this energy pathway. During less than maximal exercise the same stored glycogen as well as circulating glucose can be converted into acetyl coenzyme A which can enter the citric acid cycle and the electron transport chain and be used to generate ATP aerobically. Stored triglycerides can be lipolized to form free fatty acids which are transported to the muscle cell where they also can enter the citric acid cycle and the electron transport chain and be used to generate ATP aerobically. However, the aerobic breakdown of stored substrates is slow compared to anaerobic glycolysis and the creatine phosphate reaction. This is due to the lag time needed to get the necessary substrates and co-factors into the energy generating machinery of the mitochondria (McGilvery,75). As well the extraction system which removes these substrates and co-factors from the blood is limited by the rate of blood flow which in turn is limited by the intensity of the exercise. Thus, aerobic production of ATP is dependent upon the intensity of the exercise. During high intensity work very little, if any, ATP is regenerated in working muscle via aerobic pathways. However, overloading the aerobic system during training sessions will increase its role in energy production in exercising muscle during high intensity exercise. During a football game the creatine phosphate reaction and anaerobic glycolysis generate ATP for the periods of maximal intensity while all systems and pathways will resynthesize ATP and CP during the stoppages in play or recovery period. The different metabolic reactions used in the resynthesize of ATP during a football game can be monitored by measuring the activity of key enzymes in the respective reactions. Therefore, creatine kinase, lactate dehydrogenase and succinate dehydrogenase activity were measured from biopsy samples of football players.

The purposes of the study are:

1. To compile profiles, based upon histochemical, biochemical and performance data for varsity football players.
2. To determine whether de-conditioning occurs over the three month football season.
3. To determine whether the physiological profiles of wide receivers, inside receivers, quarterbacks, running backs, offensive linemen, defensive backs, linebackers and defensive linemen differ from one another.

METHODOLOGY

SUBJECTS

Permission was obtained from the coaching staff of the University of Alberta Intercollegiate Football team to administer a battery of tests to all individuals who attended their 1977 training camp. Prior to training camp a letter explaining the purposes of the testing was sent to all prospective "Golden Bear" football players. This letter was endorsed by the coaching staff. In effect, the coaching staff indicated that the results would be used for evaluation purposes. However, since the majority of testing occurred prior to the start of training camp, the coaching staff did not make participation mandatory. A copy of the letter that the players received can be found in Appendix B.

DESIGN

All players were assigned to a group based upon the major position played during the 1977 season. The groups selected were:

(1) Running Backs,
(2) Wide Receivers,
(3) Inside Receivers,
(4) Offensive Lineman,
(5) Defensive Lineman,
(6) Defensive Linebackers,

(7) Defensive Backs,

(8) Quarterbacks.

Five tests were selected based upon their ability to measure aerobic capacity, anaerobic capacity, leg power, leg strength and leg endurance, for pre and post analysis of any de-conditioning which might occur over the football season. These tests were:

(1) Maximum Oxygen Consumption - aerobic capacity,

(2) Endurance Stair Run - anaerobic capacity,

(3) Power Stair Run - leg power,

(4) Maximal Knee Extension - Flexion Torque on Cybex II - leg strength and power,

(5) Maximal Knee Extension - Flexion Endurance on Cybex II - leg endurance.

Four additional tests and a muscle biopsy from the vastus lateralis were also administered to collect data for other physiological variables. The remaining four tests were:

(6) Percent Body Fat,

(7) Agility Run,

(8) Sprint Speed over Ten Yards,

(9) Sprint Speed over Forty Yards.

The muscle biopsy was used for the following analysis:

(1) Percent Muscle Fiber Population,

(2) Succinate Dehydrogenase Activity (SDH)

(3) Lactate Dehydrogenase Activity (LDH)

(4) Creatine Phosphokinase Activity (CPK),

(5) Myofibrillar Adenosine Triphosphatase Activity.

All data was used to determine whether the eight groups differed significantly from one another and if so for which variables. Since the objective was to establish a physiological profile of a football player by position, only data from individuals who practised and competed with the team during the season was used for this analysis.

Finally, to see whether any relationship existed between the measured variables, correlations were computed using pre test data from all subjects.

Due to technical difficulties percent body fat was not measured until the week of October 2nd, ten and forty yard sprint speed the week of October 16th, and agility run time the week of October 30th. All other testing was completed prior to the teams first league game on September 10th. All post-test data was collected within two weeks of the Wednesday following the final game or by November 16th.

STATISTICAL ANALYSIS

The ten different tests utilized in this study provided a total of twenty-nine variables. Due to unequal sample size for most of the variables a one-way analysis of variance (ANOVA1) was used to determine whether a significant difference existed between the groups of football players. The Newman-Keuls post-hoc test was used whenever a significant F value was found to show which groups significantly differed from one another. A one-way repeated measures analysis of variance (RMAOV1) was used to determine whether a significant difference existed between the nineteen pre-test and post-test variables.

A Pearson Product Moment Correlation for missing data (DEST05 from the DERS computer program documentation) was used to compute a correlation matrix for all twenty-nine variables as well as calculate the mean, standard deviation and the probabilities that the correlations in the population from which the sample was drawn are equal to zero.

The input portion of the ANOVA1, RMAOVI and DEST05 can be found in Appendix C.

ADMINISTRATION OF TESTS

1. Maximum Oxygen Consumption

Maximum oxygen consumption was measured by the Beckman Metabolic Measurement Cart while running on a motor driven treadmill. The metabolic cart gives a read-out which includes expired volume, oxygen consumption in liters per minute and in milliters per kilogram per minute, respiratory quotient, percent oxygen and percent carbon dioxide. Volumes are automatically corrected for STPD and BTPS. For the warm-up, which lasted three minutes, the treadmill was set at a five percent grade and seven miles per hour. For the exercise bouts the treadmill speed remained constant at seven miles per hour and the elevation was increased two and one-half degrees every minute. Oxygen consumption was recorded every thirty seconds until a maximal value was reached. Criterion for having reached maximal oxygen consumption was that point where oxygen consumption levelled off or decreased (within 100 ml) with an increasing work load. An example of the printout for a subject is found in Appendix D.

2. Ten and Forty Yard Sprint Speed

Photo-electric cells were utilized to measure velocity to the nearest one-hundredth of a second over a distance of ten and forty yards. This test was administered on the running track in the ice hockey arena. The subjects began from a stationary position utilizing the starting technique of their choice. A set of photo-electric cells were situated on the starting line, and at ten and forty yards from this line. Timing clocks were connected to the sets of photo-electric switches positioned at ten and forty yards. On his own volition the subject sprinted fifty yards as fast as possible. By breaking the light emitted from the photo-electric cells the subject started the timing device on crossing the starting line and stopped a clock after having run ten yards and another clock after forty yards. Each subject warmed-up prior to his sprint run and the fastest time of two trials was used as his score. A minimum of five minutes recovery time was taken between trials.

3. Power Stair Run

A system utilizing electronic timing pads connected to a clock recorder* was set up to measure to the nearest one-hundredth of a second, the time taken to run at top speed up a flight of stairs. The stairs were located outside the main basketball gymnasium at the University of Alberta and lead up to the balcony seats. There were twenty steps with a combined vertical distance of 3.8 meters (19 cm/step). A two meter long flat surface between the tenth and eleventh steps interrupted the vertical climb. Each subject was requested to perform two different tasks of running up the stairs. The first task was to ascend the stairs as quickly as possible taking only two steps at a time and with only one step on the flat surface between steps ten and eleven. Therefore, the subject landed on steps two, four, six, eight and ten took one step on the flat and then landed on steps twelve, fourteen, sixteen, eighteen and twenty. One electronic timing pad was placed at the base of the stairs to start the clock while the pad on step twenty stopped the clock. The second task (freestyle) was to ascend the stairs as quickly as possible but this time no restriction was placed upon the number of steps that could be taken in one stride. Prior to the testing situation (not more than three days) every subject practiced each task a minimum of twenty trials. On the testing day every subject was entitled to three warm-up runs for each task at seventy-five percent of maximum speed. All subjects performed five runs for each task at maximal speed and the fastest time was used for statistical analysis. Sufficient time was allowed for recovery between trials and between tasks, and subjects were informed of their times on each trial.

---

* Automatic Performance Analyzer - Dekan Industries, Illinois.

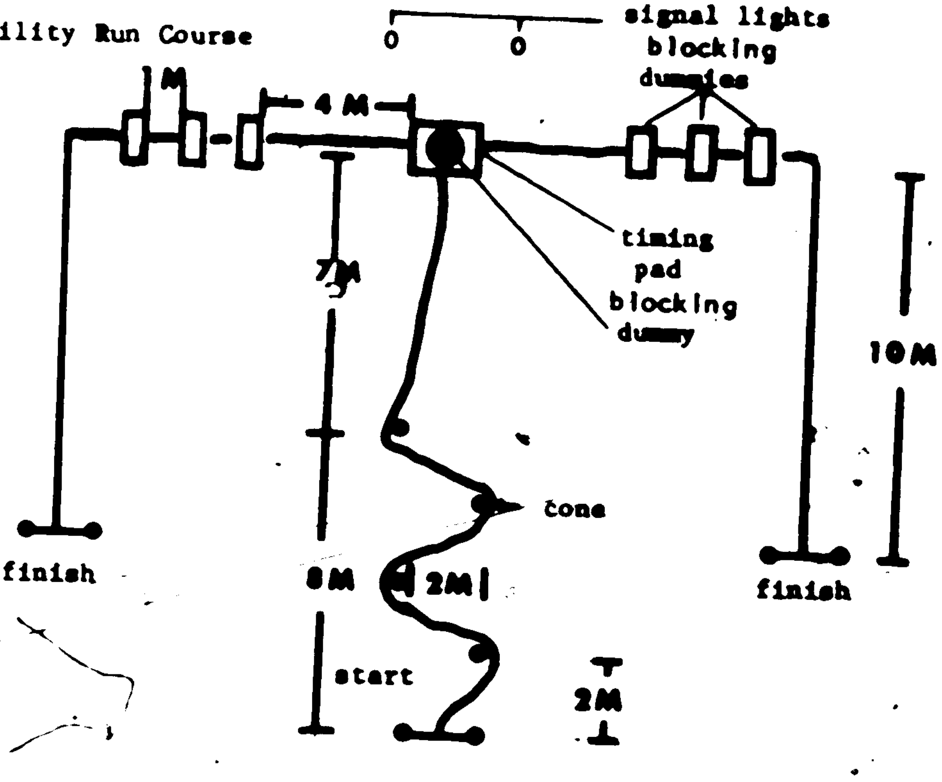
4. Endurance Stair Run

This test utilized the same recording device as used for the power stair run. The object of this test was to ascend the stairs as quickly as possible and for as long as possible while carrying an additional 10% of body weight. The weight was carried in a specially designed belt supported with shoulder straps. (See Appendix E). Lead shot in two, one, and half pound bags, which slipped into pockets on the belt, served as the weight. The ten per cent weight was rounded off to the nearest one-half pound. All subjects were informed that the fastest time of their first five trials was used in assessing their leg power and that less than maximal effort on each trial could be detected by their drop-off rate. All subjects discontinued running when their times for three consecutive trials were each one second slower than their fastest time of the first five trials. No subjects were informed as to the stopping criterion, but all were told that the total number of trials completed was not as important as the number of times they could maintain close to their best time. Thus, the emphasis was to go "all-out" for as long as possible rather than less than maximal effort for a longer time. This usually meant that the subject stopped due to fatigue before having reached the pre-set stopping criterion. Whenever possible, two subjects ran at the same time. As one ran up the stairs the other came down. A maximum of fifteen and a minimum of ten seconds was taken between the completion of one trial and the start of the next trial. The sum of trials between start and cessation of running as well as the rate of decrease in time were used for statistical analysis. This test was not administered on the same day as the power stair run.

5. Agility Run

The photo-electric timing system was used to time this run. One set of [illegible]lls was set up at the start of the course and another at each finish line. The course was designed to simulate the movements a football player might make during a game situation (see Diagram 1).

Diagram 1. Agility Run Course



The blocking dummy was placed on top of a pad containing a weight sensitive switch. This switch was connected to a mercury switch which controlled the two signal lights. When the dummy sat on the pad both lights would be off. A light came on only when the dummy was knocked off the pad. Which light came on was determined by the mercury switch. This mercury switch was manipulated by a research assistant such that neither the subjects nor the research assistant knew which light would be activated.

Subjects began from a three-point stance and on their own command weaved between the cones as fast as possible to the large blocking dummy fifteen meters from the start line. On reaching the dummy the subject knocked it over with a two-handed shiver technique and then side-stepped to the left or right depending upon which light was activated. The subject then had to step over three blocking dummies situated one meter apart while moving laterally with his head and shoulders facing in the direction opposite to the finish line. After stepping over the third dummy the subject proceeded to the finish line by running backwards. Each subject had eight trials on the same day. Ample recovery time was taken between trials. The fastest time of all the trials was used for statistical analysis.

6. Percent Body Fat

The underwater weighing technique was used to estimate the percent body fat. For the calculations of per cent body fat with this method measurements of weight in dry air, water temperature and vital capacity while standing in the water at neck level were taken. After having entered the water tank the subject submerged himself and ran his fingers through his hair to remove all air trapped in his hair. The subject then sat in the chair, inflated his lungs maximally and leaned forward slowly (while pinching his nose) until completely submerged. He was cautioned to remain as stationary as possible without touching the cables supporting the chair. While underwater a measurement of body density was taken with a recorder attached to a strain gauge. Three such measurements were taken, with the lowest value recorded used for statistical analysis. Additional measurements were taken if the three recordings were not within five chart units of one another. A lead belt of known weight was used to aid the subject in totally submerging his body. Residual volume was estimated from the vital capacity. See Appendix F for a sample calculation.

7. Maximal Knee Extension - Flexion Torque and Endurance on Cybex II

The Cybex II is capable of measuring muscular torque in foot - pounds at pre-selected controlled velocities from isometric contractions (0° per second) to fast functional speeds (300° per second). Once a speed is selected, the lever arm cannot be accelerated beyond that speed regardless of the input torque. Thus, as more force is exerted against the lever arm of the apparatus the resistance supplied via the input attachment automatically varies to accommodate this force. The torque output of the muscle is measured by a dynamometer and displayed on a front gauge dial and a fast response recorder with heated stylus. The fast response recorder gives a graphic readout of the force curve over the entire range of motion. The gauge helps the subject achieve maximal effort by supplying a visual feedback of his performance.

Each subject contracted maximally in both directions, at 30° per second and 180° per second, until fifty percent of the maximal torque value was reached. The protocol manual for Cybex II testing, published by Lumex Incorporated, states that recording at 30° per second measures basic muscular strength whereas 180° per second measures functional muscular strength or power. Two sub-maximal practice trials were administered prior to the test trials at each speed to allow the subject to experience the accommodating resistance provided by the machine. The subject was seated in the chair as illustrated in the photograph (see Appendix G); strapped, just above the ankle to the lever arm of the machine; strapped around the chest and across the upper thighs to the chair; and asked to perform the required extension (starting with knee at 90° angle and ending with knee at 180° angle) and flexion (starting with knee at 180° angle and ending when knee reached 90° angle) movements. All subjects were tested at 180° per second first. A minimum of fifteen minutes recovery was taken before being tested at 30° per second. All subjects used stretching exercises to warm-up the quadriceps and hamstring muscle groups prior to testing. Verbal motivation was supplied by the test administrator. Peak torque and rate of fatigue were extrapolated from the chart recording. See Appendix G for an example of a chart recording.

8. Percent Fiber Population and Enzyme Activity of Vastus Lateralis Muscle

Muscle biopsies were taken from the vastus lateralis by the method of Bergstrom (62). The site of the biopsy was the lateral side of the thigh, on the approximate mid-point of a line between the spina ilica anterior superior and the upper border of the patella. This site was chosen because in the middle portion of the vastus lateralis the risk for complications of the biopsy procedure is minimal due to a scarcity of nerves and vessels. Also, the vastus lateralis is one of the most common sites of biopsy due to its importance in locomotion for athletic activities. Extreme care was taken to keep the operating area sterile.

Two muscle cores were taken from the same incision on the right leg. One core was removed from the needle and frozen within five seconds in isopentane cooled in liquid nitrogen for biochemical determinations. The other core was dissected free of fat and connective tissue, oriented under a dissecting microscope, mounted in OCT mounting medium on a cork and frozen in isopentane cooled in liquid nitrogen for histochemical determinations. Both samples were stored at -60° centigrade until analyzed.

Fiber typing was based upon the staining intensity of ATPase at pH 9.4 with pre-incubations at pH 10.4 and 4.65 (Guth and Samaha, 70). Muscle fibers were classified as fast contracting (FT) or slow-contracting (ST) by this method. Serial sections, 10 um thick, were cut in a cryostat at -20° centigrade, picked up onto a slide and allowed to dry at room temperature for twenty-four hours before being stained. (See Appendix H for the exact procedure). Fibers were counted from photomicrographs. A minimum of two hundred fully intact fibers were used to calculate the fiber type percent for each sample.

Fluorometric techniques (Lowry and Passonneau 72) were used to measure the activities of the four enzymes under consideration. Fluorometry is a method of measuring the fluorescence or instantaneous emission of light from a molecule or atom which has absorbed light. The rate of change of fluorescence with time, ΔF/minute, is directly proportional to the concentration of the enzyme being measured provided the concentrations of substrates and auxillary enzymes are in excess thus allowing the enzyme under study to be the rate limiting step in the reaction. All reactions were either NADH or NADPH coupled to provide a molecule with measurable fluorescence. Fluorometry is precise enough to accurately measure enzyme activities of muscle samples as small as one milligram wet weight.

The frozen muscle samples were thawed in ice-cold 0.1 M Tris buffer (pH 7.5) and blotted to remove any blood. Noticeable chunks of connective tissue were also removed. Each sample was then weighed to the nearest one-tenth of a milligram on a Mettler H20T analytical balance. Samples were homogenized in a Potter-Elvehjem glass homogenizer five times for three seconds each in 0.5 ml of ice-cold 0.1M Tris buffer at pH 7.5. Thirty seconds was allowed between each grinding to prevent denaturation of the enzymes as a result of heat build-up. The homogenizers were also placed in ice-cold water baths to keep the temperature down. The samples were poured off and the homogenizers washed with an additional 2.5 ml of the same buffer to give a final dilution of three ml per sample. Any noticeable pieces of connective tissue remaining in the homogenizers were removed and weighed on the Mettler. This weight was subtracted from the original sample weight to give a more accurate wet weight of muscle tissue. A Biuret protein determination (See Appendix I for procedure) was performed on each sample using 0.5 ml of the homogenate. Succinate dehydrogenase (Essen et al. 75), lactate dehydrogenase going from both pyruvate to lactate and lactate to pyruvate, creatine phosphokinase (CPK) and myofibrillar ATPase activities were then determined using portions of the whole muscle homogenate. (For exact procedures see

Appendix J). All activities are expressed in umoles per gram wet weight per minute (µmoles x g^{-1} x min^{-1}). Primary and secondary filters with excitation wavelengths of 365 and 465 nanometers respectively were used in a Turner model 111 fluorometer. For the CPK and ATPase measurements a piece of duct tape with a spherical hole in it was placed over the light source to reduce the size of the opening from which the light was emitted This allowed higher concentrations of NADH to be used. Blank samples containing everything but the fluorescent substances were recorded for each enzyme assay. Standards for NADH were computed on a Unicam SP1800 Spectrophotometer and matched against the ΔF on the fluorometer to give the value in µmoles per milliliter for a change of one unit in fluorescence. Change in fluorescence was graphically recorded on a Unicam AR55 linear recorder on a scale from zero to one-hundred. All enzyme assays were recorded at 30° centigrade using the Turner temperature regulating door and a Thelco water bath. Matched 3 ml culture tubes were used as sample containers.

RESULTS

The results are presented in three major sections: Correlations between Histochemical, Biochemical and Performance Data; Physiological Changes after a Competitive Season; and Physiological Profiles of Football Players. Group data are summarized in tabular form with means, standard errors of the mean, group sizes and significant effects reported. Complete data for all subjects are presented in Tables 16 and 17 of Appendix K. Analysis of variance tables with post hoc analysis are located in Appendices M and N. The Pearson Product Moment correlation matrix is located in Appendix L.

CORRELATIONS BETWEEN HISTOCHEMICAL, BIOCHEMICAL AND PERFORMANCE DATA

Summaries of all significant correlations for each variable are found in Table 19 of Appendix L. VO_2 max had negative correlations of 0.51 with % body fat and 0.56 with the stair run fatigue slope for all trials. Positive correlations of 0.43 with the number of stair run trials performed, 0.57 with LDH activity going from pyruvate to lactate and 0.54 with LDH activity going from lactate to pyruvate were observed for VO_2 max. Low correlations were noted between VO_2 max and % FT muscle fibers and SDH activi[illegible](0.10 and 0.27 respectively). Percentage of body fat had positive correlations with those variables where total body weight served as a resistive force; 0.63 with 40 yd. sprint time, 0.50 with two stairs per stride stair run time, 0.61 with freestyle stair run time and 0.61

with stair run time while carrying 10% of body weight. It appears then that players with the highest % body fat had the slowest time and players with the lowest % body fat had the fastest time.

Sprint speed over 10 yards had r values of 0.82 with 40 yd. sprint speed, 0.46 with agility run time, -0.44 with myofibrillar ATPase activity, and 0.25 with % FT muscle fibers. Sprint speed over 40 yds had r values of 0.71 with two stairs/stride stair run, 0.62 with freestyle stair run time and 0.73 with stair run time while carrying 10% of body weight. Thus, subjects with the fastest times over 40 yds. also would be expected to have the fastest times for the power stair run variables. Agility run time and % FT fiber population had low correlations with 40 yd. sprint speed (r = 0.36 and 0.29 respectively).

The enzymes CPK and ATPase, which are involved in the generation of energy while running 40 yds at maximal speed, had r values of -0.42 and -0.43 respectively, with sprint speed time over 40 yards.

The three power scores obtained by running up a flight of stairs at maximal speed appear to be similar. This is indicated by correlations of 0.70 between two-stairs and freestyle, 0.70 between two-stairs and two-stairs weighted and 0.58 between freestyle and two-stairs weighted. Although the correlations between the three power stair run times and % FT, CPK activity and myofibrillar ATPase activity were in the expected direction-negative- the r values were low (ranging from -0.25 to -0.43).

The r value of -0.77 between the number of trials completed on the stairs whi[illegible]rying 10% body weight and fatigue slope for all stair run trials indicates that those subjects who completed the least number of tr[illegible]ls di[illegible] the quickest fatigue rate. When only the first thirteen trials were used to compute the regression line for the fatigue slope a correlation of -0.63 still resulted. The four enzymes measured had higher correlations when compared to the rate of fatigue (0.34 to 0.38) than when compared to the number of trials completed (0.01 to 0.21) for stair run endurance.

Measures of maximal leg power and strength on the Cybex II at both slow (30°/s) and fast (180°/s) speeds and by both quadriceps and hamstrings muscle groups were highly correlated (range of r values from 0.60 for 30°/s quadriceps max. torque with 180°/s hamstrings max. torque to 0.82 for 30°/s hamstrings max. torque with 180°/s hamstrings max. torque). The same relationship does not exist however when comparing the number of trials performed and the rate of fatigue to 50% of maximal torque. Only high correlations were found between number of trials performed by hamstrings and quadriceps at the same angular velocity ($r = 0.64$ at 30°/s and 0.66 at 180°/s). For fatigue rate the only high correlation occurred at 180°/s ($r = 0.69$ between hamstrings and quadriceps).

Agility run time was the only non-Cybex variable to show correlations of greater than 0.50 with any of the Cybex variables at 30°/s ($r = -0.50$ with quadriceps trials and $r = -0.59$ with quadriceps fatigue slope). At 180°/s the highest correlation between a non-Cybex and Cybex variable was -0.43 for VO_2 max and quadriceps fatigue slope.

The percentage of fast contracting fibers had poor correlations with the other twenty-eight variables. The time taken to ascend the stairs at two stairs per stride had the highest r value with % FT (-0.41).

In general, enzyme activities did not correlate highly with themselves or with other variables. However, the highest r value obtained for any two variables was between LDH activity going from pyruvate to lactate and LDH activity going from lactate to pyruvate ($r = 0.91$). Other enzyme correlations over 0.50 were:

(1) 0.57 for LDH Py→La and VO_2 max.
(2) 0.54 for LDH La→Py and VO_2 max.
(3) -0.55 for LDH Py→La and % FT.
(4) -0.52 for LDH La→Py and % FT.
(5) 0.50 for LDH Py→La and CPK.
(6) -0.54 for SDH and freestyle stair run time.
(7) -0.51 for SDH and weighted stair run time.
(8) 0.64 for SDH and myofibrillar ATPase.
(9) 0.59 for CPK and myofibrillar ATPase.

PHYSIOLOGICAL CHANGES AFTER A COMPETITIVE SEASON

Tables 1, 2 and 3 summarize the pre-test and post-test differences of nineteen variables for all subjects (grand mean) as well as for five groups of players. These five groups are: 1. receivers (R) = wide receivers (WR) + inside receivers (IR); 2. offensive backs (OB = quarterbacks (QB) + running backs (RB); 3. defensive backs (DB); 4. defensive running game (DRG) = linebackers (LB) + defensive lineman (DL); 5. Offensive lineman (OL). All differences, significant at the 0.05 level ($p<0.05$) will be reported for group and grand means. As well, noticeable changes will be reported as a positive or negative percentage change of the post-test score compared to the pre-test score.

Table 1. Pre-Post Data for VO_2 max and Stair Run Variables
($^{*}p<0.10$, $^{**}p<0.05$, $^{***}p<0.01$)

Group	Subject	VO_2 max ml x kg^{-1} x min^{-1}		Two-Stairs Sec.		Freestyle Sec.		Two-Stairs With Weight Sec.		Trials with Weight		Fatigue Slope-All Trials		Fatigue Slope- 1st 13 Trials	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
WR	1	56.1	60.6												
	2	59.5	56.5	2.32	2.21	2.03	1.93	2.58	2.48	36	28	.028	.028	.016	.030
	3	53.5	57.2												
IR	5	63.3	59.7												
	7	55.8	56.1	2.29	2.15	2.04	1.99	2.60	2.33	18	18	.069	.052	.063	.059
	8	53.0	50.2	2.54	2.51	2.33	2.07	2.97	3.07	24	44	.040	.012	.026	.016
Mean		54.9	56.7	2.38	2.29	2.13	2.00	2.72	2.63	26	30	.044	.011	.035	.035
QB	9	52.4	52.7	2.35	2.45	2.49	2.20	2.54	2.95	34	36	.040	.021	.024	.021
	10	67.1	63.1	2.49	2.44	2.04	1.97	2.72	2.67	36	34	.007	.016	.014	.021
RB	11	53.7	49.3	2.55	2.56	2.39	2.40	2.93	2.90	25	25	.024	.010	.031	.021
	14	60.9	54.4												
Mean		58.5	54.9*	2.46	2.48	2.31	2.19	2.73	2.84	31.7	31.7	.024	.016	.023	.021
DB	17	62.0	50.2												
	18	66.2	63.0	2.44	2.47	2.25	2.33	2.81	2.96	41	25	.013	.034	.022	.009
	19	56.1	54.3	2.39	2.44	2.17	2.22	2.75	2.67	25	25	.032	.040	.040	.022
	20	66.8	58.1	2.33	2.20	1.95	1.86	2.75	2.54	33	26	.026	.026	-.003	.026
	21	61.1	58.6												
	25	69.5	61.5	2.59	2.37	2.34	2.30	2.61	2.73	35	25	.014	.031	.018	.025
Mean		63.6	57.6**	2.44	2.37	2.18	2.18	2.73	2.73	33.5	25.3	.021	.033*	.019	.021
LB	32	58.6	58.4	2.39	2.42	2.13	2.14	2.74	2.85	28	55	.018	.009	.000	-.005
				2.34	2.33	2.24	2.26	2.65	2.88	20	17	.059	.056	.070	.055
DL	33	59.3	55.1	2.48	2.53	2.35	2.29								
Mean		59.0	56.8	2.40	2.43	2.24	2.23	2.70	2.87	24	36	.039	.033	.039	.025
OL	37	50.7	51.8	2.55	2.59	2.57	2.56	3.02	2.90	15	18	.080	.058	.070	.064
	38	53.3	52.7	2.48	2.32	2.12	2.00	2.61	2.62	44	24	.017	.044	.025	.056
	40	50.2	48.4												
	41	52.4	50.5	2.47	2.35	2.34	2.18								
	42	53.9	50.9	2.37	2.38	2.25	2.18	2.79	2.75	29	16	.032	.042	.020	.048
	44	58.0	56.2												
	43			2.36	2.34	2.17	2.12	2.79	2.65	36	16	.030	.068	.028	.069
	39	53.2	53.8												
Mean		53.1	52.0	2.45	2.40	2.29	2.21**	2.80	2.73	31	20.5	.040	.053	.036	.059
Grand Mean		57.9	55.3***	2.43	2.39	2.23	2.17***	2.74	2.75	29.9	27	.033	.034	.029	.033
Total n		25		18		18		16		16		16		16	

Table 2. Pre-Post Test Data for Cybex 30°/s
(*p < 0.10, **p < 0.05) # Max Torque in ft/lbs

Group	Subject	QUADRICEPS						HAMSTRINGS					
		Max Torque #		Trials		Fatigue Slope		Max Torque #		Trials		Fatigue Slope	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
WR	1	165	144	18	43	.308	.119	101	97	22	17	.215	.218
	2	198	183	25	15	.328	.564	102	105	26	13	.188	.428
	3	182	202	16	26	.433	[illegible]	100	120	14	21	.335	.275
IR	5	228	288	25	19	.303	.683	132	131	16	25	.509	.174
	7	205	208	17	27	.663	.358	117	104	13	19	.468	.280
	8	208	235	17	18	.661	.690	114	120	27	19	.177	.296
Mean		197.7	210	19.7	24.7	.463	.421	111	112.8	19.3	19	.315	.279
QB	9	170	173	17	23	.478	.383	121	132	[illegible]	29	.316	.196
	10	198	175	29	16	.323	.684	105	118	32	16	.130	.295
RB	11	207	194	13	15	.727	.730	153	131	13	21	.486	.230
	13	173	176	24	21	.336	.487	122	124	22	22	.238	.311
Mean		187	179	20.8	18.8	.466	.521	125.3	126.3	21.5	22	.293	.258
DB	17	186	184	10	11	1.04	.656	108	110	14	11	.310	.386
	18	206	163	30	47	.305	.137	79	96	43	37	.065	.117
	19	151	143	18	15	.424	.531	94	78	18	15	.262	.305
	20	175	192	34	19	.234	.476	90	115	45	26	.038	.187
	24	204	204	18	20	.570	.620	123	133	24	17	.231	.273
	25	168	200	12	18	.716	.582	71	120	10	15	.412	.368
Mean		181.7	181	20.3	21.7	.548	.500	94.2	108.7	[illegible]	20.2	.220	.280*
LB	32	252	262	37	25	.260	.508	132	142	[illegible]	12	.299	.694
DL	33	360	298	18	17	1.12	.835	174	166	15	14	.636	.641
	35	318	287	13	23	.830	.670	156	147	[illegible]	24	.544	.331
	36	223	238	12	12	.930	.995	130	138	[illegible]	18	.595	.481
Mean		288.3	271.3	20	19.3	.785	.752	148	148.3	15	17	.519	.537
OL	37	161	186	20	18	.328	.617	84	106	33	24	.096	.220
	38	306	353	24	10	.629	1.50	123	157	10	13	.854	.701
	40	282	204	15	34	.991	.229	132	132	20	34	.261	.149
	41	204	192	13	16	.862	.568	117	126	13	17	.464	.361
	42	219	243	12	9	1.08	.423	90	170	10	9	.431	.23
	44	297	310	18	19	.706	.718	129	133	19	21	.242	.276
	43	360	315	27	15	.750	.808	153	160	22	15	.349	.483
Mean		261.3	257.6	18.4	17	.764	.695	118.3	132	18.1	19.6	.385	[illegible]
Grand Mean		222.4	220.4	19.7	20.3	.600	.374	116.7	124.5**	20.1	19.4	.339	.342
Total n		27		27		27		27		27		27	

Table 3. Pre-Post Data for Cybex 180°/s
(*p < 0.10, **p < 0.05, ***p < 0.01). # Max Torque in ft/lbs

Group	Subject	QUADRICEPS						HAMSTRINGS					
		Max Torque #		Trials		Fatigue Slope		Max Torque #		Trials		Fatigue Slope	
		Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
	1	92	115	21	19	.653	.630	62	83	33	22	.186	.446
WR	2	108	94	20	17	.516	.518	79	81	20	17	.309	.438
	3	103	105	20	17	.492	.551	69	78	23	20	.305	.407
	5	110	112	21	21	.525	.493	88	90	17	22	.557	.369
IR	7	117	116	20	22	.581	.517	80	98	22	21	.369	.446
	8	97	120	27	20	.347	.619	68	91	29	21	.215	.395
Mean		104.5	110.3	21.5	19.3	.487	.547	74.3	86.8**	23.8	20.5	.335	.414
QB	9	94	97	22	21	.420	.429	80	89	24	21	.303	.379
	10	89	108	27	19	.302	.506	65	69	24	21	.275	.336
RB	11	92	82	23	21	.308	.369	77	77	21	21	.347	.334
	13	85	82	20	23	.358	.345	73	71	26	23	.275	.247
Mean		90	92.3	23	21	.367	.412	73.8	76.5	23.8	21.5*	.300	.326
	17	75	74	21	23	.374	.352	57	60	22	24	.242	.347
	18	88	81	21	26	.391	.292	53	67	25	27	.203	.250
DB	19	58	85	22	18	.275	.460	52	68	25	18	.197	.371
	20	77	87	24	29	.311	.283	62	74	23	29	.238	.196
	24	95	120	15	12	.628	1.02	76	87	16	13	.498	.663
	25	60	76	19	21	.278	.321	44	62	15	23	.264	.367
Mean		75.5	87.2	20.3	21.5	.376	.455	57.0	69.7***	21.3	22.3	.274	.332
LB	32	96	115	30	24	.328	.491	72	88	30	25	.161	.362
	33	135	131	20	22	.716	.621	92	94	26	30	.329	.467
DL	35	137	144	24	24	.508	.612	98	106	27	30	.321	.371
	36	96	108	20	20	.435	.577	72	92	26	28	.267	.330
Mean		116	124.5	23.5	22.5	.517	.575	83.5	95*	27.3	28	.269	.383*
	37	71	95	25	22	.290	.435	68	69	25	24	.191	.270
	38	144	162	19	23	.672	.600	66	98	19	21	.172	.305
	40	116	134	25	21	.462	.622	80	95	26	21	.263	.375
OL	41	102	91	16	18	.673	.319	72	77	20	20	.391	.260
	42	102	120	21	20	.435	.548	63	91	20	20	.323	.630
	44	96	110	25	20	.275	.486	63	80	27	24	.214	.315
	43	153	152	25	20	.616	.690	98	97	20	22	.493	.438
Mean		111.7	123.4*	22.4	20.6	.489	.530	70.0	86.7***	22.4	21.7	.307	.380
Grand Mean		99.5	108***	22	20.9	.449	.508***	70.6	82.7***	23.7	22	.290	.363***
Total n		27		27		27		[illegible]		27		27	

For the total population, maximal oxygen consumption significantly decreased from 57.9 to 55.3 ml x kg^{-1} x min^{-1} (4.5%). By group the VO_2 max changes were: R = -0.4%, OL = -2.1%, DRG = -3.7%, OB = -6.2% and DB = -9.4%. The decrease for DB was significant.

Freestyle stair run times for the total population were significantly faster post-season than pre-season (a 2.7% decrease from 2.23 to 2.17 s) By group the freestyle stair run time changes were: DB = no change, DRG = -0.4%, OL = -3.5%, OB = -5.2% and receivers = -6.1%.

No significant changes occurred over the season for the endurance variables of the stair run for all subjects as one group. However, rather noticeable differences did occur within some of the groups. For stair run trials to exhaustion these changes were: R = +15.4%, DRG = +50%, DB = -24.5% and OL = -41.3%. For fatigue slope of all stair run trials the changes were: R = -32.8%, DRG = -15.4%, OB = -33.3%, DB = +57.1% and OL = +32.5%. For fatigue slope of the first thirteen stair run trials the changes were: R = no change, DRG = -35.9%, OB = -8.7%, DB = +10.5% and OL = +63.9%.

Maximal hamstrings torque at 30°/s or strength, significantly increased post-season for the total group (6.7%) whereas quadriceps strength did not. For comparative purposes hamstrings (H) and quadriceps (Q) changes (reported respectively) by group were: R = +1.6% and +6.4%, DB = +15.4% and -0.4%, OB = +0.8% and -4.3%, DRG = +0.2% and -5.9%, OL = +11.6% and -1.4%.

No significant changes occurred over the season in the number of contractions or trials completed at 30°/s before reaching 50% of maximal torque. For comparative purposes, percentage changes by group for the number of trials completed to 50% of maximal torque at 30°/s were (H and Q respectively): R = -1.5% and +25.4%, DB = -31.4% and +6.9%, OB = +3.3% and -9.6%, DRG = +13.3% and -3.5%, OL = +5.0% and -7.6%.

No significant changes occurred over the season in the rate of fatigue while performing maximal contractions at 30°/s to 50% of maximal torque. For comparative purposes percentage changes by group for the fatigue slope at 30°/s were (H and Q respectively): R = -11.4% and -9.1%, DB = +31.4% and -8.8%, OB = -11.9% and +11.8%, DRG = +3.5% and -4.2%, OL = -3.9% and -9.0%.

For the total group, maximal hamstrings and quadriceps torque at 180°/s or power, significantly increased post-season, (17.1% and 8.5% respectively). By group, the percentage power changes were (H and Q respectively): R = +16.8% and +5.6%, DB = +22.3% and +15.5%, OB = +3.7% and +2.6%, DRG = +13.8% and +7.3%, OL = +23.9% and +10.5%. The hamstring power increases for OL, DB and R were all significant.

For the total group, the slope of the regression line of all trials completed to 50% of maximal torque at 180°/s (fatigue rate) was significantly steeper post-season for both the hamstrings (+21.8%) and quadriceps (+13.1%) muscle contractions. This indicates that the increases in power were accompanied by increases in fatigue rate. The changes in fatigue rate at 180°/s by group were (H and Q respectively): R = +23.6% and +12.3%, DB = +21.2% and +21.0%, OB = +8.0% and +12.3%, DRG = +44.5% and +11.2%, OL = +16% and +8.4%.

No significant grand or group mean changes occurred over the season for the number of hamstrings or quadriceps contractions or trials completed to 50% of maximal power. Changes in power trials completed by group were (H and Q respectively): R = -13.9% and -10.2%, DB = +4.7% and +5.9%, OB = -9.7% and -8.7%, DRG = -14.7% and -4.3%, OL = -3.1% and -8.0%.

PHYSIOLOGICAL PROFILES OF FOOTBALL PLAYERS

In Tables 4 through 9 the means, standard errors of the mean, F-values and significant F-values as determined by a Newman-Keuls post-hoc test are reported for the twenty-nine physiological variables. In Tables 22 and 2[illegible] in Appendix N the results of the Newman-Keuls post-hoc test on the significant F-values are reported. In Tables 4 and 5 players have been divided into eight groups: (1) Wide Receivers, WR; (2) Inside Receivers, IR; (3) Quarterbacks, QB; (4) Running Backs, RB; (5) Defensive Backs, DB; (6) Linebackers, LB: (7) Defensive Lineman, DL; (8) Offensive Lineman, OL. In Tables 6 and 7 players have been divided into four groups: (1) Receivers, R = WR + IR; (2) DB; (3) Offensive Running Game, ORG = OL + RB + QB; (4) Defensive Running Game, DRG = DL + LB. In Tables 8 and 9 the players have been divided into two groups: (1) Offense; (2) Defense. The results will also be discussed in terms of the similarities of group means as well as the order of the group means.

Defensive lineman (286ft/lbs) were significantly stronger for quadriceps maximal torque at 30°/s than QB (184 ft/lbs) and RB(182 ft/lbs), who were ranked lowest for quadriceps strength. For quadriceps strength OL (252.7 ft/lbs) were similar to DL; WR (203.8), IR (213.7)

Table 4. Means, Group Sizes, Standard Error of the Means and F-Values of Cybex Data for Football Players Grouped into Eight Positions ($^{**}p < 0.05$). # Max Torque in ft/lbs

		Cybex 30°/s						Cybex 180°/s					
		Quadriceps			Hamstrings			Quadriceps			Hamstrings		
		Max Torque #	Trials	Slope	Max Torque #	Trials	Slope	Max Torque #	Trials	Slope	Max Torque #	Trials	Slope
Wide Receivers n = 4	$\overline{X}$ SEM	203.8 23.1	20.8 2.2	.396 .048	113.3 12.3	21.3 2.6	.251 .032	99.8 3.6	21.3 1.0	.462 .028	73.5 5.0	25.0 2.6	.299 .044
Inside Receivers n = 3	$\overline{X}$ SEM	213.7 7.2	19.7 2.7	.569 .093	121.0 5.6	18.0 4.5	.385 .105	108.0 5.8	22.7 2.2	.484 .071	78.7 5.8	22.7 3.5	.374 .100
Quarterbacks n = 2	$\overline{X}$ SEM	184.0 14.1	23.0 4.2	.401 .078	113.0 8.1	25.0 7.1	.223 .094	91.5 2.5	24.5 2.5	.361 .060	72.5 7.6	24.0 0	.289 .014
Running Backs n = 4	$\overline{X}$ SEM	182.0 8.7	15.8 2.9	.601 .105	118.3 12.8	18.0 3.3	.313 .071	68.3 2.5	19.8 1.5	.366 .061	66.8 4.9	20.3 2.5	.315 .051
Defensive Backs n = 12	$\overline{X}$ SEM	200.4 9.5	19.9 2.2	.559 .064	107.8 6.7	23.2 3.3	.267 .051	87.6 5.2	21.8 .84	.388 .028	64.9 3.4	23.1 1.4	.278 .026
Linebackers n = 6	$\overline{X}$ SEM	228.5 20.6	23.0 3.1	.541 .076	122.8 12.5	22.2 1.8	.252 .020	102.7 7.4	21.3 1.9	.528 .074	80.5 8.5	25.2 2.9	.324 .056
Defensive Line n = 4	$\overline{X}$ SEM	286.0 32.0	15.0 1.5	.971 .080	155.5 9.3	14.3 1.5	.575 .025	126.3 10.1	21.5 1.0	.587 .058	95.3 9.7	27.0 .7	.328 .026
Offensive Line n = 9	$\overline{X}$ SEM	252.7 21.5	17.6 1.8	.768 .091	118.9 7.0	17.9 2.4	.394 .070	112.6 8.3	21.0 1.3	.513 .054	72.4 4.9	22.9 1.1	.311 .031
Grand Mean n = 43		219.2	19.2	.613	119.0	20.2	.328	101.0	21.6	.461	73.6	23.6	.308
F		2.72**	0.99	2.90**	1.91	0.87	2.49**	3.03**	0.44	2.00	2.31**	0.81	0.39

Table 5. Means, Group Sizes, Standard Error of the Means and F-Values of Stair Run Data, Biopsy Data, Aerobic Capacity, Body Composition and Agility Run for Football Players Grouped into Eight Positions. (**$p < 0.05$).

		VO_2 max ml^{-1} x kg x min^{-1}	% Body Fat	Agility Run s	Two Stairs s	Free-Style s	Two Stairs Weight s	Stair Trials	Stairs Slope All	Stairs Slope 13	% FT	LDH Py→La	LDH La→Py	SDH	CPK	ATPase
												µmoles x g^{-1} x min^{-1}				
Wide Receivers	$\bar{X}$	57.8	5.80	10.71	2.31	1.98	2.62	28.7	.023	.031						
	n	4	4	2	3	3	3	3	3	3	45.4	162.6	92.3	2.77	905.1	15.2
	SEM	1.9	1.5	.04	.08	..06	.06	3.7	.003	.017						
Inside Receivers	$\bar{X}$	56.6	9.61	10.94	2.35	1.96	2.71	22.3	.044	.037	4	3	3	4	3	3
	n	4	4	2	3	3	3	3	3	3						
	SEM	2.3	2.3	.41	.10	.10	.13	2.2	.014	.013	.60	49.5	27.5	.35	135.4	.31
Quarterbacks	$\bar{X}$	59.8	9.64	11.30	2.42	2.09	2.63	35	.023	.019	51.9	152.3	84.5	2.70	853.1	16.1
	n	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
	SEM	7.4	.31	.53	.07	.11	.09	1.0	.016	.005	.05	53.1	25.5	1.0	246.2	3.6
Running Backs	$\bar{X}$	59.9	9.85	11.40	2.36	2.22	2.65	27.3	.031	.044	47.2	136.0	73.7	1.92	1226.6	12.5
	n	4	3	3	3	3	3	3	3	3	4	4	4	4	4	4
	SEM	2.3	2.6	.23	.11	.12	.15	8.4	.015	.009	9.6	27.4	14.4	.23	337.7	2.5
Defensive Backs	$\bar{X}$	60.9	8.93	11.73	2.37	2.10	2.66	32.9	.026	.028	50.7	153.6	86.5	3.68	861.2	14.0
	n	12	12	3	9	9	9	9	9	9	3	8	8	8	6	8
	SEM	1.6	.96	.40	.04	.06	.04	3.1	.005	.006	3.1	18.2	10.5	.59	64.4	1.7
Linebackers	$\bar{X}$	54.7	13.27	11.27	2.41	2.23	2.77	21.0	.060	.054	46.1	101.1	65.4	2.49	942.9	14.3
	n	6	5	2	4	4	3	3	3	3	5	5	5	5	5	5
	SEM	2.0	1.9	.39	.04	.05	.08	3.8	.024	.023	4.2	15.8	9.3	.51	254.5	3.8
Defensive Line	$\bar{X}$	53.2	12.98	12.20	2.42	2.16	2.83	22.3	.053	.054	42.2	149.4	82.5	2.20	832.9	10.2
	n	4	4	2	4	4	4	4	4	4	3	3	3	3	3	3
	SEM	2.7	.90	.33	.04	.07	.06	2.7	.009	.008	7.8	32.2	17.7	.16	102.1	2.2
Offensive Line	$\bar{X}$	53.3	13.54	11.59	2.47	2.28	2.81	27.9	.048	.042	49.0	112.9	65.0	2.05	799.0	10.9
	n	9	9	7	9	9	9	9	9	9	7	7	7	7	7	7
	SEM	1.1	1.3	.14	.04	.06	.06	3.4	.011	.010	2.7	9.3	6.2	.38	92.8	2.0
Grand Mean		57.1	10.65	11.45	2.40	2.15	2.73	27.9	.039	.038	47.8	134.7	77.0	2.64	910.0	13.0
F		2.65**	2.98**	1.97	0.92	2.19	1.30	1.27	1.32	0.85	0.38	1.03	0.71	1.72	0.59	0.59

and DB (200.4) had similar strength values; and LB (228.5) were ranked higher than backs and receivers but lower than lineman. However, for hamstring strength the same similarities did not exist. All groups, with the exception of DL (155.5) were within 15 ft/lbs of each other (DB lowest at 107.8 and LB highest at 122.8). Of particular interest is the low hamstring strength in comparison to quadriceps strength of the offensive lineman (118.9 to 252.7 respectively).

No significant differences were observed between the eight groups relating to the number of contractions completed before decreasing to 50% of maximal strength. Generally, high strength groups completed fewer contractions (example: DL had mean of 15 for quadriceps and 14.3 for hamstrings) than low strength groups. An exception to this are the RB who ranked lowest for quadriceps strength yet could only complete 15.8 trials.

Defensive lineman reached 50% of their maximal quadriceps strength (slope = 0.97 trails x time^{-1}) significantly faster than WR (0.40) and QB (0.40). Inside receivers (0.57), RB (0.60), DB (0.56) and LB (0.54) had similar rates of quadriceps fatigue while OL ([illegible].77) more resembled the DL. For hamstrings contractions the quicker rate of fatigue of DL (0.58) was significantly different from the rate of QB (0.22). Wide receivers (0.25), RB (0.31), DB (0.27), and LB (0.25) had similar rates of hamstrings fatigue as did IR(0.39) and OL (0.39).

Defensive lineman were significantly more powerful for quadriceps contractions (126.3 ft/lbs) as measured on the Cybex II at 180^{o}/s than RB (88.3) and DB (87.6). For hamstrings contractions DL (95.3 ft/lbs) were significantly more powerful than DB (64.9). Quarterbacks (91.5) were similar to RB and DB in quadriceps power. Wide receivers

(99.8) and linebackers (102.7) had similar quadriceps power values as did IR (108) and OL (112.6). Running backs (66.8) had hamstrings power values similar to those of DB (64.9). Wide receivers (73.5), QB (72.5) and OL (72.4) had similar hamstrings power values as did LB (80.5) and IR (78.7). The low hamstrings power in comparison to quadriceps power (72.4 to 112.6) of OL corresponds to the previously mentioned low hamstrings strength to quadriceps strength of this same group.

For leg strength, as measured by quadriceps and hamstrings maximal torque at 30°/s on Cybex II, the mean ratio of quadriceps strength to hamstrings strength was 1.80 indicating that on the average the quadriceps group was 80% stronger than the hamstrings group. However, for leg power (180°/s on Cybex II) the mean ratio was only 1.35 indicating that the quadriceps group was only 35% more powerful than the hamstrings group. The only group to noticeably deviate from these two mean ratios for strength and power were the OL, who were 113% stronger and 56% more powerful for quadriceps than hamstrings.

No significant differences existed between the eight groups in relation to the number of contractions completed before reaching 50% of maximal power or the fatigue rate to 50% maximal power for either the quadriceps or hamstrings. This is interesting because for strength measurements the strongest groups generally fatigued the quickest and completed the least number of contractions. The range for the number of quadriceps contractions completed at 180°/s was from a high of 24.5 for QB to a low of 19.8 for RB while for hamstrings contractions DL completed 27 trials with RB again ranking the lowest at 20.3 trials.

In terms of rate of fatigue for quadriceps three groupings result; DL (0.59), LB (0.53) and OL (0.51); WR (0.46) and IR (0.48); and QB (0.36), RB (0.37) and DB (0.39). The similarities for rate of fatigue of hamstrings were different from those of the quadriceps groups in that with the exception of IR (0.37) and DB (0.28) the differentiation between groups was small (range of 0.29 for QB to 0.33 for DL).

Defensive backs had significantly higher maximal oxygen consumption, when expressed in proportion to body weight, (60.9 ml x kg^{-1} x min^{-1}) than OL (53.2) and DL (53.3). Linebackers (54.7) most resembled the lineman while wide receivers (57.8), IR (56.6), QB (59.8) and RB (59.9) most resembled the defensive backs.

Wide receivers (5.8%) were significantly leaner than linebackers (13.3%) and OL (13.5%). Defensive lineman had percentages of body fat (13.0%) similar to OL and LB. All of the backs - DB (8.9%), RB (9.9%) and QB (9.6%) - and IR (9.6%) had nearly identical percentages of body fat.

No significant differences were observed between the eight groups for the stair run variables or the agility run. Defensive lineman were ranked highest for agility run time while inside and wide receivers were ranked lowest (fastest times); all other groups had similar agility run times. Offensive lineman were ranked slowest for two stairs per stride stair run times while WR and IR were ranked fastest; all other groups had similar times. When 10% of body weight was added before ascending the stairs the order by group from fastest to slowest was different than it was without the weight. Although WR still ranked the fastest (2.62) they were closely followed by QB (2.63), RB (2.65) and DB (2.66). Offensive lineman were ranked second slowest (2.81) and had similar times to DL (2.83) and LB (2.77). The freestyle method of ascending the stairs provided still a different order of fastest to slowest. Receivers again ranked the fastest - IR (1.96) and WR (1.98) but were not closely followed by any of the other groups. Quarterbacks (2.09) and DB (2.10) had similar times as did RB (2.22) and LB (2.23). Defensive lineman and OL with times of 2.16 and 2.28 respectively, did not closely resemble any of the other groups. No consistent patterns are evident for the number of stair run trials or the fatigue slope of these trials for the eight groups. For the total stair run trials completed before exhaustion, IR (22.3), LB (21.0) and DL (22.3) were similar as were WR (28.7), RB (27.3) and OL (27.9). For the fatigue slope (trails/time) of all trials, WR (0.02), QB (0.02), DB (0.03) and RB (0.03) were similar as were DL (0.05) and OL (0.05). For fatigue slope of the first thirteen trials, WR (0.03) and DB (0.03) were similar as were RB (0.04), OL (0.04) and IR (0.04) as were LB (0.05) and DL (0.05); QB ranked lowest with 0.02.

No significant differences existed between the eight groups for % FT fiber population or for any of the enzyme activities. Defensive lineman ranked lowest for % FT (42.2) while QB (51.9) and DB (50.7) ranked highest. Linebackers (101.1) and OL (112.9) ranked lower for LDH activity going from pyruvate to lactate than the other six groups. For LDH-Py→La, DL (149.4), DB (153.6) and QB (152.3) had similar activities while receivers ranked highest (162.6). When LDH was assayed going from

Table 6. Means, Group Sizes, Standard Error of the Means and F-Values of Cybex Data for Football Players Grouped into Four Positions ($**p < 0.05$). # Max Torque in ft/lbs

		Cybex 30°/s						Cybex 180°/s					
		Quadriceps			Hamstrings			Quadriceps			Hamstrings		
		Max Torque #	Trials	Fatigue Slope	Max Torque #	Trials	Fatigue Slope	Max Torque #	Trials	Fatigue Slope	Max Torque #	Trials	Fatigue Slope
Receivers	$\bar{X}$	208.0	20.3	.470	116.6	19.9	.308	103.3	21.9	.472	75.1	24.0	.331
n = 7	SEM	12.8	1.6	.056	7.1	2.3	.051	3.4	1.0	.031	3.6	2.0	.047
Defensive Backs	$\bar{X}$	200.4	19.9	.559	107.8	23.2	.267	87.6	21.8	.389	64.9	23.1	.278
n = 12	SEM	9.5	2.2	.064	6.7	3.3	.051	5.2	.84	.028	3.4	1.4	.026
Quarterbacks Running Backs Offensive Lineman. n = 15	$\bar{X}$ SEM	224.7 15.8	17.8 1.5	.674 .069	117.9 5.2	18.9 1.8	.349 .048	103.6 5.8	21.5 .93	.454 .040	70.9 3.3	22.5 .96	.309 .022
Linebackers Defensive Lineman. n = 10	$\bar{X}$ SEM	251.5 19.2	19.8 2.3	.687 .080	135.9 9.6	19.0 1.8	.393 .057	112.1 6.8	21.4 1.2	.552 .049	86.4 6.5	25.9 1.7	.325 .034
Grand Mean		219.2	19.2	.613	119.0	20.2	.328	101.1	21.6	.461	73.6	23.7	.308
F		2.02	0.38	1.72	2.69	0.74	1.00	3.07**	0.04	2.81	4.41**	1.15	0.62

Table 7. Means, Group Sizes, Standard Error of the Means and F-Values of Stair Run Data, Biopsy Data, Aerobic Capacity, Body Composition, Agility and Sprint Speed for Football Players Grouped into Four Positions. ($^{**}p < 0.05$).

															μmoles x g^{-1} x min^{-1}				
		VO_2 max ml x kg^{-1} x min^{-1}	% Body Fat	Agility Run s	10 yd. Sprint s	40 yd. Sprint s	Two Stairs s	Free-Style s	Two Stairs Weight s	Two Stairs Trials	Stairs Slope All	Stairs Slope 13	% FT	LDH Py→La	LDH La→Py	SDH	CPK	ATPase
Receivers	$\bar{X}$	57.2	7.70	10.83	1.66	4.89	2.33	2.00	2.65	27.3	.033	.033	45.5	162.6	92.3	2.77	905.3	15.2
	n	8	8	4	5	8	6	6	7	7	7	7	4	3	3	4	3	3
	SEM	1.4	1.44	.18	.03	.08	.06	.07	.07	2.7	.007	.008	.6	49.5	27.5	.35	135.4	.31
Defensive Backs	$\bar{X}$	60.9	8.93	11.73	1.70	4.89	2.37	2.11	2.66	32.9	.026	.028	50.7	153.6	86.5	3.68	861.2	14.0
	n	12	12	3	6	6	9	9	9	9	9	9	7	8	8	8	6	8
	SEM	1.6	.96	.40	.03	.09	.04	.06	.04	3.1	.005	.006	3.1	18.2	10.5	.60	64.4	1.7
Quarterbacks	$\bar{X}$	55.9	12.24	11.49	1.74	5.09	2.44	2.29	2.75	28.6	.041	.039	48.9	126.1	70.7	2.11	938.9	12.2
Running Backs	n	15	14	[illegible]	10	9	14	14	14	14	14	14	13	13	13	13	13	13
Offensive Lineman	SEM	1.4	1.08	.12	.03	.07	.04	.05	.05	2.9	.007	.007	3.1	11.6	6.2	.25	122.2	1.4
Linebackers	$\bar{X}$	54.1	13.14	11.73	1.70	5.08	2.42	2.20	2.80	21.7	.056	.054	44.7	94.1	71.9	2.38	901.6	12.8
Defensive Lineman	n	10	9	4	5	5	8	8	7	7	7	7	8	8	8	8	8	8
	SEM	1.5	1.06	.34	.03	.12	.03	.04	.05	2.0	.010	.010	3.6	11.6	8.6	.32	157.3	2.3
Grand Mean		57.1	10.65	11.45	1.71	5.02	2.40	2.15	2.73	27.9	.039	.038	47.8	134.7	77.0	2.64	910.0	13.0
F		3.68**	4.79**	2.96	1.16	1.41	1.56	5.47**	1.57	2.68	2.18	1.73	0.63	2.72	0.97	3.46**	0.06	0.36

lactate to pyruvate the same similarities were evident as those seen in going from Py→La: LB (65.4) and OL (65.0) ranked lowest, receivers (92.3) ranked highest and DL (82.5), DB (86.5) and QB (84.5) were similar. Defensive backs (3.7) ranked highest for SDH activity while RB (1.9) and OL (2.1) ranked lowest. Receivers (2.8) and QB (2.7) had similar SDH activity. Running backs (1226.6) ranked highest for CPK activity while OL (799.0) ranked lowest. Quarterbacks (853.1), DB (861.2), and DL (832.9) had similar CPK activity. Quarterbacks (16.1) and receivers (15.2) ranked highest for myofibrillar ATPase activity while OL (10.9) and DL (10.2) ranked lowest. Defensive backs (14.0) and linebackers (14.3) had similar myofibrillar ATPase activity.

The player groupings shown in Tables 6,7,8 and 9 were made in an attempt to see whether units who compete against one another are similar in physiological profiles. Thus comparisons will be made between: (1) receivers (R) and defensive backs (DB). (2) offensive running game (ORG) = QB + RB + OL and defensive running game (DRG) = LB + DL. (3) offense and defense. Differences between the means of the groups within each comparison will be presented as plus or minus changes for one group compared to the other. As well statistically significant differences between the means of receivers, defensive backs, offensive running game players and defensive running game players will be reported.

Receivers tended to be stronger and more powerful than defensive backs. The percentage strength and power differences between these two groups are: (1) quadricep strength, R were +3.8%; (2) hamstring strength R were +8.2%; (3) quadriceps power R were +17.9%; (4) hamstrings power R were +15.7%.

Receivers and defensive backs demonstrated almost an equal ability to sustain a muscular contraction to 50% of maximal torque. The largest difference between these two groups occurred for hamstrings contractions at 30°/s where defensive backs were +16.6%.

For receivers and defensive backs the fatigue slope, determined from the regression line of the torque values for each contraction up to 50% of maximal torque, did not follow a set pattern as did the strength and power values. For quadriceps contractions at 30°/s DB were +18.9% (indicating a quicker fatigue rate) while for quadriceps at 180°/s R were +21.3%. For hamstrings contractions at 30°/s and at 180°/s receivers were +15.4% and +19.1% respectively.

DRG players tended to be stronger and more powerful than ORG players. The percentage strength and power differences between these two groups are: (1) quadriceps strength DRG were +11.9%; (2) hamstrings strength DRG were +15.3%; (3) quadriceps power DRG were +8.2%; (4) hamstrings power DRG were +21.9%.

DRG players and ORG players were quite similar in their ability to sustain a muscular contraction to 50% of maximal torque. For hamstrings contractions at 30°/s and quadriceps contractions at 180°/s the percentage differences were only 0.5% while DRG were +11.2% for quadriceps at 30°/s and +15.1% for hamstrings at 180°/s.

DRG players, as a group, displayed a greater fatigue rate, while performing maximal contractions for both muscle groups at both speeds, to 50% of maximal torque than did ORG players. The percentage differences are as follows: (1) quadriceps 30°/s = +1.9%; (2) hamstrings 30°/s = +12.6%; (3) quadriceps 180°/s = +21.6%; (4) hamstrings 180°/s = +5.2%.

The only significant differences between means of Cybex variables of the four groups were for quadriceps and hamstrings maximal power. In both instances, DRG were more powerful than defensive backs.

Defensive backs had +6.5% aerobic capacity in proportion to body weight when compared with receivers even though they tended to have greater percentages of body fat. Receivers and DB did not differ in straight sprinting speed but receivers were -8.3% (indicating faster times) for the agility run. Receivers in comparison to defensive backs ascended the stairs -1.7% for two stairs per stride, -5.5% freestyle and -0.4% for two stairs weighted (indicating faster times) yet DB were +20.5% for stair run trials completed as well as -26.9% for fatigue slope for all trials and -17.9% for fatigue slope for the first thirteen trials (indicating a slower rate of fatigue).

ORG players had +3.3% aerobic capacity in proportion to body weight when compared with DRG players. DRG players tended to have greater percentages of body fat than did ORG players. DRG and ORG did not differ in straight sprinting speed or agility run time (ORG only 2.1% more agile). Stair run times for all three methods were very similar between ORG and DRG (largest difference was DRG being -4.1% for freestyle method). However, ORG were +31.8% for stair run trials completed before becoming fatigued as well as -36.6% for fatigue slope of all trials and -38.5% for fatigue slope of first thirteen trials.

Defensive backs had significantly higher maximal oxygen consumptions, when expressed per kilogram body weight than did DRG. Receivers were significantly leaner than both ORG and DRG. Receivers also had significantly faster freestyle stair run trials than both ORG and DRG.

Defensive backs had a higher percentage of FT muscle fibers yet also had +32.9% SDH activity when compared to receivers. LDH (in both directions), CPK and ATPase activities were +5.9% (Py→La), +6.7% (La→Py), +5.1% and +8.6% for receivers in comparison to defensive backs.

DRG had less percentage of FT muscle fibers as well as +12.8% SDH activity when compared to ORG. LDH, Py→La was +34% for ORG in comparison to DRG yet LDH, La→Py was +1.7% for DRG in comparison to ORG. CPK w[illegible] +4% in ORG in comparison to DRG yet ATPase was +4.9% for DRG in c[illegible]on to ORG.

Defensive backs had significantly higher SDH activity than did ORG players.

The offensive players used in this study have almost the identical physiological profile, as measured by twenty-nine variables, as the defensive players used in this study. No significant differences were found between the means of the offensive group and the defensive group. The greatest percentage difference between the means of these two groups (mean 1 - mean 2 divided by grand mean) are: (1) SDH activity (+28.8% in favour of defensive players); (2) number of hamstring contractions to 50% maximal torque at 30°/s (+10.4% in favour of defensive players) (3) number of hamstring contractions to 50% of maximal torque at 180°/s (+6.4% in favour of defensive players).

Table 8. Means, Group Sizes, Standard Error of the Means and F-Values of Cybex Data for Football Players - Offense versus Defense. # Max Torque in ft/lbs

		Cybex 30°/s						Cybex 180°/s					
		Quadriceps			Hamstrings			Quadriceps			Hamstrings		
		Max Torque #	Trials	Fatigue Slope	Max Torque #	Trials	Fatigue Slope	Max Torque #	Trials	Fatigue Slope	Max Torque #	Trials	Fatigue Slope
Offense	$\overline{X}$	219.4	18.6	.609	117.5	19.2	.336	103.5	21.6	.459	72.5	22.9	.316
n = 22	SEM	11.5	1.2	.053	4.1	1.4	.036	4.1	.70	.029	2.5	.87	.021
Defense	$\overline{X}$	219.1	19.9	.617	120.6	21.3	.319	98.7	21.6	.463	74.7	24.4	.300
n = 22	SEM	12.5	1.5	.051	6.3	2.0	.038	4.9	.70	.032	4.1	1.1	.021
Grand Mean		219.2	19.2	.613	119.0	20.2	.328	101.1	21.6	.461	73.6	23.6	.308
F		-	0.45	0.01	0.16	0.74	0.11	0.57	-	0.01	0.21	1.16	0.33

Table 9. Means, Group Sizes, Standard Error of the Means, and F-Values of Stair Run Data, Biopsy Data, Aerobic Capacity, Body Composition, Agility and Sprint Speed for Football Players - Offense versus Defense

																umoles x g^{-1} x min^{-1}		
		VO_2 max^{-1} ml x kg^{-1} x min	% Body Fat	Agility Run s	10Yd.Sprint Speed s	40Yd.Sprint Speed s	Two Stairs s	Free-Style s	Two Stairs Weight s	Trials With Weight	Fatigue Slope All Trials	Fatigue Slope 1st 13 Trials	% FT	LDH Py→La	LDH La→Py	SDH	CPK	ATPase
Offense	$\bar{X}$	56.3	10.56	11.33	1.71	5.01	2.41	2.16	2.72	27.7	.039	.038	48.1	132.9	74.7	2.27	932.6	12.7
	n	23	22	16	15	20	20	20	20	20	20	20	17	16	16	17	16	16
	SEM	1.0	.96	.12	.02	.05	.03	.05	.04	2.1	.006	.006	2.4	12.8	7.0	.21	101.0	1.2
Defense	$\bar{X}$	57.8	10.74	11.73	1.70	5.02	2.39	2.15	2.72	28.0	.039	.040	47.5	136.4	79.2	3.03	884.3	13.4
	n	22	21	7	11	11	17	17	16	16	16	16	15	16	16	16	14	16
	SEM	1.3	.84	.23	.02	.07	.02	.04	.04	2.4	.006	.006	2.5	12.7	6.8	.27	91.3	1.5
Grand Mean		57.1	10.65	11.65	1.71	5.02	2.40	2.15	2.73	27.9	.039	.038	47.8	134.7	77.0	2.64	910.0	13.0
F		0.80	0.02	2.85	0.22	0.02	0.17	0.02	-	0.01	-	0.06	0.03	0.04	0.21	3.40	0.12	0.12

DISCUSSION

The discussion is presented under the same major headings as were previously used: Correlations Between Histochemical, Biochemical and Performance Data; Physiological Changes After a Competitive Season; and Physiological Profiles of Football Players.

CORRELATIONS BETWEEN HISTOCHEMICAL, BIOCHEMICAL AND PERFORMANCE DATA

Correlations were computed for two purposes:

(1) to evaluate whether expected relationships between variables associated with the same physical fitness parameter exist for a group of Canadian intercollegiate football players;

(2) to determine whether a[illegible]ected relationships between physical fit[illegible]iables exist for a group of Canadian inter[illegible]te football players.

Costill et al.(76) found a correlation of 0.79 between VO_2 max and SDH activity. The correlation between the same two variables in this study was only 0.27. The difference in these two correlations is likely due to the homogeneity of the subjects used in this study (as demonstrated by a small variance in $\dot{V}O_2$ max and SDH values) as compared to the heterogeneity of the subjects used in the Costill et al. study (as demonstrated by a large variance in VO_2 max and SDH values. Highly endurance trained athletes have been shown to possess high oxidative capacities and high percentages of slow contracting muscle fibers in vastus lateralis (Gollnick et al. 72 Gollnick et al. 73, Costill et al. 73). The correlations of -0.10 for % ST with VO_2 max and -0.16 for % ST with SDH could indicate that for football players there is a poor relationship between % ST muscle fibers and oxidative capacity. Although % ST had a large variance (range of 25 to 70%) the homogeneity of the group for VO_2 max and SDH cannot be discarded as the possible cause of lack of correlation between these variables.

The r of -0.51 between % body fat and VO_2 max is expected as research has shown that individuals with high percentages of body fat possess low oxidative capacities (Boileau et al. 71, Girandola and Katch, 73). The correlations for VO_2 max and LDH activity (0.57 Py→La and 0.54 La→Py) were unexpected in light of the research by Karlsson et al. 75, Costill et al. [illegible] Sjodin et al. 76, and Thorstensson et al. 76a, who reported that subjects with high percentages of ST fibers and high oxidative capacities have low LDH activity. The observation that football players are involved in work of an interval nature that utilizes both anaerobic and aerobic means of regenerating ATP might explain the relationship between VO_2 max and LDH since high intensity anaerobic training has been shown to maintain LDH activity (Sjodin et al. 76, Houston and Thomson, 77) while aerobic or endurance training decreases LDH activity (Karlsson et al. 75, Sjodin et al. 75).

The correlations between % body fat and 40 yd sprint speed (0.63), freestyle stair run (0.61), two stairs per stride stair run (0.50), two stairs per stride stair run while carrying 10% of body weight (0.61) and stair run fatigue slope for all trials (0.55) were expected since performance of speed and power activities which require moving the body weight a horizontal or vertical distance as fast as possible have been shown to deteriorate as the percentage contribution of fat to total body weight increases.

Power is the ability to generate a force over a distance in a certain time ($P = F \times D \times t^{-1}$). Metabolically, power is the ability to generate and utilize energy quickly. The enzymes ATPase and CPK catalyze the reactions that release energy at a very high rate (Davis et al. 59, Barnay 67, Fox and Mathews, 74). Fast contracting muscle fibers are the fiber type best suited for generating large force outputs over a short period of time (Gordon et al. 67, Goldspink 70, Close 72, Burke and Edgerton 75). Activities involving high force generation in five seconds or less (anaerobic power) should demonstrate a positive relationship with physiological variables that contribute to increased amount and rate of force generation (power). Therefore, myofibrillar ATPase activity, CPK activity and % FT muscle fiber population should be positively correlated with measures of power. This study utilizes eight tests in which power should be a major factor in quality performance. These tests were: (1) Agility run; (2) 10yd sprint; (3) 40yd sprint; (4) two stairs per stride stair run time; (5) freestyle stair run time; (6) two stair per stride stair run time while carrying 10% of body weight;

(7) maximal quadriceps torque on Cybex II at 180°/s ; (8) maximal hamstring torque on Cybex II at 180°/s . The significant correlations between 40 yd sprint time and the three measures of stair run power (0.71, 0.62 and 0.73), between 10 yd sprint time and 40 yd sprint time (0.82) and between the three power stair run tests (0.70, 0.70 and 0.58) imply that a relationship exists between the scores for these five tests. This relationship could be the ability of these five tests (10 yd sprint time, 40 yd sprint time, and the three stair run tests) to measure the same power component. Agility run time and quadriceps and hamstrings maximal torque at 180°/s did not correlate significantly with 10 and 40yd sprint time or the three stair run tests. This implies that the Cybex power tests and the agility test do not measure the same power component as the sprint and stair run tests. None of the power tests demonstrated high correlations with % FT (the highest was -0.41 with two stairs per stride stair run test). This data suggests that % FT fiber population by itself does not contribute to the prediction of anaerobic power. However, % FT fiber population does not indicate the total number of FT muscle fibers that can be recruited to perform this type of work. As well, fiber cross-sectional area is directly related to the muscle's ability to generate tension. Thus if the total number of FT fibers that can contribute towards the generation of anaerobic power, as well as the total cross-sectional area of these useable fibers were known then higher correlations between FT muscle population and anaerobic power might be found. A significant correlation of 0.59 was found between ATPase and CPK activity. This implies that a relationship exists between these two

enzymes. However, the correlations of CPK and ATPase with the sprint and stair run tests, although significant, were low (from -0.36 to -0.43). These low correlations imply that other factors probably also contribute to whatever relationship exists between the two enzyme activities and the sprint and stair run tests. The concentration of ATP and CP (reactions catalyzed by ATPase and CPK respectively) might very well be the above mentioned contributing factors.

Anaerobic capacity is a function of the initial energy stores available for anaerobic metabolism as well as the rate at which the body can regenerate the phosphagen energy stores. ATP and CP are the fuels available in the muscle cell which can be used for the immediate generation of energy to produce anaerobic power. Glycogen is an energy substrate stored in the muscle cell which is used to regenerate ATP via glycolysis. LDH catalyzes the conversion of pyruvate and NADH into lactate and NAD^+- a step necessary for glycolysis to continue. Therefore, LDH activity is directly related to the rate of regeneration of energy. High intensity interval work with a relief interval of fifteen seconds or less utilizes anaerobic glycolysis for the regeneration of energy stores. The number of high intensity repetitions completed during interval work of no greater than 1:5 work to relief ratio would be a measure of anaerobic capacity. The endurance stair run tests and the Cybex quadriceps endurance tests at 30°/s and 180°/s are high intensity interval tests with work to relief ratios of 1:5 and 1:1 respectively. The correlations of LDH Py→La with stair run trials (0.14), quadriceps 30°/s trials (0.13), hamstrings 30°/s trials (-0.14), quadriceps 180 /s trials (0.11) and hamstrings 180°/s trials (-0.02) as well as LDH La→Py with the same variables (consecutively as above = 0.21, 0.22, -0.05, 0.09 and -0.07) suggest, however, that factors other than LDH activity contribute more to the prediction of anaerobic capacity. These factors could well be the initial stores of glycogen in the muscle fibers and the ability to recruit muscle fibers for this type of work.

In conclusion, correlational data do not imply causal relationships. However, the lack of a correlation does suggest that no causal relationship exists.

PHYSIOLOGICAL CHANGES AFTER A COMPETITIVE SEASON

A large variation in post-season fitness levels in comparison to pre-season fitness levels was observed within the sample population as well as within groups in the sample population. It is likely that these large variations were a function of:

(1) the initial fitness levels of the subjects;

(2) the amount and intensity of physical activity during practice sessions over the course of the season.

There was no control over either of these factors. Since a pre-training camp conditioning program was not compulsory large differences in initial fitness levels were expected. Through conversations with coaches and players it became obvious that certain players had participated in very little, if any, fitness training whereas other players had been weight training and running for at least three months. As well, it was learned that few players deviated from the traditional weight training and jogging regime. Of those who chose programs other than weight training and jogging most ran stairs or wind sprints. Many players were relying upon the rigors of training camp to improve their physical fitness.

Based upon accessability to practice outlines and through personal observation it was decided that the major emphasis during practice was on the learning of offensive and defensive systems through repetitious execution of techniques. Brief bouts of agility drills and 'sled work' followed a stretching type of warm-up and preceded the systems portion of practice. Practice was usually concluded with either 'wind sprints' or interval runs around the football field. Every Monday, practice was concluded with a two mile jog. During practice, the different groups rarely participated in the same drills. Backs, receivers and linebackers seldom worked on the sled whereas linesman seldom did agility or running drills. In fact, receivers, quarterbackers and running backs rarely participated in drills other than practicing plays, running pass patterns, pass catching or ball handling. Defensive backs and linebackers seldom tried drills other than running backwards, footwork, tackling, pass catching or pursuit. Lineman seldom changed their daily practice routine of sled work and one-on-one line blocking. As well, some groups had such an excess of players (especially defensive backs) that during systems and specialty team practice many players were inactive observers.

The majority of players who had participated in a fitness program prior to the season discontinued these programs once training camp started. A few players continued weight training but only on a maintenance program (once or twice a week compared to three or four). Some players also were unable to participate in practice at various times throughout the season due to illness or injury. Based upon the above description of differences in pre-season training programs and in-season activity levels it is easy to explain the large changes in fitness levels.

Generally speaking, players who reported to training camp in poor physical condition improved their physical fitness whereas players who were extremely physically fit prior to training camp were less fit by the end of the season.

The decrease in maximal oxygen consumption in football players over a competitive season was unexpected in light of the aerobic training during practice. A decrease in VO_2 max can be attributed to the lack of a suitable overload to the cardiorespiratory and muscular systems over an extended time period. Defensive backs, with the highest VO_2 max pre-season, were the only group to show a significant decrease in VO_2 max. It appears that the VO_2 max decrease for DB could be attributed to a reduction in physical activity during practice as a result of the large number of players who practiced with the team over the season. Twelve players were kept after training camp to compete for five starting positions. This meant that, since no other group had enough surplus players to make up a second squad, at least one-half of the DB spent a good portion of practice as inactive observers. It is interesting to note that receivers, who probably did the greatest amount of aerobic training over the season also showed the least reduction (-0.4%) in VO_2 max post-season compared to pre-season.

The significant decrease in freestyle stair run time post-season could be related to the great amount of sprint type running performed during the season in comparison to the small amount of sprint time running performed prior to training camp. Wide receivers, who probably did the greatest amount of sprint type running ranked highest in terms of magnitude of change in freestyle run times post-season compared to pre-season. This increase in sprint running speed in combination with an increase over the season in the amount of resistive type exercise, such as that performed during 'sled work' and when attempting to block or defend against a block, might also explain the significant increases in maximal hamstrings torque at 30°/s and maximal hamstrings and quadriceps torque at 180°/s It is interesting to note that defensive backs, who do the greatest amount of sprint type running backwards, were ranked highest for magnitude of change in hamstrings strength (30°/s) and second highest for magnitude of change in hamstrings power (180°/s).

It was not the intent of this study to determine the causes associated with physiological change over a competitive season but to determine whether any change did in fact occur. Since the reported physiological changes are directly related to the amount and intensity of specific physical activity these results could prove to be very helpful to the coaches and players of the University of Alberta 'Golden Bears' football team in designing pre-season and in-season physical training programs.

PHYSIOLOGICAL PROFILES OF FOOTBALL PLAYERS

The discussion of these results would be simplified and more meaningful if all subjects were at their optimal fitness level when tested. However, as has been previously mentioned, the pre-test fitness levels of the subjects had a large variance due to the lack of compulsory pre-season fitness programs which would specifically improve those fitness components most needed by football players. The discussion of these results would also be simplified and more meaningful if all subjects were playing in the position best suited to their physiological abilities. However, data on the physiological abilities of the professional football player (likely the most homogeneous of all football players by position) are not available.

The [illegible]ts of this study indicate that the players used in this investigat[illegible]n, when grouped as offense against defense, defensive backs against wide receivers or offensive running game players against defensive running game players, did not differ significantly for the following variables:

(1) activities of the enzymes LDH, SDH, CPK and myofibrillar ATPase in the vastus lateralis;

(2) % fiber population of vastus lateralis;

(3) leg power;

(4) leg strength;

(5) leg endurance;

(6) % body fat;

(7) agility;

(8) anaerobic capacity;

(9) aerobic capacity.

If the data of Novak et al. 68, Wilmore and Haskell 72, Forsyth and Sinning 73, Wickkiser and Kelly 75, Smith and Byrd 76, and Wilmore et al. 76 are pooled to provide the same comparisons, the same similarities exist. Since these different units directly compete against one another superiority by one unit over the other should be an advantage in winning football games. Two hypotheses can be formulated from the results of this study:

(1) that factors such as hand -eye coordination, learning ability, skill acquisiton, skill level, motivation, previous experience, leadership, intelligence, and strategy contribute more to the success of specific groups of football players which in turn would provide the advantage necessary to win football games.

(2) that by improving the physiological variables measured in this study, for a specific group of football players, a superiority would be gained which would be an advantage in winning football games.

If success in football is based upon winning games, most people will agree that an improvement in the coachable factors as well as the trainable factors will best accomplish this goal. Based upon the winning percentages in relation to daily practice procedures, of specific teams, the writer hypothesizes that improvements in the physiological variables of football players by position (specific positions would require greater improvement of some variables than others) would improve the winning percentage of a football team. The physiological data collected on the football players used in this study (divided into eight groups) will now be used to expand this hypothesis.

The ability of the muscle cell to utilize oxygen for the generation of ATP, which can be hydrolized to produce energy for work, is one of many variables which contribute to a football players success. During high intensity work the role of aerobic generation of ATP is minimal. Football is a game involving many short bouts of high intensity work, each being followed by a longer, less intense bout of recovery. It is during this recovery period that the aerobic energy production system functions. The capacity of the aerobic energy production system and the rate at which this sytem can produce ATP will determine the total amount of ATP that can be produced during a given quantity of submaximal exercise. Maximal oxygen consumption has been used as an indicator of aerobic power whereas SDH activity has been used as an indicator of the aerobic systems rate. If a large amount of energy is used during an activity, as is the case during a football practice or game, and the body cannot supply this amount of energy over a given time period, then performance will suffer. Thus, individuals with high aerobic power and a high aerobic energy production rate should have a decided advantage during a football practice or game. This suggests that all football players should have high oxidative capacity. However, players such as receivers and defensive backs, who do considerably more running than other players, will need higher aerobic capacities and therefore for them, greater emphasis should be placed on aerobic training. The results of this study which show defensive backs and receivers having the highest oxidative capacity (both VO_2 max and SDH) are in agreement with the data of Smith and Byrd (76) and Wilmore et al. (76).

Muscle strength and power, especially in the legs, are probably the two most important physiological variables needed by a football player for successful performance. Two subjects in the offensive lineman group will be used to illustrate this point. Subject 37, who was subjectively rated one of the worst offensive lineman by the coaching staff, ranked lowest for the power and strength variables whereas subject 43, who was subjectively rated one of the best offensive lineman by the coaching staff, ranked highest for the power and strength variables. All players need leg power and strength but players who are more involved in blocking and tackling should possess higher values than the defensive backs, quarterbacks and wide receivers. The results of this study did show DL, OL, LB, IR and RB to generally be ranked highest for Cybex leg strength and power variables.

The finding that lineman and linebackers possess greater percentages of body fat than backs agrees with what has previously been reported (Novak et al. 68, Forsyth and Sinning 73, Wickkiser and Kelly 75, and Smith and Byrd 76). It is possible that lineman and linebackers need this additional percentage of body fat for protective reasons. Of all football players, lineman and linebackers take the most physical abuse during practices and games. The body fat could serve as a form of protective padding to reduce the severity of muscle injuries. Based upon the known % body fat in comparison to the player's ability (subjective rating by coaches) the writer suggests that 6% to 8% for backs and receivers and 10% to 12% for lineman and linebackers would be recommended levels of % body fat. The previously reported correlation of 0.61 between % fat and power stair run time indicates the loss of power associated with excess fat. It is evident from tables 22.3 and 22.6 that the lineman as compared to the receivers were significantly less powerful as well as significantly fatter.

Saltin (73) has suggested that athletes participating in activities that involve both aerobic and anaerobic energy production might best be serviced by an equal distibution of FT and ST muscle fibers. The findings of this study (grand mean = 47.8%) support this hypothesis.

No conclusion will be formulated concerning the enzyme data reported in this study. However, examples of a few very noticeable differences for certain subjects might infer, that with additional research, certain relationships might be found. Subjects 13 and 82 who were ranked highest for the number of stair run trails completed to exhaustion as well as lowest for the rate of fatigue had 74% and 54% greater CPK activity than any other subject (see tables 17.4 and 17.6). Subject 13 who had the fastest 40 yd sprint speed time also had the highest percentage of FT muscle fibers (75%), the largest CPK activity, and the third largest myofibrillar ATPase activity (see table 17.4). Subject 13 also ranked very high for VO_2 max, LDH activity, and SDH activity and very low for % body fat and power stair run times (see table 17.4).

CONCLUSIONS

Within the limits of this study the following conclusions have been made:

(1) That for the football players in this study the intercorrelations between the scores on the three power stair run tests (freestyle, two stairs per stride and two stairs per stride weighted) were higher than the intercorrelations with the scores of the Cybex power tests.

(2) That percentage of vastus lateralis muscle fiber population, by itself, is not useful in predicting football ability as measured by the performance tests used in this study.

(3) That the University of Alberta Football Team decreased in aerobic fitness over the competitive season as measured by VO_2 max.

(4) That for the University of Alberta Football Team leg power and strength increased over the competitive season as indicated by a decrease in freestyle stair run time and increases in Cybex torque values.

(5) That different positions in football display different degrees of development for certain fitness components. This implies that football players should be physically trained by a program that will improve the physical fitness components most needed in that position for successful performance.

(6) That vastus lateralis enzyme activities in combination with the concentration of the metabolite used in the reactions the enzymes catalyze might be useful in measuring anaerobic and aerobic power and capacity.

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APPENDIX A

REVIEW OF LITERATURE

Maximal oxygen consumption or uptake (VO_2 max) is one of the most commonly measured variables in physiological studies. Table 10 lists mean VO_2max values for athletes from different sports as well as normal untrained or sedentary populations.

Table 10. Mean VO_2max of Males From Select Populations

Activity	n	Age yrs	VO_2max (SEM) ml x kg^{-1} x min^{-1}	Author(s)
1. College Football	16	20.3	51.3	Novak et al. 68
2. College Football	27	19.3	56.5 ± 6.6	Smith & Byrd 76
3. Pro Football	15		50.1	Wilmore & Haskell 72
4. Pro Football	168		50.4	Wilmore et al. 76
5. Elite Canoeists	6	22.6	69.7	Tesch et al. 76
6. Elite Cyclists	11	24.6	67.1 ± 1.3	Burke et al. 77
7. Elite Distance Runners	14	26.2	77.4 ± 1.0	Costill et al. 76b
8. Elite Cross-Country Skiers	6		72.8	Stromme et al. 77
9. Wrestlers	10		57.1	Saltin & Astrand 67
10. Weight Lifters	4	25	40.1 ± 6.4	Gollnick et al. 72
11. Untrained	10		43.5	Saltin & Astrand 67
12. Untrained	19	27.4	38.4 ± 1.8	Costill et al. 76b
13. Untrained	12	27	42.9 ± 1.9	Gollnick et al. 72

From Table 10 it is apparent that: (a) athletes involved in highly aerobic activities (5,6,7 & 8) have high VO_2 max values as compared to athletes involved in highly anaerobic activities (10); (b) athletes involved in activities with both aerobic and anaerobic components (1,2,3,4 & 9) display VO_2 max values about half between the values for the highly aerobic and highly anaerobic; (c) untrained subjects have the lowest VO_2 max values.

Aerobic capacity, as measured by oxygen consumption, is dependent upon level of training (Orlander et al. 77) as well as genetic endowment (Klissauras 73, Leitch et al. 75, Weber et al. 76). With endurance training oxygen consumptions can be increased by as much as 20%. (Gollnick et al. 73, Karlsson et al. 72, Kiessling et al. 74, Pollock et al. 75).

Of special interest in Table 10 are the studies by Smith and Byrd (76), and Wilmore et al. (76). Smith and Byrd divided 27 college football players into four groups and reported mean VO_2 max values for each group; offensive backs had the highest value (60.2) followed by defensive backs (59.3), offensive lineman (55.9) and defensive lineman and linebackers (53.2). Wilmore and his associates used six groups for reporting mean VO_2 max values for 168 pro-football players; defensive backs had the highest value (53.1) followed by running backs and wide receivers (52.2) linebackers (52.1), offensive lineman and tight ends (49.9), quarterbacks and kickers (49.0) and defensive lineman (44.9). The results from these two studies seem to indicate that running backs, wide receivers and defensive backs are very similar in their aerobic capacities as are the offensive and defensive lineman. However, these two groups differ from one another with the lighter backs, who do more running, having higher aerobic capacities. Linebacker's VO_2 max values fall between the backs and li[illegible]

Body composition, percent of fat and lean body weight (LBW), vary depending upon level of training and activity or sport participated in (see Table 11).

Table 11. Body Composition of Males From Select Populations

Activity	n	Age yrs	% Fat	LWB (kg)	Author(s)
College Football	65	17-23	15.0	74.2	Wickkiser & Kelly 75
College Football	27	18-26	13.7	80.3	Smith & Byrd 76
College Football	16	20.3	13.8	82.6	Novak et al. 68
College Football	11		14.6		Forsyth & Sinning 73
Pro-Football	180		13.5	86.6	Wilmore et al. 76
Marathon Runners	114		7.5	59.4	Costill et al. 70
Wrestlers	37		8.8	67.9	Sinning 74
Untrained	38	21.4	19.5	74.5	Clark et al. 77
Untrained	29	21.3	16.9	63.5	Girandola & Katch 73
Untrained - lean	15	17.9	15.1	57.4	Boileau et al. 71
Untrained - obese	8	18.1	38.5	75.3	Boileau et al. 71

From Table 11 it is apparent that:

(a) college and professional football players have similar % body fat even though professional players have a larger total body weight.

(b) marathon runners and wrestlers, athletes who expend large amounts of energy in training and competition, are considerably leaner than football players or untrained subjects.

(c) football players, as a group (all positions) are leaner than untrained subjects.

However, a different result emerges when football players are grouped by position. Wickkiser and Kelly (75) used five groups to report % fat of 65 college football players; defensive backs were the leanest (11.5%) followed by offensive backs and wide receivers (12.4%), linebackers (13.4%), defensive lineman (18.5%), and offensive lineman and tight ends (19.1%). Smith and Byrd (76) divided 27 college players into four groups; defensive backs were again the leanest (9.6%) followed by offensive backs (13.8%), defensive lineman (14.3%), and offensive lineman (14.6%). Wilmore, et al. (76) used six groups with 180 professional players to report % fat; defensive backs (9.6%) were similar to running backs and wide receivers (9.4%) while linebackers (14%), quarterbacks and kickers (14.4%), offensive lineman and tight ends (15.6%) and defensive lineman (18.2%) had considerably larger percentages of body fat.

It appears then, that defensive backs, ~~running backs~~ and wide receivers possess similar percentages of body fat as do offensive and defensive lineman with linebackers having slightly less percentage fat than the lineman. Also, backs are much leaner than lineman. On referring back to Table 11 one now sees that backs are very similar to wrestlers whereas lineman differ very little from a sedentary, untrained population in percentage of body fat.

The use of isokinetic machinery to measure muscular strength and endurance is relatively new thus, to [illegible]ry little data of this nature has been reported in the liter[illegible] Isokinetic machines are considered the best available means of accurately measuring the muscle's maximum force curve, work, power and endurance capacities at performance speeds (Perrine 68). Also, Pipes and Wilmore (75) found that isokinetic training produced superior strength gains to isotonic or isometric training over an eight week program. Van Oteghen (75) demonstrated that volleyball players with the highest torque values at both slow and fast isokinetic speeds also recorded the highest power values as measured by vertical jump performance. The Cybex II, an isokinetic machine, has been shown to give torque values of high reliability (Moffroid et al. 69, Thorstensson et al. 76a). Isometric contractions performed with the Cybex II set at zero degrees per second produce the highest torque values and as the speed of the lever arm or angular velocity increases the torque output decreases (Thorstensson et al. 76a). A significant positive correlation has been shown to exist between torque output at high angular velocities (180°/s), as measured by the Cybex II, and % FT muscle fiber population of vastas lateralis (Thorstensson et al. 76a). As well, a positive correlation between fatiguability with rapid maximal voluntary isokinetic contractions and % FT fibers in contracting vastus lateralis has been reported (Thorstensson and Karlsson 76b). Thus, high angular velocities (180°/s) produce lower torque outputs than do low angular velocities (30°/s) and individuals with high proportions of FT fiber population in contracting muscle will fatigue sooner at high angular velocities even though they can generate higher torque outputs.

In the studies reviewed concerning biopsy data, only data pertaining to muscle vastus lateralis in males is reported unless otherwise stated.

From research data it appears that trained athletes and untrained non-athletes differ in fiber population of muscle vastus lateralis (see Table 12). This difference appears to be a result of natural migration to an activity for which the athletes are physiologically suited rather than a training effect from the activity itself.

Table 12. Percent FT Fiber Population of Vastus Lateralis in Select Male Populations

Activity	n	Age yrs	% FT	Author(s)
Long Distance Runners	7	26	39	Karlsson et al. 75
Long Distance Runners	3	25	40	Costill et al. 74
Long Distance Runners	8	23	40	Gollnick et al. 72
Weight Lifters	7	26	51	Karlsson et al. 75
Weight Lifters	4	25	54	Gollnick et al. 72
Weight Lifters	8	20.3	56	Edstrom and Ekblom 72
Sprinters	4	-	56	Karlsson et al. 75
Sprinters & Jumpers	9	24	61	Thorstensson et al. 77b
Cyclists	22	24.6	45	Burke et al. 77
Untrained	12	27	61	Gollnick et al. 72
Untrained	13	21.7	60	Saltin et al. 76

If the means for all the subjects listed in Table 12 are computed by activity the long distance runners possess 39.6% FT fibers, the weight lifters 53.7%, the sprinters and jumpers 59.5% and untrained subjects 60.5% FT fibers. Thus, endurance athletes (long distance runners) differ from power athletes (weight lifters, sprinters and jumpers), combined power and endurance athletes (cyclists) and untrained males by having a smaller percentage of FT muscle fiber. Power athletes and untrained individuals appear to differ very little in their fiber populations of vastus lateralis, both having approximately 60% FT fibers whereas the athletes who need both power and endurance capabilities have approximately an equal percentage of FT and ST muscle fibers. These differences in fiber populations assume more meaning if one relates them to the contractile and metabolic characteristics of the two fiber types and then relates these findings to the contractile and metabolic characteristics of power versus endurance activities (see Table 13). Thus, power athletes should be best served by the FT fiber, endurance athletes by the ST fiber and combined power and endurance athletes by a fiber type proportion that is approximately equal but possibly favouring the contractile and metabolic components more responsible for successful performance,

Table 13. Contractile, Ultrastructural, [illegible] and Biochemical Difference in Skeletal Muscle Fibres (Burke and Edgerton (75) and Close (72))

Parameter	Fast Contracting FT	Slow Contracting ST
Speed of Contraction	Fast	Slow
Reaction Time	Fast	Slow
Time to Peak Tension	Short	Long
Twitch Tension	High	Low
Peak Isometric Tension	High	Low
% Contribution to Tension	80%	4%
Nerve Impulse Frequency	High	Low
Fibre Diameter	Large	Small
Size of Motor Neuron	Large	Small
Myclination of Motor Nerve	Yes	No
Conducation of Velocityon Motor Nerve	Fast	Slow
Ca^{++} Release of Sarcoplasmic Reticulum	Fast	Slow
Acetycholine Esterase	High	Low
Glycolytic Enzyme Activity	High	Low
Stored Glycogen	High	Very High
Phosphorylase Activity	High	Low
Reaction Velocity of Myosin ATPase	Fast	Slow
Lactate Production	High	Low
Lactate Uptake	Low	High
Contractile Protein	High	Low
Number of Mitochondria	Few	Many
Oxidative Enzyme	Low	High

An extensive review of the literature failed to reveal any studies which reported myofibrillar ATPase activity in vastus lateralis mustle of athletes. However, Thorstensson et al. (76c, 76d) has reported values for physical education students before and after eight weeks of strength training. For twenty-two subjects from two different studies resting values averaged 7.5 umoles x g^{-1} x min^{-1}. Following the eight weeks of strength training the average resting value rose slightly to 8.1 umoles x g^{-1} x min^{-1}. These twenty-two subjects averaged 52.5 percent FT fibers. Thorstensson et al. (75) in another study, using four physical education students who averaged 57 percent FT fibers showed an increase from 7.0 to 9.1 umoles x g^{-1} x min^{-1} in activity of Mg^{2+} stimulated ATPase activity after eight weeks of sprint training on a motor driven treadmill. Histochemically, FT fibers are identified by a more intense staining pattern for myosin ATPase. It follows then, that FT fibers should have an ATPase activity higher than ST fibers. By teasing out individual fibers Thorstensson et al. (77a) found that f[illegible] staining darkly for ATPase at pH 9.4 after pre-incubation at pH 10.3 (FT) had an actomyosin ATPase activity of 0.84 compared to 0.30 umoles X g protein^{-1} X min^{-1} for the light staining (ST) fibers.

An extensive review of the literature also failed to reveal any studies which reported CPK activity in athletes. Gollnick et al. (74) reported an activity of 2200 umoles x g^{-1} x min^{-1} at rest for nine men varying in age from 24 to 41 and with varying fitness levels. Thorstensson et al. (76c, 76d) noted CPK activity levels of 107 and 100 umoles x g^{-1} x min^{-1} in twenty-two male physical education students before and after eight weeks of strength training. Eight weeks of sprint training on a motor driven treadmill by four physical education students produced an increase from 99 to 135 umoles x g^{-1} x min^{-1} in activity of CPK (Thorstensson et al. 75). CPK activity in FT fibers (166 umoles x g $protein^{-1}$ x min^{-1}) has been shown to be higher than that found in ST fibers (131 umoles x g $protein^{-1}$ x min^{-1}) (Thorstensson et al. 77a). The differences in activity levels reported by Gollnick et al. (74) and Thorstensson et al. (77), 2200 versus 99 umoles x g^{-1} x min^{-1}, indicate a wide variation exists in CPK activity in human subjects.

Different lactate dehyodrogenase activity levels have been observed between power and endurance trained athletes. Karlsson et al. (75) reported activity levels (pyruvate to lactate) of 156 umoles x g^{-1} x min^{-1} in seven weight lifters with an average of 49 percent FT fibers while in seven long distance runners with only 29 percent FT fibers the activity levels averaged 67 umoles x g^{-1} x min^{-1}. In a study using nine males ranging in age from 24 to 41 and of varying fitness levels Gollnick et al. (74) found resting LDH activity levels of 112 (pyruvate to lactate) and 63 umoles x g^{-1} x min^{-1} (lactate to pyruvate). LDH activity has been shown to be higher in FT fibers (568 for pyruvate to lactate and 366 umoles x g $protein^{-1}$ x min^{-1} for lactate to pyruvate) than ST fibers (280 for pyruvate to lactate and 145 umoles x g $protein^{-1}$ x min^{-1} for lactate to pyruvate) (Thorstensson et al. 77).

Thorstensson et al. (75) reported an increase of twenty percent in LDH activity (from 156 to 166 umoles x g^{-1} x min^{-1}) after eight weeks of sprint training on a motor driven treadmill (four physical education students aged 16-18). Houston and Thomson (77), using older (34-37 years) and more highly trained men (averaged 35 km running per week) found no significant changes in LDH activity (76.1 to 73.4 umoles x g^{-1} x min^{-1}) following six weeks of high intensity anaerobic training. Kiessling et al. (74) observed mean LDH activity levels of 458 and 1070 umoles x g^{-1} x min^{-1} in well trained men (mean age 53 years) and sedentary men (mean age 54 years) respectively. The sedentary group showed an increase of 11 percent (to 1192 umoles x g^{-1} x min^{-1}) in LDH activity after thirteen weeks of endurance training. On the other hand, Bylund et al. (77) showed no significant increases in LDH activity in nine males (mean age of 44 years) after six months of endurance training (265 umoles x g^{-1} x min^{-1} pre-training versus 256 umoles x g^{-1} x min^{-1} post-training). Suominen et al. (77) also found no significant changes in LDH activity in 69 year old men (121.4 to 118.8 umoles x g^{-1} x min^{-1}) and women (107.8 to 89.7 umoles x g^{-1} x min^{-1}) following eight weeks of physical training.

Sjodin et al. (76) found no significant changes in total LDH activity (214 to 224 umoles x g^{-1} x min^{-1} for pyruvate to lactate and 70 to 72 umoles x g^{-1} x min^{-1} for lactate to pyruvate) in six moderately trained men (15-23 years) following eight weeks of anaerobic training. The same authors (Sjodin et al. 76) however, observed a decrease in total LDH activity (123 to 106 umoles x [illegible]$^{-1}$ for pyruvate to lactate and 60 to 51 umoles x g^{-1} x min^{-1} for lactate to pyruvate) in an eighteen year old long distance runner who increased his training distance from 116 to 160 km. per week over a twelve month period. This same subject also exhibited a shift in the relative contribution of the specific LDH-isozymes; an increase in H-LDH isozyme contribution from 34% to 50% over the twelve months. The data presented on LDH activity suggests that endurance trained athletes have lower total LDH activities than power trained athletes and that activity can be altered via specific training programs.

Different succinate dehydrogenase (SDH) activity levels have also been observed between power and endurance trained athletes. Gollnick et al. (72) measured SDH activity in different groups of athletes (see Table 14). They concluded that SDH activities were highest in athletes involved in endurance type activities.

Table 14. SDH Activities of Vastus Lateralis in Males from Select Populations

Activity	n	Age yrs	SDH Activity (μmoles x g^{-1} x min^{-1})
Bicyclists	4	24	11.0 ± 1.0
Runners	8	23	6.4 ± 0.5
Swimmers	5	21	7.6 ± 0.5
Weight Lifters	4	25	3.0 ± 0.3
Untrained	12	27	4.3 ± 0.6

Burke et al. (77) measured SDH activity in competitive cyclists and untrained males and although their values are somewhat higher (19.4 umoles x g^{-1} x min^{-1} for 22 cyclists versus 6.4 umoles x g^{-1} x min^{-1} for 19 sedentary males) it is evident that endurance training enhances muscle

SDH activity.

The activity of SDH can be increased through physical training. Saltin et al. (76), using untrained males (21.7 years) with a mean SDH activity of 3.9 umoles x g^{-1} x min^{-1}, showed enhancement of SDH activity following both sprint [illegible] endurance training for only four weeks. Eriksson et al. (73) showed a 30% increase in SDH activity (5.4 to 7.0 umoles x g^{-1} x min^{-1}) in thirteen boys (11-13 years) following six weeks of endurance training on a bicycle ergometer. Gollnick (73) found SDH activity increased 95% (4.7 to 9.1 umoles x g^{-1} x min^{-1}) in six males (32.5 years) following a five month endurance training program on a bicycle ergometer.

Slow contracting (ST) fibers have been shown to have higher SDH activity than fast contracting (FT) fibers. Essen et al. (75), using freeze drying techniques, isolated FT and ST fibers and found ST fibers had SDH activity of 29.6 umoles x g^{-1} x min^{-1} as compared to 19.3 umoles x g^{-1} x min^{-1} dry weight for FT fibers. Henriksson and Reitman (76), also using the freeze-drying technique to isolate FT and ST fibers, looked at the effects of a two month training program (nine males aged 20-28 years) on SDH activity (both crude homogenate and pooled FT and ST fibers). Two different training protocols were employed on a bicycle ergometer; continuous submaximal (CT) and interval maximal intensity (IT). Both training protocols produced substantial increases in crude homogenate SDH activity (I.T. from 9.1 to 11.6 umoles x g^{-1} x min^{-1} and C.T. from 10.1 to 12.3 umoles x g^{-1} x min^{-1}). However, in the CT group SDH activity increased only in the ST fibers whereas in the I.T. group SDH activity increased only in the FT fibers. Slow contracting fibers ~~had higher~~ SDH than FT fibers both before (11.6 to 8.0 umoles x g^{-1} x min^{-1}) and after (14.0 to 10.1 umoles x g^{-1} x min^{-1}) training (subjects from both groups were pooled to compute these means). In another study Henriksson and Reitman (77) measured SDH activity in eight males (20-23 years) over a period of training (on bicycle ergometer at average of 89% VO_2 max) and detraining. These authors found that SDH activity of vastus lateralis increased 32% above pre-training levels following eight weeks of training but then returned to pre-training levels following six weeks of normal activity.

APPENDIX B

TO: ALL 1977 GOLDEN BEARS **DATE:** July 21, 1977.

FROM: The Coaching Staff

In less than one month, the 1977 GOLDEN BEAR Training Camp will open. From the observations we have made, the team appears more prepared than ever for camp. That has to be a great sign.

As a method of testing your level of preparedness, a new, improved battery, of fitness tests will be administered prior to our first full gear practice. Included in the items are a series of physical tests of agility, speed, strength, power, maximum oxygen consumption, muscle fiber population and muscle enzyme activity. Clearly, this is an expansion of the number of test items in previous pre-camp fitness appraisals and therefore will require more of your time before camp opens.

Enclosed is a Player Information Sheet. Please complete ALL parts of the form if you are a NEW player. If you are a returning veteran, indicate whether you require room and board during training camp and fill out the Testing Appointment Chart.

For all players: If you are from out of town, we will assume room and board costs beginning August 17th (evening). Thus, you could devote both the 17th and 18th to the testing program. If you live in the Edmonton area, we would like to begin testing August 8th. The testing is quite extensive so allow a number of alternatives when blocking out the times you can be available.

If you are around the University, drop it off or slide it under my office door. It is very important we receive this information at the earliest possible date! This pre-camp fitness profile forms the basis of an ambitious and extensive longitudinal study being carried out by Ray Mens, a 1976 graduate of our team. We appreciate the fact that subjecting yourself to the test items may be inconvenient and, in some cases, time consuming. Nevertheless, it is important that you understand the rationale of our commitment to this and other studies.

In order that intercollegiate athletics continue to remain viable within an academic environment, it is becoming apparent that the total program demonstrate increased involvement in other aspects of university life. Merely playing the games is not enough to justify large financial expenditures and satisfy critics of intercollegiate athletics.

Our participation in projects such as this aids our credibility, gives us vital exposure and provides you, as well as the coaching staff, with invaluable information about training programs and your fitness level. In a word, the GOLDEN BEARS are doing their thing for the expansion and proliferation of knowledge.

Please return the INFORMATION SHEET quickly. We will be in touch with you the first week of August.

Take care,

[illegible] Donlevy.
For the Coaching Staff.

APPENDIX C

Input Portion of One-Way Analysis of Variance APL Program

```
      ∇ ANOVA1
[1]   'ONE-WAY UNIVARIATE ANALYSIS OF VARIANCE'
[2]   ''
[3]   'DESIGN MATRIX:'
[4]   DS←⎕
[5]   'MATRIX OF SCORES:'
[6]   SC←⎕
[7]   ''
[8]   DS1←⌹((⍉DS)+.×DS)
[9]   DS2←(⍉DS)+.×SC
[10]  D←DS1+.×DS2
[11]  SS1←(⍉SC)+.×SC
[12]  SS2←((⍉D)+.×(⍉DS))+.×SC
[13]  SSWIT←SS1−SS2
[14]  NDS←(⍴SC)⍴1
[15]  BB←(⍉NDS)+.×NDS
[16]  BB←⌹BB
[17]  BB1←(⍉NDS)+.×SC
[18]  BB←BB+.×BB1
[19]  NSS2←((⍉BB)+.×(⍉NDS))+.×SC
[20]  ''
[21]  SSTOT←SS1−NSS2
[22]  SSGR←SSTOT−SSWIT
[23]  ''
[24]  DFT←(⍴(,SC))−1
[25]  DFG←0 1/(⍴DS)−1
[26]  DFW←DFT−DFG
[27]  MSG←SSGR÷DFG
[28]  MSW←SSWIT÷DFW
[29]  F←MSG÷MSW
[30]  'SOURCE          SUM OF SQUARES'
[31]  (⍕'GROUP      :'),⍕SSGR
[32]  (⍕'WITHIN     :'),⍕SSWIT
[33]  (⍕'TOTAL      :'),⍕SSTOT
[34]  ''
[35]  'MEAN SQUARE:'
[36]  (⍕'GROUP        :'),⍕MSG
[37]  (⍕'WITHIN       :'),⍕MSW
[38]  ''
[39]  (⍕'VALUE OF F  :'),⍕F
[40]  (⍕'DEGREES OF FREEDOM :'),⍕DFG,DFW
      ∇
```

Input Portion of Repeated Measures One-Way Analysis of Variance APL Program

```
    ∇ RMAOV1
[1]   'ONE-WAY ANALYSIS OF VARIANCE WITH REPEATED MEASURES'
[2]   ''
[3]   '  SUBJECTS ARE REFERRED TO AS S; REPEATED MEASURES AS T'
[4]   ''
[5]   'NUMBER OF REPEATED MEASUREMENTS:'
[6]   NA←⎕
[7]   'NUMBER OF SUBJECTS:'
[8]   NR←⎕
[9]   I←X←0
[10]  I←I+1
[11]  (⍕'SCORES OF SUBJECT  '),⍕I
[12]  XX←⎕
[13]  X←X,XX
[14]  →(I<NR)/10
[15]  X←1↓X
[16]  M←(NR,NA)⍴X
[17]  A←(+/(+/⍉M)*2)÷NR
[18]  AR←+/X*2
[19]  U←((+/X)*2)÷NA×NR
[20]  R←(+/(+/M)*2)÷NA
[21]  SSA←A-U
[22]  SSR←R-U
[23]  SSAR←AR+U-(A+R)
[24]  SSW←SSA+SSAR
[25]  DFA←NA-1
[26]  DFR←NR-1
[27]  DFAR←DFR×DFA
[28]  DFW←NR×DFA
[29]  MSA←SSA÷DFA
[30]  MSR←SSR÷DFR
[31]  MSAR←SSAR÷DFAR
[32]  F←MSA÷MSAR
[33]  MSW←SSW÷NR×NA-1
[34]  REL←1-MSW÷MSR
[35]  ''
[36]  'ESTIMATED MEANS:'
[37]  (+/M)÷NR
[38]  ''
[39]  'SUMS OF SQUARES, NUMBERS OF DEGREES OF FREEDOM AND MEAN SQUA
[40]  ''
[41]  '      AMONG SUBJECTS'
[42]  (⍕'         S          '),⍕(SSR,DFR),MSR
[43]  '      WITHIN SUBJECTS'
[44]  (⍕'         T          '),⍕(SSA,DFA),MSA
[45]  (⍕'         TS         '),⍕(SSAR,DFAR),MSAR
[46]  ''
[47]  (⍕'MEAN SQUARE WITHIN SUBJECTS:   '),⍕MSW
[48]  ''
[49]  (⍕'VALUE OF F:    '),⍕F
[50]  (⍕'NUMBERS OF DEGREES OF FREEDOM:   '),⍕DFA,DFAR
    ∇
```

DIVISION OF EDUCATIONAL RESEARCH SERVICES
FACULTY OF EDUCATION
UNIVERSITY OF ALBERTA

Computer Program Documentation

TITLE:	CORRELATIONS WITH OPTIONAL T-TESTS (missing data)
MACHINE:	IBM 360/67
LANGUAGE:	FORTRAN IV(H)
SUBPROGRAMS:	CORMD, STUDT, PNORM (XDER:SUB) TITLE, FLGCHK, PMAT, ERRR, WARN (USER) DATRAN
LIMITS:	MAXIMUM OF 100 VARIABLES
LIBRARY:	XDER
OPERATING SYSTEM:	MTS
PROGRAMMER:	S. Hunka, revised by W.S. Ebersberger

DESCRIPTION

This program calculates means, variances, standard deviations, and correlation coefficients (Pearson) for up to 100 real variables. Zero is taken as missing data the user may supply a Datran subroutine for handling transformations of input data.

As options, the user may have the correlation coefficients output on cards and have calculated T values and probabilities to test the hypothesis that the correlations are zero.

PREPARATION OF CARDS

CARD SEQ.	SEE NOTE	CARD TYPE	COLS.	DESCRIPTION
1		Title Card	1-80	Any title descriptive of the run. (Not to be left blank)
2	1	Parameter Card	1-5	Number of variables to be input. (Maximum: 100)
			6-10	Number of variables after Datran. (Maximum: 100)
			11-15	Expected number of observations. (No limit; if over 99,999 leave blank)
			16-20	Number of data format cards. (Maximum: 5)
			21-25	1 if T-tests are desired. 0 or blank otherwise.
			26-30	1 for card output of correlation coefficients. 0 or blank otherwise.

Preparation of Cards Continued:

CARD SEQ.	SEE NOTE	CARD TYPE	COLS.	DESCRIPTION
3		Data Format Card(s)	1-80	F format for each variable to be input (max. 5 cards)
4		Data Cards	1-80	As described by format statement.
5		$ENDFILE	1-8	Indicates end of data for the run.
6	2	Blank card or card types 1-6 for nest run.		Execution terminates if card if blank. A non-blank card will be read as the title card for the next run.

USER NOTES

(1) All parameters integer and right-justified in the columns indicated.

(2) The same datran will be used for all runs.

DATRAN SUBROUTINE

The user may supply a datran subroutine in order to transform input data or to cause a record to be ignored. The subroutine is to be specified as follows:

```
SUBROUTINE DATRAN(X,NVI,NVD,MISS)
DIMENSION X(1)
    .
    .
    .
RETURN
END
```

Executable fortran statements are to be placed between the dimension X(1) and return statements in the order in which they are to be executed.

The parameters are:

X	Vector of observations from current record
NVI	Number of variables input
MISS	Has the value 0 when subroutine is called; if changed to 1, all observations from the current record will be dropped.

NVI and NVD must not be changed by the subroutine.

APPENDIX D

Sample print-out from Beckman Metabolic Measurement Cart showing the last four work bouts for this subject. Print-out A and B are the same work load whereas print-out C and D are at a 2½ degree steeper grade.

```
A.                                    151,146.   V
                                        4,836.   A
VO2=oxygen  ————————————————            57.5
   consumption
ml x min-1 x kg-1 (STPD)                5,701.   C1
                                         1.18    R
Cumulative Time ————————————————      301.00
                    .....................
                                         4.99 % CO2
                                        16.56 % O2
                                        27.60   C2
                                       703.00   P
                                        71.14    V
                                        30.10   T
```

```
B.                 166,210.   V
                     4,996.   A
                      59.4

                     6,057.   C
                      1.21    R
                    331.10
    ....................
                      4.82 % CO2
                     16.79 % O2
                     27.60   C
                    703.00   P
                     78.23    V
```

V = $\dot{V}_E$ - minute volume ml/min (BTPS)
A = VO_2 - oxygen consumption ml/min (STPD)
C_1 = VCO_2 - ml/min (STPD)

R = Respiratory Quotient
C_2 = Expired Air Temperature (°C)
P = Barometric Pressure (MMHG)
V = Expired Volume (ATPS)
T = Time of Measurement (seconds)

```
C.                       180,169.   V
                           5,019.   A
                            59.7
                           6,386.   C
                            1.27    R
                          361.20
          ......................
                            4.69 % CO2
                           17.05 % O2
                           27.60   C
                          703.00   P
                           84.80    V
                           30.10   T
```

```
D.                 164,914.   V
                     4,865.   A
                      57.8
                     6,027.
                      1.24    R
                    391.30
    ....................
                      4.84 % CO2
                     16.85 % O2
                     27.60   C
                    703.00   P
                     77.62    V
                     30.10   T
```

APPENDIX E

PHOTOGRAPH OF WEIGHT BELT AND STAIRS
USED FOR STAIR RUN TESTS

APPENDIX F

Sample Percent Body Fat Calculation

MEASUREMENTS: SUBJECT: ____________

(1) Wt. in air ________ lbs.

(2) Vital capacity (v.c.) ________ li x 61.02 = ________ cu.in.

(3) Residual Volume 25% (♀) or 30% (♂) V.C. = ________ cu.in.

(4) Vol. Gastro-intestinal track = 7.01 cu.in.

(5) Wt. in water (full inspiration) = ________ lbs. - (belt wt.) ________

= ____________

(must be negative)

CALCULATIONS:

(6) Total Body Air (T.B.A.) = V.C. ________ cu.in.

+ R.V. ________ cu.in.

+ VGI ________ cu.in.

= ________ x .0362 = ________ lbs.

(7) True wt. in water = weight in water (from 5 above) ________ lbs.

+ total body air (from 6 above) ________ lbs.

= ________ lbs.

(8) Body Volume = wt in air (1) ________ - true wt. in water (7) ________

= ________

(9) Body Density = wt. in air (1) ________ / body vol. (8) ________ x ________ Density of H_2O

(10) % Fat = $\left[\frac{4.570}{\text{Body Density}} - 4.142\right] \times 100$

= ________ %

(11) Lbs. Fat = ________ (%fat) x ________ (wt.) = ____________

(12) Lbs. fat free wt. = ________ (wt.) - ______ (lbs. fat (11)

= ________

APPENDIX G

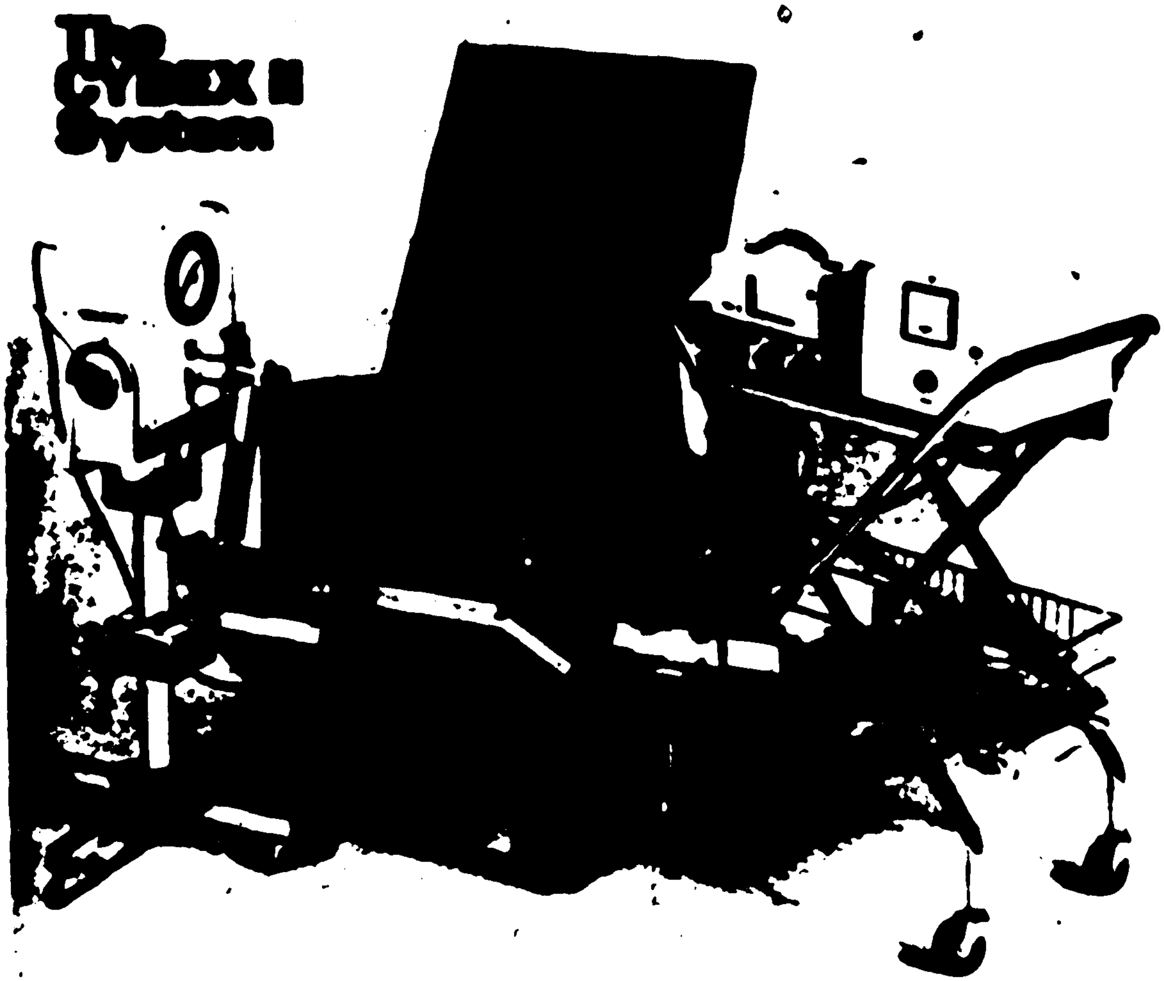

The
CYBEX II
System

Figure 1

The Cybex II Isokinetic System

Sample Cyb[illegible]lculation

30 degrees per second

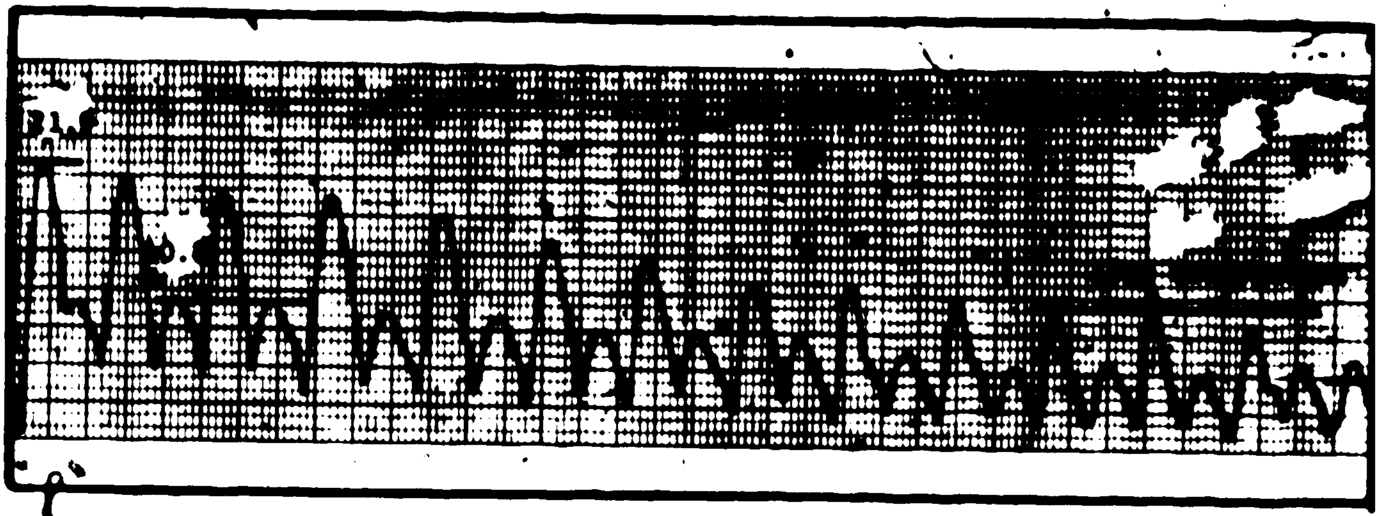


chart speed = 4 sec/cm or 4 sec/10 units
1 unit = 12 ft·lbs
max. quadriceps torque = 21.9 units = 21.9 x 12 = 262.8 ft·lbs.
max. hamstrings torque = 10.8 units = 10.8 x 12 = 129.6 ft·lbs.
number of contractions to 50% of max. torque for quadriceps = 12
fatigue slope is calculated from the regression line of all 12 contractions.

180 degrees per second

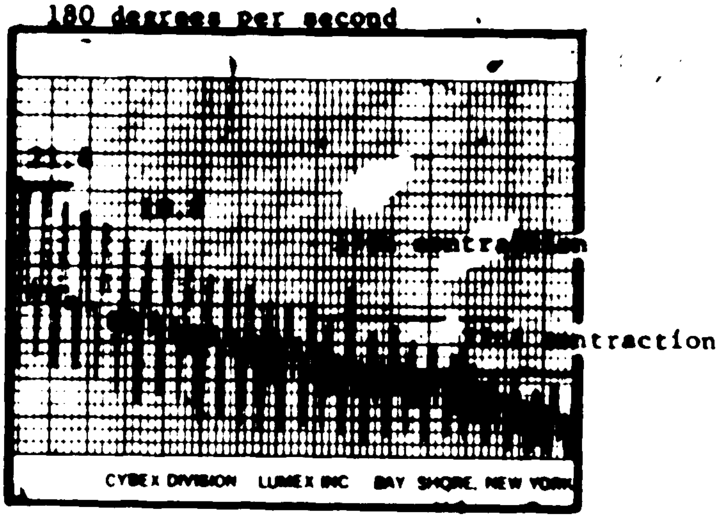


chart speed = 4 sec/cm or 4 sec/10 units
1 unit = 6 ft·lbs
max. quadriceps torque = 21.4 units = 21.4 x 6 = 128.4 ft·lbs.
max. hamstrings torque = 10.8 units = 10.8 x 6 = 64.8 ft·lbs.
number of contractions to 50% of max. torque for quadriceps = 17
number of contractions to 50% of max. torque for hamstrings = 22
fatigue slope is calculated from the regression line of all contractions to 50% of max. torque.

APPENDIX H

Myosin ATPase Histochemical Procedure

A. Solutions

1. 10.4 pre-incubation medium

   0.1M 2-amino-2-methyl-1 proponal

   18mM $CaCl_2$

   mix into appropriate volume of H_2O and adjust pH to 10.4

2. 4.65 pre-incubation medium

   0.5M sodium acetate $.3H_2O$

   0.5M KCl

   mix into appropriate volume of H_2O and adjust pH to 4.65 with glacial acetic acid.

3. 9.4 incubation medium (made fresh)

   0.1M 2-amino-2-methyl-1-propanol

   18mM $CaCl_2$

   2.7mM ATP

   mix into appropriate volume H_2O and adjust pH to 9.4

B. Pre-incubation Procedures.

i) Alkali

1. Rinse dried sections in 0.1M Tris-HCl containing 18mM $CaCl_2$ at pH 7.8 twice for 30 sec. each. Blot off excess solution on a paper towel.
2. Incubate in 10.4 medium for 15 minutes at room temperature.
3. Rinse twice more in 0.1M Tris-HCl with 18mM $CaCl_2$ at pH 7.8 but this time for 1 minute each and with agitation.

(ii) Acid

1. Incubate in 4.65 medium for 1 minute at room temperature.
2. Wash twice in 9.4 incubation medium without ATP for 30 sec. each.

C. Incubation and Staining Procedures.

The following steps are identical for the alkali and acid stains and are carried out at room temperature unless otherwise stated.

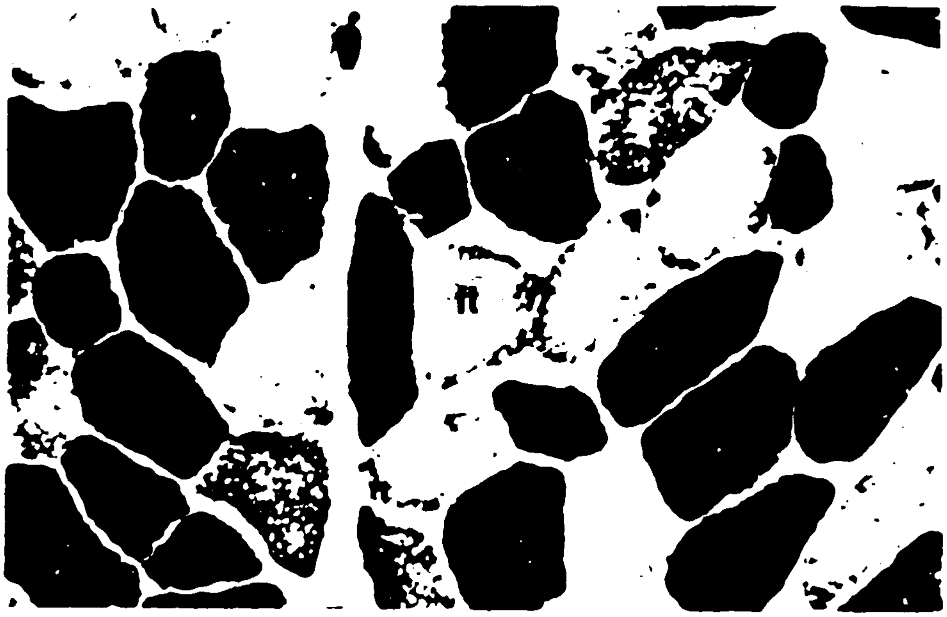
1. Incubate for 30 min. in 9.4 incubation medium in water bath at 37°C.
2. Wash in 4 - 30 sec. changes of 0.07M $CaCl_2$.

3. Place in 2% cobalt chloride twice for 1.5 min. each.
4. Rinse 4 x 30 sec. in 0.1M 2-amino-2-methyl-1-proponal at pH 9.4.
5. Place in 1% ammonium sulfide for 2 min.
6. Rinse in cold running tap water 3-5 min.
7. Blot on paper towel and dehydrate in two changes of acetone of 3 min. each.
8. Blot on paper towel and clear in two changes of xylene of 3 min. each.
9. Mount in diatex.

PHOTOMICROGRAPH OF VASTUS LATERALIS
MUSCLE STAINED FOR MYOSIN ATPase
(pH 9.4) MAGNIFICATION X 120

PHOTOMICROGRAPH OF VASTUS LATERALIS
MUSCLE STAINED FOR MYOSIN ATPase
(pH 4.65) MAGNIFICATION X 120

st


ft

APPENDIX I

Biuret Protein Determination

Reagent Mixture

1. 1.5 g $CuSO4 \cdot 5H_2O$
   6.0 g $NaKC_4H_4O_6 \cdot 4H_2O$
   mix in 500 ml H_2O
2. While stirring add 300 ml of 10% NaOH (30g/300ml H_2O)
3. Adjust final volume to 1000 ml.

Procedure

1. Add .05 ml. muscle homogenate to 2.5 ml. of reagent mixture and mix.
2. Make a blank using 0.5 ml. of homogenate buffer in 2.5 ml. reagent mixture.
3. Let stand at room temperature for 10 min.
4. Read the O.D. at 540 nm. on spectrophotometer.

Table 15. Protein Determinations from Vastus Lateralis Muscle of Football Players.

Subject No.	Protein mg x ml	Protein Content mg x gram wet wt.	Subject No.	Protein mg x ml	Protein Content mg x gram wet wt.
2	.186	99.6	26	.353	211.8
5	.404	378.6	28	.513	213.8
7	.263	234.4	29	.340	92.7
9	.397	67.3	30	.301	70.5
10	.442	159.7	31	.180	53.5
11	.224	47.7	32	.647	218.1
12	.026	65.0	33	.308	100.4
13	.782	85.7	34	.718	151.7
14	.276	104.8	36	.160	129.7
17	.404	82.5	37	.186	136.1
18	.282	105.7	38	.122	43.1
20	.070	104.9	40	.609	88.7
21	1.026	188.8	41	.769	120.8
23	.500	327.7	42	.224	113.9
24	.506	143.3	43	.154	98.3
25	.096	160.0	44	.686	58.8

APPENDIX J

HOMOGENIZATION PROCEDURE

Buffer = 0.1 M Tris at (6.05g/500 ml.) pH 7.5 - stored in fridge

1. Remove blood and connective tissue from sample while thawing in ice cold Tris buffer.
2. Blot sample and weigh on Mettler to nearest tenth of a milligram.
3. Place sample in glass homogenizer with 0.5 ml. buffer. Place homogenizer in an ice water bath. Grind three times for 3-4 seconds in 30 sec. intervals. Add another 0.5 ml. of buffer and grind twice more. Pour off into test tube. Add another 2 ml. buffer to homogenizer, swish around also cleaning pestle and pour into test tube thus diluting sample in 3 ml. of buffer.
4. Do protein (Biuret) determination on Spec at 540 mm. 0.5 ml. homogenate in 2.5 ml. reagent; mix and read after 10 min. incubation at room temperature.
5. Do enzyme determinations in this order:
   (a) SDH.
   (b) LDH.
   (c) CPK.
   (d) ATPase.

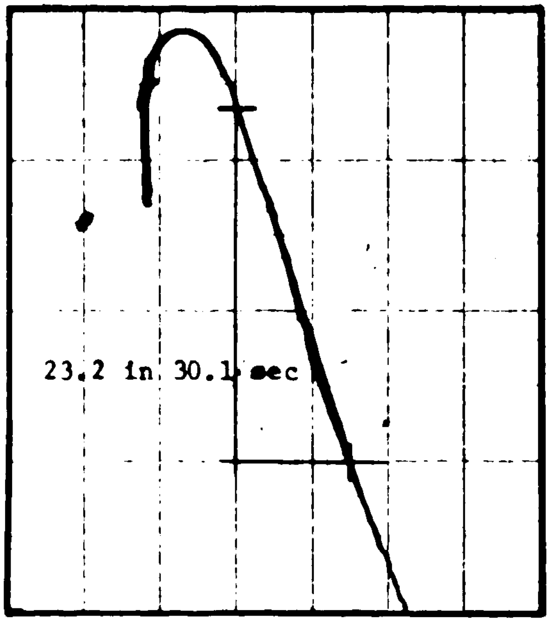
Lactate Dehydrogenase Biochemical Procedure

		Initial Concentration	Final Concentration
Forward Reaction.			
1.	2 ml Tris buffer (3.633 g/100 ml H_2O) pH 8.2	0.3M	0.2M
2.	1 ml pyruvate (4 mg/10 ml H_2O)	3mM	1mM
3.	2 ul NADH (10 mg /ml H_2O and 1 ul of 2-mercapoethanol)	14mM	9.2uM
4.	Incubate 5 min. at 30°C.		
5.	Add 25 ul of muscle homogenate and record reaction.		
	3027 ul = final volume.		
Backward Reaction			
1.	1 ml Tris buffer (3.633 g/100 ml H_2O) pH 8.2	0.3M	0.1M
2.	2 ml lactic acid (54 mg) } mixture in 20ml H_2O	30mM	20mM
	NAD (23 mg) }	1.5mM	1mM
3.	Incubate 5 min. at 30°C.		
4.	Add 25 ul muscle homogenate and record reaction.		
	3025 = final volume		

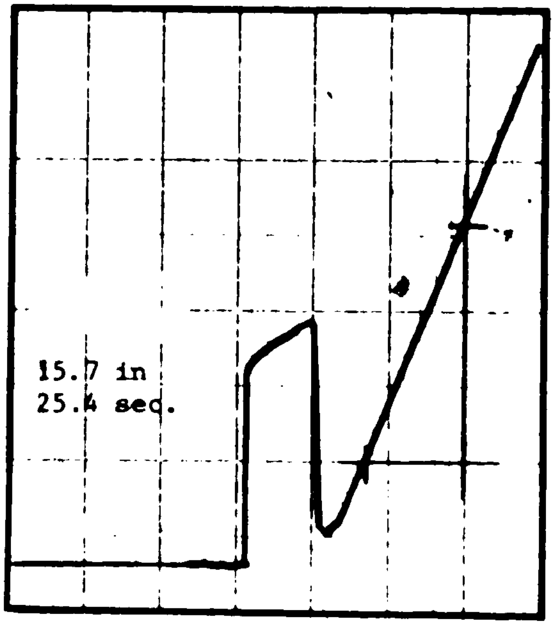
$$\text{Pyruvate} + \text{NADH} \xrightleftharpoons{\text{LDH}} \text{lactate} + \text{NAD}$$

Sample LDH Calculation

Forward Reaction



Backward Reaction



Paper speed = 20 sec/cm.

Sample size = 25 ul

Rate = 46.25 units/min.

Paper speed = 20 sec/cm.

Sample size = 25 ul

Rate = 37.09 units/min.

Final volume	3027 ul	3025 ul
Volume muscle homogenate added	25 ul	25 ul
size of sample and dilution	3mg/3ml	10.6 mg/3ml
standard 1 Δ F	0.00007 µmoles/ml	0.00007 µmoles/ml
Δ F rate	46.5 / min.	37.09 / min.
concentration of muscle tissue in final volume	0.0083 mg/ml.	0.029 mg/ml.

To convert above to µmoles x g^{-1} x $min.^{-1}$ follow these steps:

(1) divide 1000 by mg/ml of final volume muscle concentration.
(2) multiply value in (1) by ΔF rate
(3) multiply value in (2) by 0.00007

1000 ÷ 0.0083 = 120481.9
120481.9 x 46.25 = 5572287.9
5572287.9 x 0.00007 = 390.1

1000 ÷ 0.029 = 34482.8
34482.8 x 37.09 = 1278967.1
1278967.1 x 0.00007= 89.5

Succinate Dehydrogenase Biochemical Procedure

		Initial Concentration	Final Concentration
1.	.02 ml of muscle homogenate.		
2.	0.75 potassium phosphate buffer (6.846g) with .05% BSA (50mg) in 100 ml H_2O at pH 7.7.	.3M	.2M
3.	Let stand 5 min. at room temperature.		
4.	Add 10 ul phenazine methosulphate - PMS 14 mg/ml	45.6mM	.42mM
5.	Add 140 ul Succinic Acid Disodium Salt (1.6 g/10ml)	1M	.13M
6.	Incubate exactly 30 min. in dark water bath at 38°C.		
7.	Stop the reaction with 225 ul of 1M NaOH		
8.	Add 500 ul of stock bromobenzene and mix.		
9.	1825 ul Total Volume.		
10.	Centrifuge at 2000g. for 5 min.		
11.	Add 500 ul supernatant to 2.5 ml of fresh hydrazine buffer (1.3g) in 100ml H_2O pH 9.0	.1M	.083M
	with 2 mM EDTA (74.5 mg)	2mM	1.67mM
	and 0.4 mM NAD (27.6 mg)	0.4mM	0.33mM
12.	Read blank fluorescence.		
13.	Add 5 ul Fumerase - 0.25 ug/ml.		
14.	Add 75 ul malic dehydrogenase - 5 ug/ml.		

Allow reaction to run to completion (approximately 2 hours) and read fluorescence again

$$\text{Succinate} + \text{FAD} \xrightleftharpoons{\text{SDH}} \text{Fumerate} + \text{FADH}_2$$

$$\text{Fumerate} + H_2O \xrightleftharpoons{\text{fumerase}} \text{Malate}$$

$$\text{Malate} + \text{NAD} \xrightleftharpoons{\text{MDH}} \text{Oxaloacetate} + \text{NADH} + H^+$$

Sample SDH Calculation

	Blank	Subject 1
Reading at end of reaction	38.0	99.0
Reading before enzyme added	22.0	24.0
Difference	16.0	75.0

ΔF due to SDH = 75 - 16 = 59 units.
mg tissue for subject 1 = 5.0 mg
homogenate dilution = 5 mg / 3 ml
= 1.67 mg / ml.

Total volume 1st reaction mixture = 1825 ul
Quantity of muscle sample in 1st reaction mixture = 1.67 x 0.2
= 0.33 mg.

concentration of muscle sample in 1st reaction mixture = 0.33 mg / 1.825 ml
= 0.183 mg / ml.

Final reaction mixture volume = 3080 ul.
Quantity of muscle sample in this volume = 500 ul of 1st mixture
= 0.183 mg x 0.5
= 0.091 mg tissue

concentration of muscle sample in final mixture = 0.091 mg in 3.08 ml
= 0.03 mg / ml.

1 ΔF unit (from spectrophotometer standard) = 0.0001 umoles/ml.
Time of SDH reaction = 30 min.

0.03 mg tissue per ml. caused ΔF of 59 units over 30 min. since want final value in μmoles x g^{-1} x $min.^{-1}$ follow these steps:

(1) convert to grams by dividing 1000 by 0.03 mg = 33,333.3
(2) convert to min. by dividing 59 by 30 = 1.97 units/min.
(3) convert to μmoles x min^{-1} by multiplying 0.0001 by 1.97 = .0002 μmoles/min.
(4) convert to μmoles x g^{-1} x min^{-1} by multiplying 0.0002 by 33,333.3 to get final activity of 6.56 μmoles x g^{-1} x min^{-1}.

Creatine Phosphokinase Biochemical Procedure

		Initial Concentration	Final Concentration
1.	2.5 ml. 0.1M Tris (6.05 g/500 ml H_2O)	0.1M	0.089M
2.	0.1 ml phosphocreatine (76.5 mg/ml H_2O)	300mM	10mM
3.	0.1 ml ADP (25.6 mg/ml H_2O)	60mM	2mM
4.	0.1 ml Glucose (1.8g/2ml H_2O)	5 M	167mM
5.	0.1 ml NADP+ (23 mg/ml H_2O)	30mM	1mM
6.	0.1 ml Sodium Fluoride (31.5 mg/ml H_2O)	750mM	25mM
7.	5 ul Hexokinase - HK (0.6 I.U./ml)		
8.	5 ul glucose - 6- phosphate dehydrogenase - G6P-DH (0.3 I.U./ml)		
9.	30 ul $MgCl_2$ (6.1g/100 ml H_2O)	300mM	3mM
10.	Incubate 7 min. at 30°C.		
11.	Add 25 ul of muscle homogenate, mix and follow the reaction.		

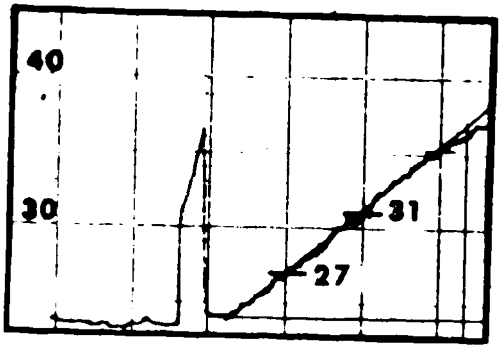
Final volume = 3065 ul

$$\text{Phosphocreatine} + \text{ADP} \xrightleftharpoons{\text{CPK}} \text{ATP} + \text{creatine}$$

$$\text{Glucose} + \text{ATP} \xrightarrow{\text{HK}} \text{Glucose 6-Phosphate} + \text{ADP} + H^+$$

$$\text{Glucose-6-phosphate} + \text{NADP}^+ \xrightleftharpoons{\text{G6P-DH}} \text{6-phosphogluconate} + \text{NADPH} + H^+$$

Sample CPK Calculation



paper speed = 60 sec/cm.
sample size = 25 ul
reading 1 = 27
reading 2 = 31
time = 1 min.

O.D. for reading 2 = .269
O.D. for reading 1 = .141
Δ OD .128 / min.

mg. of tissue = 8.7
homogenate dilution = 8.7 mg/ 3 ml.
= 2.9 mg/ml.
Final volume = 3065 ul
volume of muscle homogenate added = 25 ul
concentration of muscle tissue in final volume = 0.024 mg/ml.

To convert above data to μmoles x g^{-1} x min.^{-1} follow these steps:

(1) convert Δ OD/min to μmoles/ml/min = 0.128 ÷ 6.27
= 0.02058 μmoles/ml/min.

(2) get conversion factor from mg/ml to grams by dividing mg/ml of muscle in final volume into 1000 = 1000 ÷ 0.024
= 41,666.7

(3) multiply value (1) by value (2) (ml. cancel each other)

0.02058 x 41,666.7 = 857.5 μmoles x g^{-1} x min.^{-1}.

Myofibrillar ATPase Biochemical Procedure

		Initial Concentration	Final Concentration
1.	2.5 ml 0.1M Tris buffer (6.05g/500ml H_2o) at pH 7.5	0.1M	0.089M
2.	100 ul phosphoenol pyruvate - PEP (20 mg/ml H_2O)	85mM	3mM
3.	50 ul ATP (28 mg / .5 ml H_2O)	102mM	1.8mM
4.	30 ul $MgCl_2$ (6.1 g/100 ml H_2O)	.3M	3.2mM
5.	5 ul pyruvate kinase - PK 0.5 mg/ml		
6.	5 ul lactate dehydrogenase - LDH 0.1 mg/ml		
7.	15 ul. NADH (10 mg in 1 ml. of H_2O and 1 ul of 2 - mercaptoethanol)	14mM	75uM
8.	Incubate 20 min. at 30°C.		
9.	Add 200 ul of muscle homogenate, mix and follow reaction.		

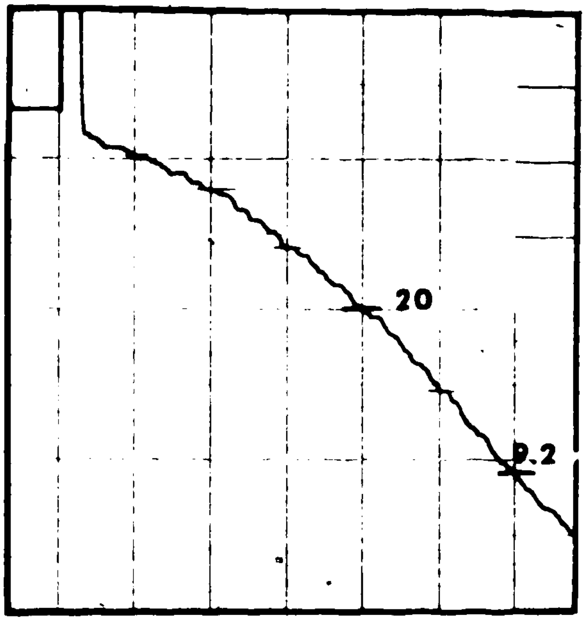
Final volume = 2905 ul

$$\text{ATP} + H_2O \xrightleftharpoons{\text{ATPase}} \text{ADP} + P_i + H^+$$

$$\text{PEP} + \text{ADP} + H^+ \xrightarrow{\text{PK}} \text{Pyruvate} + \text{ATP}$$

$$\text{Pyruvate} + \text{NADH} \xrightleftharpoons{\text{LDH}} \text{Lactate} + \text{NAD}$$

Sample Myofibrillar ATPase Calculation



paper speed = 60 sec/cm.
sample size = 200 ul.
reading 1 = 20.0
reading 2 = 9.2
time = 2 min.

OD for reading 1 = 0.0457
OD for reading 2 = 0.0080
Δ OD = 0.0377

OD/min. = 0.01885

mg of tissue = 10.6
homogenate dilution = 10.6 mg/3 ml
= 3.53 mg/ml.

Final volume = 2905 ul
volume of muscle homogenate added = 200 ul
concentration of muscle tissue in final volume = 0.243 mg/ml.

To convert above data to µmoles x g^{-1} x $min.^{-1}$ follow these steps:

(1) convert Δ OD/min to µmoles/ml/min = 0.01885 ÷ 6.27
= 0.00303 µmoles/ml/min.

(2) get conversion factor from mg/ml of muscle in final volume to grams by dividing mg/ml concentration into 1000 = 1000 ÷ 0.243
= 4115.2

(3) multiply value (1) by value (2) (ml.cancel each other)
0.00303 x 4115.2 = 12.5 µmoles x g^{-1} x $min.^{-1}$.

APPENDIX K

Table 16. Pre-Test Means, Sample Size and Standard Error of the Means for All Twenty-Nine Variables for All Subjects.

	VO_2 max ml x kg^{-1} x min^{-1}	% Fat	Agility Run s	10Yd.Sprint s	40Yd.Sprint s	Two Stairs s	Freestyle s	Two Stairs With Weight s	Trials	Fatigue Slope All Trials	Fatigue Slope 1st 13 Trials	% FT	LDH Py→La	LDH La→Py	SDH	CPK	ATPase
													umoles x g^{-1} x min^{-1}				
n	45	43	23	26	31	37	37	36	36	36	36	32	32	32	33	30	32'
Mean	57.1	10.65	11.45	1.71	5.02	2.40	2.15	2.73	27.9	.039	.038	47.8	134.7	77.0	2.64	910.1	13.0
SEM	.82	.63	.11	.02	.04	.02	.03	.03	1.5	.004	.004	1.7	8.7	4.7	.21	66.5	.9

	Cybex 30°/s						Cybex 180°/s					
	Quadriceps			Hamstrings			Quadriceps			Hamstrings		
	Max.* Torque	Trials	Fatigue Slope	Max.* Torque	Trials	Fatigue Slope	Max.* Torque	Trials	Fatigue Slope	Max.* Torque	Trials	Fatigue Slope
n	44	44	44	44	44	44	44	44	44	44	44	44
Mean	219.2	19.2	.613	119	20.2	.328	101.1	21.6	.461	73.6	23.6	.308
SEM	8.2	.94	.036	3.7	1.2	.026	3.1	.5	.021	2.4	.7	.014

* Max. Torque in foot/pounds.

Table 17.1 - 17.8 Pre-Test Means, Group Sizes and Standard Error of the Means for All Twenty-Nine Variables for Football Players Grouped into Eight Positions.

17.1 **Wide Receivers**

Subjects														μmoles x g^{-1} x min^{-1}				
Initials	No.	$VO_{2\,max}$ ml x kg^{-1} x min^{-1}	% Body Fat	Agility Run Sec.	10Yd. Sprint Sec.	40Yd. Sprint Sec.	Two Stairs Sec.	Freestyle Sec.	Two Stairs With Weight Sec.	Trials	Fatigue Slope of All Trials	Fatigue Slope 1st 13 Trials	% FT	LDH Py→La	LDH La→Py	SDH	CPK	ATPase
LM	1	56.1	02.83	00000	1.64	4.91	2.45	2.06	2.75	24	.021	.012	0000	00000	00000	0000	000000	0000
RL	2	59.5	06.72	10.75	1.68	4.80	2.32	2.03	2.58	36	.028	.016	46.4	107.4	069.5	2.46	0878.0	15.4
JT	3	53.5	04.19	00000	0000	4.86	2.17	1.85	2.53	26	.020	.065	0000	00000	00000	0000	000000	0000
JP	4	61.9	09.44	10.67	1.60	4.69	0000	0000	0000	00	0000	0000	0000	00000	00000	0000	000000	0000
Mean		57.8	5.80	10.71	1.64	4.82	2.31	1.98	2.62	29	.023	.031	-	-	-	-	-	-
n		4	4	2	3	4	3	3	3	3	3	3	-	-	-	-	-	-
SEM		1.9	1.5	.04	.02	.05	.08	.06	.06	4	.003	.017	-	-	-	-	-	-

Subject	Cybex 30°/Sec.						Cybex 180°/Sec.					
	Quadriceps			Hamstrings			Quadriceps			Hamstrings		
No.	Max.* Torque	Trials	Fatigue Slope	Max.* Torque	Trials	Fatigue Slope	Max.* Torque	Trials	Fatigue Slope	Max.* Torque	Trials	Fatigue Slope
1	165	18	0.308	101	22	0.215	092	21	0.453	062	32	0.186
2	198	25	0.328	102	26	0.188	108	20	0.517	079	20	0.399
3	182	16	0.433	100	14	0.335	103	20	0.492	069	23	0.305
4	270	24	0.515	150	23	0.267	096	24	0.387	084	25	0.307
Mean	204	21	0.396	113	21	0.251	100	21	0.462	74	25	0.299
n	4	4	4	4	4	4	4	4	4	4	4	4
SEM	23	2	0.048	12	3	0.032	4	1	0.028	5	3	0.044

* Max. Torque in foot/pounds.

17.2 Inside Receivers

Subjects Initials	No.	VO_2 max $kg^{-1}x$ min^{-1}	% Body Fat	Agility Run Sec.	10Yd. Sprint Sec.	40Yd. Sprint Sec.	Two Stairs Sec.	Freestyle Sec.	Two Stairs With Weight Sec.	Trials	Fatigue Slope of All Trials	Fatigue Slope 1st 13 Trials	% FT	LDH Py→La	LDH La→Py	SDH	CPK	ATPase
														umoles x g^{-1} x min^{-1}				
LB	5	63.3	06.13	10.53	1.63	4.80	2.21	1.77	2.56	25	.023	.022	43.7	261.3	146.9	3.64	1151.7	14.6
RD	6	54.1	08.57	00000	0000	4.85	0000	0000	0000	00	0000	0000	45.5	00000	00000	2.93	000000	0000
DG	7	55.8	07.50	00000	1.76	5.00	2.29	2.04	2.60	18	.069	.063	46.0	119.1	060.6	2.04	0685.5	15.6
JW	8	53.0	16.25	11.35	0000	5.37	2.54	2.07	2.97	24	.040	.026	0000	00000	00000	0000	000000	0000
Mean		56.6	9.61	10.94	1.70	5.00	2.35	1.96	2.71	22	.044	.037	45.1	190.2	103.8	2.87	918.6	15.1
n		4	4	2	2	4	3	3	3	3	3	3	3	2	2	3	2	2
SEM		2.3	2.3	.41	.06	.13	.10	.10	.13	2	.014	.013	.60	49.5	27.5	.33	135.4	.31

Subjects No.	Cybex 30°/Sec.						Cybex 180°/Sec.					
	Quadriceps			Hamstrings			Quadriceps			Hamstrings		
	Max.* Torque	Trials	Fatigue Slope	Max.* Torque	Trials	Fatigue Slope	Max.* Torque	Trials	Fatigue Slope	Max.* Torque	Trials	Fatigue Slope
5	228	25	0.382	132	14	0.509	110	21	0.525	088	17	0.557
6	000	00	00000	000	00	00000	000	00	00000	000	00	00000
7	207	17	0.663	117	13	0.468	117	20	0.581	080	22	0.349
8	208	17	0.661	114	27	0.177	097	27	0.346	068	29	0.215
Mean	214	20	0.569	121	18	0.385	108	23	0.484	79	23	0.374
n	3	3	3	3	3	3	3	3	3	3	3	3
SEM	7	3	0.093	6	5	0.105	6	2	0.105	6	4	0.100

* Max. Torque in foot/pounds.

17.3 Q[illegible]terbacks.

Subjects Initials	No.	VO$_2$ max g^{-1} x min^{-1}	% Body Fat	Agility Run Sec.	10Yd. Sprint Sec.	40Yd. Sprint Sec.	Two Stair Sec	Freestyle Sec.	Two Stairs With Weight Sec.	Trials	Fatigue Slope of All Trials	Fatigue Slope 1st 13 Trials	% FT	umoles x g^{-1} x min^{-1} LDH Py→La	LDH La→Py	SDH	CPK	ATPase
DM	9	52.4	09.33	11.82	0000	4.91	2.35	2.20	2.54	34	.039	.024	51.8	099.7	059.2	1.70	0609.3	12.5
BE	10	67.1	09.94	10.77	1.73	5.14	2.49	1.97	2.72	36	.008	.014	51.9	204.9	109.7	3.69	1096.8	19.6
Mean		59.8	9.64	11.30	-	5.03	2.42	2.09	2.63	35	.023	.019	51.9	152.3	84.5	2.70	853.1	16.1
n		2	2	2	-	2	2	2	2	2	2	2	2	2	2	2	2	2
SEM		7.4	.31	.53	-	.11	.07	.11	.09	1	.016	.005	.05	53.1	25.5	1	246.2	3.6

Subject	Cybex 30°/Sec.						Cybex 180°/Sec.					
	Quadriceps			Hamstrings			Quadriceps			Hamstrings		
No.	Max.* Torque	Trials	Fatigue Slope	Max.* Torque	Trials	Fatigue Slope	Max.* Torque	Trials	Fatigue Slope	Max.* Torque	Trials	Fatigue Slope
9	170	17	0.478	121	18	0.316	094	22	0.420	080	24	0.303
10	198	29	0.323	105	32	0.130	089	27	0.302	065	24	0.275
Mean	184	23	0.401	113	25	0.223	92	26	0.361	73	24	0.289
n	2	2	2	2	2	2	2	2	2	2	2	2
SEM	14	6	0.078	8	7	0.094	3	3	0.060	8	0	0.014

* Max. Torque in foot/pounds.

17.4 Running Backs

Subjects Initials	No.	VO_2 max g^{-1} x min^{-1}	% Body Fat	Agility Run Sec.	10Yd. Sprint Sec.	40Yd. Sprint Sec.	Two Stair Sec	Freestyle Sec.	Two Stairs With Weight Sec.	Trials	Fatigue Slope of All Trials	Fatigue Slope 1st 13 Trials	% FT	umoles x g^{-1} x min^{-1} LDH Py→La	LDH La→Py	SDH	CPK	ATPase
PB	11	53.7	00000	11.68	0000	0000	2.55	2.39	2.93	25	.024	.031	32.0	095.6	055.4	1.97	0652.9	12.2
KO	12	60.4	10.31	10.95	0000	0000	0000	0000	0000	00	0000	0000	31.9	154.2	083.5	1.33	1145.9	07.1
SK	13	64.6	05.07	11.57	0000	4.60	2.16	1.98	2.47	43	.009	.042	72.8	205.4	109.5	2.45	2193.6	19.1
SKr	14	60.9	14.17	00000	0000	0000	2.38	2.29	2.55	14	.054	.060	52.0	088.9	046.2	1.94	0914.0	11.4
Mean		59.9	9.85	11.40	0000	-	2.36	2.22	2.65	27	.031	.044	47.2	136.0	73.7	1.92	1220.6	12.5
n		4	3	3	0000	-	3	3	3	3	3	3	4	4	4	4	4	4
SEM		2.3	2.6	.23	0000	-	.11	.12	.15	8	.015	.009	9.6	27.4	14.4	.23	337.7	2.5

Subject	Cybex 30°/Sec.						Cybex 180°/Sec.					
	Quadriceps			Hamstrings			Quadriceps			Hamstrings		
No.	Max.* Torque	Trials	Fatigue Slope	Max.* Torque	Trials	Fatigue Slope	Max.* Torque	Trials	Fatigue Slope	Max.* Torque	Trials	Fatigue Slope
11	207	13	0.727	153	13	0.486	092	23	0.388	077	21	0.347
12	168	15	0.535	101	12	0.365	083	16	0.506	077	14	0.439
13	173	24	0.336	122	22	0.239	085	20	0.358	073	26	0.275
14	180	11	0.806	097	25	0.165	093	20	0.209	060	00	0.199
Mean	182	16	0.601	118	18	0.313	88	20	0.366	67	20	0.315
n	4	4	4	4	4	4	4	4	4	4	4	4
SEM	9	3.	0.105	13	3	0.071	3	1	0.061	5	2	0.051

* Max. Torque in foot/pounds.

17.5 Defensive Backs

Subject Initials	No.	VO_2 max $ml \times kg^{-1} \times min^{-1}$	% Body Fat	Agility Run Sec.	10Yd. Sprint Sec	40Yd. Sprint Sec	Two Stairs Sec.	Freestyle Sec.	Two Stairs With Weight Sec.	Trials	Fatigue Slope of All Trials	Fatigue Slope 1st 13 Trials	% FT	umoles x g^{-1} x min^{-1} LDH Py→La	LDH La→Py	SDH	CPK	ATPase
NP	15	64.0	09.07	00000	1.61	4.70	0000	0000	0000	00	0000	0000	0000	00000	00000	0000	000000	0000
MH	16	54.7	07.85	00000	1.59	4.75	2.24	1.96	2.63	47	.022	.036	0000	00000	00000	0000	000000	0000
GP	17	62.0	13.13	00000	0000	0000	2.39	2.16	2.61	40	.016	.032	50.5	091.7	048.3	4.30	0683.0	14.7
GS	18	66.2	13.51	00000	1.75	5.09	2.44	2.25	2.81	41	.013	.022	51.4	121.8	062.3	1.66	0681.2	04.5
TB	19	56.1	13.96	12.52	1.74	5.07	2.39	2.17	2.75	25	.032	.040	0000	00000	00000	0000	000000	0000
BT	20	66.8	08.48	11.41	1.74	5.05	2.33	1.95	2.75	33	.024	.003	38.7	136.6	092.5	2.42	0920.9	10.4
PT	21	59.6	03.44	00000	0000	0000	2.25	1.95	2.39	25	.027	.036	56.1	136.[illegible]	058.0	5.25	000000	13.7
DC	22	50.8	08.81	00000	0000	0000	0000	0000	0000	00	0000	0000	0000	00000	00000	0000	000000	0000
TM	23	56.7	09.27	00000	0000	0000	2.29	2.31	2.75	33	.028	.010	0000	123.7	091.2	2.34	000000	17.9
WM	24	61.1	08.18	00000	0000	0000	2.41	1.89	2.67	17	.060	.059	61.1	156.5	088.9	3.55	1088.4	13.2
TC	25	69.5	06.78	11.26	1.78	5.21	2.59	2.34	2.61	35	.014	.018	41.2	221.3	116.7	3.22	0933.8	19.0
MC	26	63.6	04.47	00000	0000	0000	0000	0000	0000	00	0000	0000	56.1	240.7	134.4	6.73	0860.0	18.2
Mean		60.9	8.93	11.73	1.70	4.98	2.37	2.10	2.66	33	.026	.028	50.7	153.6	86.5	3.68	861.2	14.0
n		12	12	3	6	6	9	9	9	9	9	9	7	8	8	8	6	8
SEM		1.6	.96	.40	.03	.09	.04	.06	.04	3	.005	.006	3.1	18.2	10.5	.59	64.4	1.7

Subject	Cybex 30°/Sec.						Cybex 180°/Sec.					
	Quadriceps			Hamstrings			Quadriceps			Hamstrings		
No.	Max.* Torque	Trials	Fatigue Slope	Max.* Torque	Trials	Fatigue Slope	Max.* Torque	Trials	Fatigue Slope	Max.* Torque	Trials	Fatigue Slope
15	237	23	0.538	141	26	0.193	111	22	0.488	081	24	0.367
16	183	27	0.321	099	30	0.131	089	22	0.357	062	24	0.252
17	186	10	1.036	108	14	0.310	075	21	0.374	057	22	0.242
18	106	30	0.305	079	43	0.065	084	21	0.391	053	25	0.202
19	151	18	0.424	094	18	0.262	058	22	0.275	052	25	0.197
20	175	34	0.234	090	45	0.038	077	24	0.311	062	25	0.232
21	184	12	0.708	110	10	0.696	082	21	0.397	066	17	0.352
22	231	17	0.667	105	19	0.214	107	23	0.435	077	27	0.285
23	267	22	0.519	144	21	0.310	101	24	0.387	074	28	0.193
24	204	18	0.570	123	24	0.230	095	15	0.628	074	16	0.498
25	168	12	0.716	071	10	0.412	060	19	0.278	044	15	0.269
26	213	16	0.671	129	18	0.346	108	27	0.340	077	29	0.246
Mean	200	20	0.559	108	23	0.267	88	22	0.389	65	23	0.278
n	12	12	12	12	12	12	12	12	12	12	12	12
SEM	9.5	2.2	0.064	6.7	3.3	0.051	5.2	.84	0.028	3.4	1.4	0.026

* Max. Torque in foot/pounds.

17.6 Linebackers

Subjects Initials	No.	VO_2 max g^{-1} x min^{-1}	% Body Fat	Agility Run Sec.	10Yd. Sprint Sec.	40Yd. Sprint Sec.	Two Stair Sec.	Freestyle Sec.	Two Stairs With Weight Sec.	Trials	Fatigue Slope of All Trials	Fatigue Slope 1st 13 Trials	% FT	umoles x g^{-1} x min^{-1}				
														LDH Py→La	LDH La→Py	SDH	CPK	ATPase
TH	27	47.1	19.07	00000	1.70	5.25	2.50	2.36	2 91	15	.102	.083	0000	00000	00000	0000	000000	0000
DB	28	51.0	15.68	00000	0000	0000	2.42	2.18	0000	00	0000	0000	40.3	066.2	079.8	3.70	0798.2	16.7
DM	29	54.6	11.69	11.66	1.64	4.75	2.34	2.24	2.65	20	.059	.070	45.4	067.5	036.5	2.07	0565.0	11.0
NB	30	60.1	08.10	00000	0000	0000	0000	0000	0000	00	0000	0000	46.9	129.1	090.1	1.09	0910.0	05.8
RF	31	56.7	00000	00000	1.69	4.95	0000	0000	0000	00	0000	0000	61.2	098.2	056.6	1.95	0526.1	10.4
DZ	32	58.6	11.83	10.88	1.64	5.01	2.39	2.13	2.74	28	.018	.008	36.8	144.5	064.7	3.63	1924.2	27.8
Mean		54.7	13.27	11.27	1.67	4.99	2.41	2.23	2.77	21	.060	.054	46.1	101.1	64.5	2.49	942.9	14.3
n		6	5	2	4	4	4	4	3	3	3	3	5	5	5	5	5	5
SEM		2	1.9	.39	.02	.11	.04	.05	.08	4	.024	.023	4.2	15.8	9.3	.51	254.5	3.8

Subject	Cybex 30°/Sec.						Cybex 180°/Sec.					
	Quadriceps			Hamstrings			Quadriceps			Hamstrings		
No.	Max.* Torque	Trials	Fatigue Slope	Max.* Torque	Trials	Fatigue Slope	Max.* Torque	Trials	Fatigue Slope	Max.* Torque	Trials	Fatigue Slope
27	165	20	0.410	104	22	0.210	111	16	0.760	090	22	0.410
28	294	22	0.770	156	23	0.278	117	19	0.660	107	19	0.522
29	210	17	0.688	126	29	0.170	110	22	0.492	083	28	0.267
30	183	17	0.561	072	15	0.279	069	20	0.327	045	21	0.234
31	267	25	0.554	147	23	0.275	113	21	0.572	086	23	0.368
32	252	37	0.259	132	21	0.299	096	30	0.328	072	38	0.141
Mean	229	23	0.541	123	22	0.252	102	21	0.528	81	25	0.324
n	6	6	6	6	6	6	6	6	6	6	6	6
SEM	21	3	0.076	13	2	0.020	7	2	0.074	9	3	0.056

* Max. Torque in foot/pounds.

17.7 Defensive Lineman

Subjects Initials	No.	VO_2 max g^{-1} x min^{-1}	% Body Fat	Agility Run Sec.	10Yd. Sprint Sec.	40Yd. Sprint Sec.	Two Stair Sec.	Freestyle Sec.	Two Stairs With Weight Sec.	Trials	Fatigue Slope of All Trials	Fatigue Slope 1st 13 Trials	% FT	umoles x g^{-1} x min^{-1} LDH Py→La	LDH La→Py	SDH	CPK	ATPase
BH	33	59.3	12.21	12.52	1.81	5.42	2.48	2.29	2.80	22	.054	.034	33.6	165.8	101.8	2.17	0715.6	06.7
DW	34	47.1	14.44	00000	0000	0000	2.46	2.26	2.92	29	.039	.050	35.3	087.3	047.2	1.95	0747.2	09.5
LL	35	55.5	10.67	11.87	00000	0000	2.31	2.06	2.68	16	.079	.072	0000	00000	00000	0000	000000	0000
LD	36	50.9	14.60	00000	0000	0000	2.43	2.04	2.91	22	.041	.060	57.7	195.1	098.4	2.49	1036.1	14.3
Mean		53.2	12.98	12.20	-	-	2.42	2.16	2.83	22	.053	.054	42.4	149.4	82.5	2.20	832.9	10.2
n		4	4	2	-	-	4	4	4	4	4	4	3	3	3	3	3	3
SEM		2.7	0.9	.33	-	-	.04	.07	.06	3	.009	.008	7.8	32.2	17.7	.16	102.1	2.2

Subjects	Cybex 30°/Sec.						Cybex 180°/Sec.					
	Quadriceps			Hamstrings			Quadriceps			Hamstrings		
No.	Max.* Torque	Trials	Fatigue Slope	Max.* Torque	Trials	Fatigue Slope	Max.* Torque	Trials	Fatigue Slope	Max.* Torque	Trials	Fatigue Slope
33	360	18	1.118	174	15	0.636	135	20	0.716	092	26	0.328
34	243	17	0.750	162	18	0.526	137	22	0.608	119	29	0.394
35	318	13	0.830	156	13	0.544	137	24	0.588	098	27	0.321
36	223	12	0.930	130	11	0.595	096	20	0.435	072	26	0.267
Mean	286	15	0.971	156	14	0.575	126	22	0.587	95	27	0.328
n	4	4	4	4	4	4	4	4	4	4	4	4
SEM	32	1	0.080	9	1	0.025	10	1	0.059	10	1	0.026

* Max. Torque in foot/pounds.

17.8 Offensive Lineman

Subjects														μmoles x g^{-1} x min^{-1}				
Initials	No.	VO_2 max kg^{-1} x min^{-1}	% Body Fat	Agility Run Sec.	10Yd. Sprint Sec.	40Yd. Sprint Sec.	Two Stair Sec	Freestyle Sec.	Two Stairs With Weight Sec.	Trials	Fatigue Slope of All Trials	Fatigue Slope 1st 13 Trials	% FT	LDH Py→La	LDH La→Py	SDH	CPK	ATPase
RR	37	50.7	17.16	11.19	1.90	5.40	2.55	2.57	3.02	15	.080	.070	40.8	100.5	054.8	0.75	0547.0	03.7
LB	38	53.3	09.46	11.29	1.67	4.93	2.48	2.00	2.61	44	.017	.025	47.6	122.8	068.8	2.29	0605.0	12.2
KM	39	53.2	14.51	00000	1.67	5.05	2.51	2.32	2.63	30	.049	.012	0000	00000	00000	0000	000000	0000
MC	40	50.2	15.81	11.61	1.70	4.96	2.28	2.25	2.72	19	.041	.041	53.1	138.3	075.3	3.27	1180.9	17.4
JD	41	52.4	10.57	12.13	1.77	5.09	2.47	2.18	2.79	22	.051	.036	41.1	104.5	055.0	2.91	1050.1	15.5
RH	42	53.9	17.79	12.02	1.77	5.27	2.37	2.18	2.79	29	.032	.020	51.9	071.9	038.3	2.56	0583.0	13.6
JH	43	58.6	08.86	11.61	1.83	5.31	2.26	2.12	2.79	36	.030	.028	48.1	108.4	076.2	0.72	0761.0	03.8
DS	44	58.0	09.77	11.27	1.59	5.10	2.64	2.51	3.11	40	.018	.031	40.3	143.6	086.6	1.85	0846.0	09.8
PG	45	49.0	18.56	00000	1.77	5.32	2.59	2.38	2.97	14	.119	.112	0000	00000	00000	0000	000000	0000
Mean		53.3	13.54	11.59	1.74	5.16	2.47	2.28	2.81	28	.048	.042	49.0	112.9	65.0	2.05	799.0	10.9
n		9	9	7	9	9	9	9	9	9	9	9	7	7	7	7	7	7
SEM		1.1	1.3	.14	.03	.06	.04	.06	.06	3	.011	.010	2.7	9.3	6.2	.38	92.8	2.0

Subject	Cybex 30°/Sec.						Cybex 180°/Sec.					
	Quadriceps			Hamstrings			Quadriceps			Hamstrings		
No.	Max.* Torque	Trials	Fatigue Slope	Max.* Torque	Trials	Fatigue Slope	Max.* Torque	Trials	Fatigue Slope	Max.* Torque	Trials	Fatigue Slope
37	161	20	0.328	084	33	0.096	071	25	0.290	048	25	0.191
38	306	24	0.629	123	10	0.854	144	19	0.672	066	19	0.272
39	258	12	1.121	126	18	0.390	126	17	[illegible].685	076	23	0.319
40	282	15	0.991	132	20	0.261	114	25	[illegible].462	080	26	0.263
41	204	13	0.862	117	13	0.464	102	[illegible]	[illegible].673	072	20	0.391
42	219	12	1.076	090	10	0.431	102	[illegible]	0.435	063	20	0.323
43	360	27	0.750	153	22	0.349	153	[illegible]	0.616	098	20	0.493
44	297	18	0.70	129	19	0.241	096	26	0.275	063	27	0.214
45	187	17	0.446	116	16	0.455	110	21	0.511	086	26	0.335
Mean	253	18	0.768	119	18	0.394	113	21	0.513	72	23	0.312
n	9	9	9	9	9	9	9	9	9	9	9	9
SEM	22	2	0.091	7	2	0.070	8	1	0.054	5	1	0.031

*Max Torque in foot/pounds.

APPENDIX L

Table 18. Pearson Product Moment Correlation Matrix.

VARIABLE (Sample Size)		VO_2 max	% Fat	Agility Run	10Yd. Sprint	40Yd. Sprint	Two Stairs	Freestyle	Two Stairs Weighted	Stair Trials Weighted	Fatigue Slope-All Stairs	Fatigue Slope-1st 13 Stairs	Cybex 30° Quads-Max. Torque	Cybex 30° Quads-Trials	Cybex 30° Quads-Fatigue Slope
		1	2	3	4	5	6	7	8	9	10	11	12	13	14
VO_2max (45)	ROW 1	1.000	-0.513	-0.418	-0.093	-0.231	-0.168	-0.371	-0.343	0.429	-0.564	-0.497	-0.177	0.323	-0.256
% Fat (43)	ROW 2	-0.513	1.000	0.375	0.384	0.626	0.499	0.605	0.611	-0.371	0.547	0.370	0.062	-0.151	0.319
Agility Run (23)	ROW 3	-0.418	0.375	1.000	0.463	0.355	0.028	0.371	0.118	-0.309	0.405	0.351	0.131	-0.502	0.597
10Yd. Sprint (26)	ROW 4	-0.093	0.384	0.463	1.000	0.822	0.261	0.413	0.278	-0.356	0.001	0.001	-0.093	-0.204	0.193
40Yd. Sprint (31)	ROW 5	-0.231	0.626	0.355	0.822	1.000	0.713	0.619	0.732	-0.396	0.438	0.155	0.113	-0.231	0.327
Two Stairs (37)	ROW 6	-0.168	0.499	0.028	0.261	0.713	1.000	0.696	0.704	-0.119	0.001	0.000	0.052	-0.177	0.183
Freestyle (37)	ROW 7	-0.371	0.605	0.371	0.413	0.619	0.696	1.000	0.584	-0.143	0.336	0.112	0.074	-0.293	0.284
Two Stairs Weighted (36)	ROW 8	-0.343	0.611	0.118	0.278	0.732	0.704	0.584	1.000	-0.190	0.269	0.145	0.157	0.027	0.060
Stairs Trials Weighted (36)	ROW 9	0.429	-0.371	-0.309	-0.356	-0.395	-0.119	-0.143	-0.190	1.000	-0.766	-0.630	0.015	0.420	-0.191
Fatigue Slope-All-Stairs (36)	ROW 10	-0.564	0.547	0.405	0.001	0.439	0.003	0.336	0.269	-0.768	1.000	0.000	0.029	-0.309	0.135
Fatigue Slope-1st 13-Stairs (36)	ROW 11	-0.497	0.370	0.351	0.001	0.155	0.000	0.112	0.145	-0.630	0.000	1.000	-0.102	-0.369	0.058
Cybex 30° Quads.-Max. Torque (44	ROW 12	-0.177	0.062	0.131	-0.093	0.113	0.052	0.074	0.157	0.015	0.029	-0.102	1.000	0.069	0.492
Cybex 30° Quads.-Trials (44)	ROW 13	0.323	-0.151	-0.502	-0.204	-0.231	-0.177	-0.293	0.027	0.420	-0.309	-0.369	0.069	1.000	-0.695
Cybex 30° Quads-Fatigue Slope(44	ROW 14	-0.256	0.319	0.592	0.143	0.327	0.183	0.284	0.060	-0.191	0.135	0.056	0.492	-0.695	1.000
Cybex 30° Hams-Max Torque (44)	ROW 15	-0.235	0.051	0.164	-0.244	-0.140	-0.029	0.054	0.161	-0.133	0.123	0.055	0.786	0.042	0.356
Cybex 30° Hams-Trials (44)	ROW 16	0.266	0.124	-0.261	-0.015	-0.061	-0.005	-0.009	0.131	0.168	-0.074	-0.154	-0.259	0.682	-0.533
Cybex 30° Hams-Fatigue Slope(44)	ROW 17	-0.236	-0.075	0.260	0.113	0.134	0.026	-0.075	-0.152	-0.001	0.066	0.044	0.419	-0.367	0.490
Cybex 180°Quads-Max Torque (44)	ROW 18	-0.384	0.112	0.114	-0.051	0.047	-0.042	-0.013	0.052	-0.100	0.273	0.150	0.752	0.055	0.367
Cybex 180°Quads-Trials (44)	ROW 19	0.110	-0.011	-0.241	-0.096	0.104	0.025	0.132	0.317	0.144	-0.267	-0.272	0.227	0.380	-0.196
Cybex 180°Quads-Fatigue Slope(44	ROW 20	-0.430	0.154	0.271	0.074	0.081	0.009	-0.070	-0.021	-0.234	0.428	0.248	0.452	-0.070	0.316
Cybex 180°Hams-Max Torque (44)	ROW 21	-0.401	0.143	0.089	-0.153	-0.127	-0.125	-0.046	0.075	-0.260	0.373	0.291	0.595	0.073	0.222
Cybex 180°Hams-Trials (44)	ROW 22	-0.206	0.115	0.098	-0.265	-0.034	0.061	0.181	0.382	-0.045	0.017	-0.032	0.114	0.286	-0.179
Cybex 180°Hams-Fatigue Slope (44	ROW 23	-0.047	-0.048	-0.146	0.052	-0.071	-0.144	-0.281	-0.165	-0.175	0.001	0.000	0.271	-0.045	0.151
% FT (32)	ROW 24	0.093	-0.113	-0.018	0.253	-0.291	-0.412	-0.245	-0.342	0.010	0.081	0.366	-0.252	-0.035	-0.136
LDH Py→La (32)	ROW 25	0.573	-0.545	-0.452	-0.166	-0.130	-0.139	-0.458	-0.194	0.138	-0.376	-0.224	-0.074	0.130	-0.232
LDH La→Py (32)	ROW 26	0.538	-0.521	-0.402	-0.126	-0.087	-0.104	-0.421	-0.103	0.206	-0.367	-0.325	0.094	0.216	-0.236
SDH (33)	ROW 27	0.266	-0.340	-0.269	-0.467	-0.322	-0.261	-0.535	-0.507	0.001	-0.342	-0.237	-0.049	-0.114	0.122
CPK (30)	ROW 28	0.308	-0.314	-0.296	-0.358	-0.416	-0.412	-0.429	-0.285	0.121	-0.357	-0.174	-0.091	0.319	-0.336
ATPase (32)	ROW 29	0.126	-0.215	-0.248	-0.441	-0.425	-0.264	-0.328	-0.387	0.073	-0.355	-0.321	-0.010	0.111	-0.086

VARIABLE (Sample Size)		Cybex 30° Hams - Max Torque	Cybex 30° Hams - Trials	Cybex 30° Hams - Fatigue Slope	Cybex 180° Quads - Max. Torque	Cybex 180° Quads- Trials	Cybex 180° Quads- Fatigue Slope	Cybex 180° Hams- Max. Torque	Cybex 180° [illegible]- Trials	Cybex 180° Hams- Fatigue Slope	% FT	LDH Py→La	LDH La→Py	SDH	CPK	ATPase
		15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
VO2 max (45)	ROW 1	-0.235	0.266	-0.236	-0.384	0.110	-0.430	-0.401	-0.206	-0.097	0.098	0.573	0.539	0.266	0.308	0.126
% Fat (43)	ROW 2	0.051	0.104	-0.078	0.112	-0.011	0.154	0.143	0.115	-0.048	-0.110	-0.545	-0.521	-0.340	-0.314	-0.215
Agility Run (23)	ROW 3	0.164	-0.261	0.260	0.114	-0.241	0.271	0.089	0.098	-0.146	-0.018	-0.452	-0.402	-0.269	-0.296	-0.298
10Yd. Sprint (26)	ROW 4	-0.244	-0.015	0.113	-0.051	-0.096	0.074	-0.153	-0.265	0.052	0.253	-0.166	-0.126	-0.467	-0.358	-0.441
40Yd.Sprint (31)	ROW 5	-0.140	-0.061	0.134	0.047	0.104	0.081	-0.127	-0.034	-0.071	-0.241	-0.134	-0.087	-0.322	-0.416	-0.425
Two Stairs (37)	ROW 6	-0.029	-0.005	0.026	-0.042	0.025	0.009	-0.128	0.061	-0.144	-0.412	-0.109	-0.104	-0.261	-0.412	-0.264
Freestyle (37)	ROW 7	0.054	-0.009	-0.076	-0.013	0.132	-0.073	-0.046	0.181	-0.281	-0.245	-0.456	-0.421	-0.535	-0.429	-0.328
Two Stairs Weighted (36)	ROW 8	0.161	0.161	-0.152	0.052	0.317	-0.021	0.075	0.382	-0.165	-0.342	-0.184	-0.103	-0.507	-0.285	-0.387
Stair Trials Weighted (36)	ROW 9	-0.133	0.168	-0.091	-0.100	0.149	-0.234	-0.260	-0.045	-0.175	0.010	0.138	0.206	0.001	0.121	0.073
Fatigue Slope-All-Stairs (36)	ROW 10	0.123	-0.074	0.069	0.273	-0.267	0.420	0.373	0.017	0.001	0.081	-0.376	-0.367	-0.342	-0.357	-0.355
Fatigue Slope-1st 13-Stairs (36)	ROW 11	0.065	-0.154	0.094	0.150	-0.272	0.240	0.291	-0.035	0.000	0.366	-0.224	-0.329	-0.237	-0.174	-0.321
Cybex 30°Quads-Max.Torque (44)	ROW 12	0.786	-0.258	0.419	0.752	0.227	0.452	0.595	0.119	0.271	-0.252	-0.074	0.094	-0.049	-0.091	-0.010
Cybex 30°Quads-Trials (44)	ROW 13	0.042	0.542	-0.397	0.055	0.380	-0.070	0.073	0.286	-0.045	-0.035	0.130	0.216	-0.114	0.314	0.111
Cybex 30°Quads-Fatigue Slope (44)	ROW 14	0.356	-0.533	0.490	0.367	-0.196	0.316	0.222	-0.174	0.151	-0.136	-0.232	-0.236	0.122	-0.336	-0.086
Cybex 30°Hams-Max Torque (44)	ROW 15	1.000	-0.206	0.396	0.698	0.174	0.489	0.822	0.230	0.385	-0.218	-0.063	0.043	0.074	0.004	0.094
Cybex 30°Hams-Trials (44)	ROW 16	-0.206	1.000	-0.806	-0.176	0.294	-0.264	-0.107	0.285	-0.250	0.159	-0.138	-0.050	-0.193	-0.008	-0.210
Cybex 30°Hams-Fatigue Slope (44)	ROW 17	0.346	-0.806	1.000	0.431	-0.246	0.436	0.278	-0.234	0.292	-0.215	0.138	0.046	0.175	-0.121	0.063
Cybex 180°Quads-Max Torque (44)	ROW 18	0.698	-0.176	0.431	1.000	-0.015	0.745	0.793	0.090	0.447	-0.176	-0.187	-0.090	-0.0[illegible]	-0.219	-0.115
Cybex 180°Quads-Trials (44)	ROW 19	0.174	0.294	-0.246	-0.015	1.000	-0.546	0.015	0.663	-0.491	-0.018	0.106	0.085	0.148	[illegible]19	0.241
Cybex 180°Quads-Fatigue Slope(44)	ROW 20	0.489	-0.264	0.436	0.745	-0.546	1.000	0.664	-0.231	0.691	-0.207	-0.215	-0.101	-0.079	-0.216	-0.161
Cybex 180°Hams-Max.Torque (44)	ROW 21	0.822	-0.107	0.278	0.793	0.015	0.664	1.000	0.153	0.595	-0.191	-0.165	-0.030	0.057	-0.057	0.062
Cybex 180°Hams-Trials (44)	ROW 22	0.240	0.285	-0.239	0.090	0.663	-0.231	0.153	1.000	-0.614	0.006	-0.020	-0.069	0.044	0.263	0.273
Cybex 180°Hams-Fatigue Slope (44)	ROW 23	0.385	-0.250	0.292	0.447	-0.491	0.691	0.595	-0.614	1.000	-0.154	0.021	0.146	0.040	-0.092	-0.138
% FT (32)	ROW 24	-0.219	0.159	-0.215	-0.176	-0.018	-0.207	-0.191	0.006	-0.154	1.000	0.155	0.058	0.157	0.172	0.075
LDH Py→La (32)	ROW 25	-0.066	-0.131	0.138	-0.187	0.106	-0.215	-0.165	-0.020	0.021	0.155	1.000	0.911	0.433	0.500	0.330
LDH La→Py (32)	ROW 26	0.043	-0.050	0.048	-0.090	0.085	-0.101	-0.030	-0.065	0.146	0.055	0.911	1.000	0.358	0.409	0.243
SDH (33)	ROW 27	0.074	-0.193	0.175	-0.095	0.148	-0.079	0.057	0.044	0.040	0.157	0.433	0.358	1.000	0.247	0.640
CPK (30)	ROW 28	0.003	-0.008	-0.121	-0.219	0.119	-0.210	-0.057	0.263	-0.092	0.172	0.500	0.409	0.247	1.000	0.589
ATPase (32)	ROW 29	0.044	-0.210	0.063	-0.115	0.241	-0.161	0.062	0.273	-0.138	0.075	0.330	0.243	0.640	0.589	1.000

Table 19.10 To 19.38 Correlations Which Were Significant as Determined From the Probability of T Matrix. (*$p < 0.10$, **$p < 0.05$, ***$p < 0.01$).

19.10	% Fat	Agility	Free-Style	Two Stairs Weight	Trials	Slope All	Slope 1st 13	Cybex 30°/sec. Quads Trials	Cybex 180°/sec. Quads Max.Torque	Cybex 180°/sec. Quads Slope	Cybex 180°/sec. Hams. Max.Torque	LDH Py→La	LDH La→Py	Cybex 30°/sec. Quad Slope	Cybex 30°/sec. Hams. Trials	CPK
VO$_2$ max	-.513 ***	-.418 **	-.371 **	0.393 **	.429 ***	-.564 ***	-.497 ***	.323 **	-.384 ***	-.430 ***	-.401 ***	.573 ***	.538 ***	-.256 *	.266 *	.308 *

19.11	VO$_2$ max	40 Yd.	Two Stairs	Free-Style	Two Stairs Weight	Trials	Slope All	Slope 1st 13	Cybex 30°/sec. Quads. Slope	LDH Py→La	LDH La→Py	Agility	10yd.	SDH	CPK
% Fat	-.513 ***	.626 ***	.499 ***	.605 ***	.611 ***	-.371 **	.547 ***	.370 **	.319 **	-.545 ***	-.521 ***	.375 *	.384 *	-.340 *	-.314 *

19.12	VO$_2$ max	Cybex 30°/sec. Quads Trials	Cybex 30°/sec. Quads Slope	LPH Py→La	% Fat	10 Yd.	Stairs Free-Style	Stairs Slope All	LDH La→Py
Agility Run	-.418 **	-.502 **	-.592 ***	-.452 **	.375 *	.463 *	.371 *	.405 *	-.402 *

19.13	40 Yd.	Free-Style	SDH	% Fat	Agility	Stairs Trials	ATPase
10 yd	.822 ***	.413 **	-.467 **	.384 *	.463 *	-.356 *	-.441 *

19.14	% Fat	10 Yd.	Two Stairs	Free-Style	Two Stairs Weight	Trials	Slope All	Cybex 30^{0}/sec. Quad Slope	CPK	ATPase
40 yd.	.626 ***	.822 ***	.713 ***	.619 ***	.732 ***	-.396 **	.438 **	.327 *	-.416 *	-.425 *

19.15	VO_2 max	% Fat	40 Yd.	Free-Style	Two Stairs Weight	% FT	CPK
Two Stairs	-.393 **	.499 ***	.713 ***	.698 ***	.704 ***	-.412 **	-.412 **

19.16	VO_2 max	% Fat	10 Yd.	40 Yd.	Two Stairs	Two Stairs Weight	Slope All	LDH Py→La	LDH La→Py	SDH	CPK	Agility	Cybex 30^{0}/sec. Quads Trials	Cybex 30^{0}/sec. Quads Slope	Cybex 180^{0}/sec. Hams. Slope	ATPase
Free-Style	-.371 **	.605 ***	.413 **	.619 ***	.698 ***	.584 ***	.336 **	-.458 **	-.421 **	-.535 ***	-.429 **	-.371 *	-.293 *	.284 *	-.281 *	-.328 *

19.17	VO_2 max	% Fat	40 Yd.	Two Stairs	Free-Style	Cybex 180^{0}/sec. Hams. Trials	SDH	ATPase	Cybex 180^{0}/sec. Quads. Trials	% FT
Two Stairs Weight	-.393 **	.611 ***	.732 ***	.704 ***	.584 ***	.392 **	-.507 ***	-.387 **	.317 *	-.342 *

19.18

	VO_2 max	% Fat	40 Yd.	Slope All	Slope 1st 13	Cybex 30°/sec. Quads Trials	10 yd.
Trials	.429 ***	-.371 **	-.396 **	-.768 ***	-.630 ***	.420 ***	-.356 *

19.19

	VO_2 max	% Fat	40 Yd.	Free-Style	Trials	Cybex 180°/sec. Quads Slope	Cybex 180°/sec. Hams. Max.Torque	LDH Py→La	Agility	Cybex 30°/sec. Quads. Trials	Cybex 180°/sec. Quads. Max.Torque	LDH La→Py	SDH	CPK	ATPase
Slope All	-.564 ***	.547 ***	.438 ***	.336 **	-.768 ***	.428 ***	.373 **	-.376 **	.405 *	-.309 *	.273 *	-.367 *	-.342 *	-.357 *	-.355 *

19.20

	VO_2 max	% Fat	Trials	Cybex 30°/sec. Quads. Trials	Cybex 180°/sec. Quads. Trials	Cybex 180°/sec. Hams. Max.Torque	% Fat	LDH La→Py	ATPase
Slope 1st 13	-.497 ***	.370 **	-.630 ***	-.369 **	-.272 *	.291 *	.366 *	-.325 *	.321 *

19.21

	Cybex 30°/sec. Quads Slope	Cybex 30°/sec. Hams. Max.Torque	Cybex 30°/sec. Hams. Slope	Cybex 180°/sec. Quads. Max.Torque	Cybex 180°/sec. Quads Slope	Cybex 180°/sec. Hams. Max.Torque	Cybex 30°/sec. Hams. Trials	Cybex 180°/sec. Hams. Slope
Cybex 30°/sec Quads. Max. Torque	.492 ***	.786 ***	.419 ***	.752 ***	.452 ***	.595 ***	-.258 *	.271 *

19.22	VO_2 max	Agility	Stair Trials	Stair Slope 1st 13	Cybex 30°/sec. Quads. Slope	Cybex 30°/sec. Hams. Trials	Cybex 30°/sec. Hams. Slope	Cybex 180°/sec. Quads. Trials	Stairs Free-Style	Stairs Slope All	Cybex 180°/sec. Hams Trials	CPK
Cybex 30°/sec Quads. Trials	.323 **	-.502 **	.420 **	-.369 **	-.695 ***	.642 ***	-.387 ***	.380 ***	-.293 *	-.309 *	86 .2*	.319 *

19.23	% Fat	Agility	Cybex 30°/sec. Quads. Max.Torque	Cybex 30°/sec. Quads. Trials	Cybex 30°/sec. Hams. Max.Torque	Cybex 30°/sec. Hams. Trials	Cybex 30°/sec. Hams. Slope	Cybex 180°/sec. Quads. Max.Torque	Cybex 180°/sec. Quads. Slope	VO_2 max	40 Yd.	Stairs Free-Style	CPK
Cybex 30°/sec Quads. Slope	.319 **	.592 ***	.492 ***	-.695 ***	.356 **	-.533 ***	.490 ***	.367 **	.316 **	-.256 *	.327 *	.284 *	-.336 *

19.24	Cybex 30°/sec. Quads Max.Torque	Cybex 30°/sec. Quads. Slope	Cybex 30°/sec. Hams. Slope	Cybex 180°/sec. Quads. Max.Torque	Cybex 180°/sec. Quads. Slope	Cybex 180°/sec. Hams. Max.Torque	Cybex 180°/sec. Hams. Slope
Cybex 30°/sec Hams. Max. Torque	.736 ***	.356 **	.396 ***	.698 ***	.489 ***	.822 ***	.385 ***

19.25	Cybex 30°/sec. Quads. Trials	Cybex 30°/sec. Quads. Slope	Cybex 30°/sec. Hams. Slope	Cybex 180°/sec. Quads. Trials	VO_2 max	Cybex 30°/sec. Quads. Max.Torque	Cybex 180°/sec. Quads. Slope	Cybex 180°/sec. Hams. Trials.	Cybex 180°/sec. Hams. Slope
Cybex 30°/sec Hams. Trials	.642 ***	-.533 ***	-.806 ***	.298 **	.266 *	-.258 *	-.264 *	.285 *	-.250 *

19.26	Cybex 30°/sec. Quads. Max.Torque	Cybex 30°/sec. Quads. Trials	Cybex 30°/sec. Quads. Slope	Cybex 30°/sec. Hams. Max.Torque	Cybex 30°/sec. Hams. Trials	Cybex 180°/sec. Quads. Max.Torque	Cybex 180°/sec. Quads. Slope	Cybex 180°/sec. Quads. Trials	Cybex 180°/sec. Hams. Max.Torque	Cybex 180°/sec. Hams. Slope
Cybex 30°/sec Hams. Slope	.419 ***	-.387 ***	.490 ***	.356 ***	-.806 ***	.431 ***	.436 ***	-.246 *	.278 *	.292 *

19.27	VO_2 max	Cybex 30°/sec. Quads. Max.Torque	Cybex 30°/sec. Quads. Slope	Cybex 30°/sec. Hams. Max.Torque	Cybex 30°/sec. Hams. Slope	Cybex 180°/sec. Quads. Slope	Cybex 180°/sec. Hams. Max.Torque	Cybex 180°/sec. Hams. Slope	Stairs Slope All
Cybex 180°/sec Quads Max. Torque	-.384 ***	.752 ***	.367 **	.698 ***	.431 ***	.745 ***	.793 ***	.447 ***	.273 *

19.28	Cybex 30°/sec. Quads Trials	Cybex 30°/sec. Hams. Trials	Cybex 180°/sec. Quads. Slope	Cybex 180°/sec. Hams. Trials	Cybex 180°/sec. Hams. Slope	Two Stairs Weight	Cybex 30°/sec. Hams. Slope
Cybex 180°/sec Quads. Trials	.380 ***	.298 **	-.546 ***	.663 ***	-.491 ***	.317 *	-.246 *

19.29	VO_2 max	Stairs Slope All	Cybex 30°/sec. Quads. Max.Torque	Cybex 30°/sec. Quads. Slope	Cybex 30°/sec. Hams. Max.Torque	Cybex 30°/sec. Hams. Slope	Cybex 180°/sec. Quads. Max.Torque	Cybex 180°/sec. Quads. Trials	Cybex 180°/sec. Hams. Max.Torque	Cybex 180°/sec. Hams. Slope	Cybex 30°/sec. Hams. Trials
Cybex 180°/sec Quads Slope	-.430 ***	.428 ***	.452 ***	.316 **	.489 ***	.436 ***	.745 ***	-.546 ***	.664 ***	.691 ***	-.264 *

19.30	VO$_2$ max	Stairs Slope All	Cybex 30°/sec. Quads. Max.Torque	Cybex 30°/sec. Hams. Max.Torque	Cybex 180°/sec. Quads. Max.Torque	Cybex 180°/sec. Quads. Slope	Cybex 180°/sec. Hams. Slope	Stairs Slope 1st 13	Cybex 30°/sec. Hams. Slope
Cybex 180°/sec Hams. Max. Torque	-.401 ***	.373 **	.595 [illegible]*	.822 ***	.793 ***	.644 ***	.595 ***	.291 *	.278 *

19.31	Two Stair Weight	Cybex 180°/sec. Quads. Trials	Cybex 180°/sec. Hams. Slope	Cybex 30°/sec. Quads. Trials	Cybex 30°/sec. Hams. Trials
Cybex 180°/sec Hams. Trials	.382 **	.663 ***	-.614 ***	.286 [illegible]	.285 *

19.32	Cybex 30°/sec. Hams. Max.Torque	Cybex 180°/sec. Quads. Max.Torque	Cybex 180°/sec. Quads. Trials	Cybex 180°/sec. Quads. Slope	Cybex 180°/sec. Hams. Max.Torque	Cybex 180°/sec. Hams. Trials	Stairs Free-Style	Cybex 30°/sec. Quads. Max.Torque	Cybex 30°/sec. Hams. Trials	Cybex 30°/sec. Hams. Slope
Cybex 180°/sec Hams. Slope	.385 ***	.447 ***	-.491 ***	.691 ***	.595 ***	-.614 ***	-.281 *	.271 *	-.250 *	.292 *

19.33	Two Stairs	Two Stairs Weight	Stairs Slope 1st 13
% FT	-.412 **	-.342 *	.366 *

19.34	VO_2 max	% Fat	Agility	Stairs Free-Style	Stairs Slope All	LDH La→Py	SDH	CPK	ATPase
LDH Py→La	.573 ***	-.545 ***	-.452 **	-.458 **	-.376 **	.911 ***	.433 **	.500 ***	.330 *

19.35	VO_2 max	% Fat	Stairs Free-Style	SDH	CPK	Agility	Stairs Slope All	Stairs Slope 1st 13
LDH La→Py	.538 ***	-.521 ***	-.421 **	.358 **	.409 **	-.402 *	-.367 *	-.325 *

19.36	10 Yd.	Stairs Free-Style	Two Stairs Weight	LDH Py→La	LDH La→Py	ATPase	% Fat	Stairs Slope All
SDH	-.467 **	-.535 ***	-.507 ***	.433 **	.358 **	.640 ***	-.340 *	-.342 *

19.37	Two Stairs	Stairs Free-Style	ATPase	VO_2 max	% Fat	40 Yd	Stairs Slope All	Cybex 30°/sec. Quads. Trials	Cybex 30°/sec. Quads. Slope
CPK	-.412 **	-.429 **	.589 ***	.308 *	-.314 *	-.416 *	-.357 *	.319 *	-.336 *

19.38	Two Stairs Weight	SDH	CPK	10 Yd.	40 Yd.	Stairs Free-Style	Stairs Slope All	Stairs Slope 1st 13	LDH Py→La
ATPase	-.387 **	.640 ***	.589 ***	-.441 *	-.425 *	-.328 *	-.355 *	-.321 *	.330 *

APPENDIX M

Table 20.1 To 20.7 **One-Way Repeated Measures Analysis of Variance Summary Tables for Significant Pre versus Post Test Differences for All Subjects. (**$p<0.05$, ***$p<0.01$).**

20.1 Cybex 30°/s Max. Torque Hamstrings

Sums of Squares, Numbers of Degrees of Freedom and Mean Squares:

Among Subjects			
S	23085.33	26	887.90
Within Subjects			
T	808.91	1	808.91
TS	3610.59	26	138.87

Mean Square Within Subjects: 163.69

Value of F: 5.825

Numbers of Degrees of Freedom: 1 26 Critical F: 4.23**

20.2 Cybex 180°/s Max. Torque Quadriceps

Sums of Squares, Numbers of Degrees of Freedom and Mean Squares:

Among Subjects			
S	26047.37	26	1001.82
Within Subjects			
T	979.63	1	979.63
TS	2027.37	26	77.98

Mean Square Within Subjects: 111.37

Value of F: 12.56

Number of Degrees of Freedom: 1 26 Critical F: 7.72***

20.3 Cybex 180°/s Fatigue Slope Quadriceps

Sums of Squares, Numbers of Degrees of Freedom and Mean Squares:

```
Among Subjects
   S       0.835   26 0.032
Within Subjects
   T       0.047   1 0.047
   TS      0.282  26 0.011
```

Mean Square Within Subjects: 0.012

Value of F: 4.300
Numbers of Degrees of Freedom: 1 26 Critical F: 4.23**

.4 Cybex 180°/s Max. Torque Hamstrings

Sums of Squares, Numbers of Degrees of Freedom and Mean Squares:

```
Among Subjects
   S       7904.81   26 304.03
Within Subjects
   T       1956.02 1 1956.02
   TS      1091.48 26 41.98
```

Mean Square Within Subjects: 112.87

Value of F: 46.59
Numbers of Degrees of Freedom: 1 26 Critical F: 7.72***

20.5 Cybex 180°/s Fatigue Slope Hamstrings

Sums of Squares, Numbers of Degres of Freedom and Mean Squares:

```
Among Subjects
   S       0.364   26 0.014
Within Subjects
   T       0.056 1 0.056
   TS      0.138 26 0.005
```

Mean Square Within Subjects: 0.007

Value of F: 10.50
Numbers of Degrees of Freedom: 1 26 Critical F; 7.72***

20.6 **Maximal Oxygen Consumption VO_2 max**

Sums of Squares, Numbers of Degrees of Freedom and Mean Squares:

Among Subjects			
S	1029.70	24	42.90
Within Subjects			
T	80.14	1	80.14
TS	159.31	24	6.64

Mean Square Within Subjects: 9.58

Value of F: 12.07
Numbers of Degrees of Freedom: 1 24 **Critical F:** 7.82**

20.7 Stair Run - Freestyle

Sums of Squares, Numbers of Degrees of Freedom and Mean [illegible]:

Among Subjects			
S	0.940	17	0.055
Within Subjects			
T	0.04	1	0.04
TS	0.078	17	0.005

Mean Square Within Subjects: 0.007

Value of F: 8.532
Numbers of Degrees of Freedom: 1 17 Critical F: 8.40***

21.12 Wide and Inside Receivers - Cybex 180°/s Max Torque Hamstrings

Sums of Squares, Numbers of Degrees of Freedom and Mean Squares:

Among Subjects
S 517.43 5 103.48
Within Subjects
T 468.75 1 468.75
TS 222.75 7 44.55

Mean Square Within Subjects: 115.25

Value of F: 10.52
Numbers of Degrees of Freedom: 1 5 Critical F: 6.61**

21.13 Defensive Backs - Cybex 180°/s Max. Torque Hamstrings

Sums of Squares, Numbers of Degrees of Freedom and Mean Squares:

Among Subjects
S 937.67 5 187.53
Within Subjects
T 481.33 1 481.33
TS 67.67 5 13.53

Mean Square Within Subjects: 91.5

Value of F: 35.57
Numbers of Degrees of Freedom: 1 5 Critical F: 16.3***

21.14 Defensive Lineman and Linebackers - Cybex 180°/s Max. Torque Hamstrings

Sums of Squares, Numbers of Degrees of Freedom and Mean Squares:

Among Subjects
S 629.5 3 209.83
Within Subjects
T 264.5 1 264.5
TS 97.5 3 32.5

Mean Square Within Subjects: 90.5

Value of F: 8.138
Numbers of Degrees of Freedom: 1 3 Critical F: 5.54*

21.15 Offensive Lineman - Cybex 180°/s **Max. Torque Hamstrings**

Sums of Squares, Numbers of Degrees of Freedom and Mean Squares:

Among Subjects
S 1842.71 6 307.12
Within Subjects
T 977.79 1 977.79
TS 416.71 6 69.45

Mean Square Within Subjects: 199.21

Value of F: 14.08
Numbers of Degrees of Freedom: 1 6 Critical F: 13.7***

21.16 Quarterbacks and Running Backs - Cybex 180°/s **Hamstring Trials**

Sums of Squares, Numbers of Degrees of Freedom and Mean Squares:

Among Subjects
S 12.38 3 4.13
Within Subjects
T 10.13 1 10.13
TS 3.38 3 1.13

Mean Square Within Subjects [illegible]

Value of F: 9
Numbers of Degrees of [illegible] 1 3 Critical F; 5.54*

21.17 Defensive Lineman and Linebackers - Cybex 180°/s Fatigue Slope Hamstrings

Sums of Squares, Numbers of Degrees of Freedom and Mean Squares:

Among Subjects
S 0.024 3 0.008
Within Subjects
T 0.028 1 0.028
TS 0.009 3 0.003

Mean Square Within Subjects: 0.009

Value of F: 8.955
Numbers of Degrees of Freedom: 1 3 Critical F: 5.54*

21.18 Defensive Backs - Maximal Oxygen Consumption VO_2 max

Sums of Squares, Numbers of Degrees of Freedom and Mean Squares:

Among Subjects
S 186.81 5 37.36
Within Subjects
T 108 1 108
TS 41.33 5 8.27

Mean Square Within Subjects: 24.89

Value of F: 13.07
Numbers of Degrees of Freedom: 1 5 Critical F: 6.61**

21.19 Quarterbacks and Running Backs - Maximal Oxygen Consumption

Sums of Squares, Numbers of Degrees of Freedom and Mean Squares:

Among Subjects
S 231.45 3 77.15
Within Subjects
T 26.65 1 26.65
TS 12.21 3 4.068

Mean Square Within Subjects: 9.713

Value of F: 6.549
Numbers of Degrees of Freedom: 1 3 Critical F: 5.54*

21.20 Offensive Lineman - Stair Run, Freestyle

Sums of Squares, Numbers of Degrees of Freedom and Mean Squares:

Among Subjects
S 0.295 4 0.074
Within Subjects
T 0.017 1 0.017
TS 0.007 4 0.002

Mean Square Within Subjects: 0.005

Value of F: 9.689
Numbers of Degrees of Freedom: 1 4 Critical F: 7.71*

21.21 Defensive Backs - Stair Run Trials

Sums of Squares, Numbers of Degrees of Freedom and Mean Squares:

Among Subjects
S 65.38 3 21.79
Within Subjects
T 136.13 1 136.13
TS 66.38 3 22.13

Mean Square Within Subjects: 50.63

Value of F: 6.153
Numbers of Degrees of Freedom: 1 3 Critical F: 5.54*

21.22 Defensive Backs - Stair Run Fatigue Slope All Trials

Sums of Squares, Numbers of Degrees of Freedom and Mean Squares:

Among Subjects
S 0.0002345 3 0.00007816666667
Within Subjects
T 0.000288 1 0.000288
TS 0.000111 3 0.000037

Mean Square Within Subjects: 0.00009975

Value of F: 7.783783784
Numbers of Degrees of Freedom: 1 3 Critical F: 5.54*

APPENDIX N

Table 22.1 To 22.6 **One-Way Analysis of Variance Summary Tables and Newman-Keuls Post Hoc Tests[a] on Significant Differences Between Football Players Divided into Four Groups (**$p<0.05$)**

22.1 Cybex 180°/s Max. Torque Quadriceps

Number of Degrees of Freedom, Sums of Squares and Mean Squares:

Among Groups	3	3529.59	1176.53
Within Groups	40	15334.85	383.37
Total	43	18864.43	

Value of F: 3.069

Numbers of Degrees of Freedom: 3 40 Critical F: 2.84**

Means.	103.3	87.6	103.6	112.1
				2

22.2 Cybex 180°/s Max. Torque **Hamstrings**

Number of Degrees of Freedom, Sums of Squares and Mean Squares:

Among Groups	3	2681.12	893.71
Within Groups	40	8107.68	202.69
Total	43	10788.80	

Value of F: 4.409

Numbers of Degrees of Freedom: 3 40 Critical F: 2.84**

Means.	75.1	64.9	70.9	86.4
				2

---

[a] Means are ordered in sequence (1. All Receivers, 2.Defensive Backs, 3. Offensive Lineman, Running Backs and Quarterbacks, 4. Defensive Lineman and Linebackers). The numbers below a mean indicate that the mean designated by the number is significantly different from the mean below which it appears.

22.3 Percent Body Fat

Number of Degrees of Freedom, Sums of Squares and Mean Squares:

Among Groups	3	196.16	65.39
Within Groups	39	532.03	13.64
Total	42	728.19	

Value of F: 4.793

Numbers of Degrees of Freedom: 3 39 Critical F: 2.85**

Means.	7.70	8.93	12.24	13.14
			1	1

22.4 Succinate Dehydrogenase Activity (SDH)

Number of Degrees of Freedom, Sums of Squares and Mean Squares:

Among Groups	3	12.97	4.32
Within Groups	29	36.25	1.250
Total	32	49.22	

Value of F: 3.458

Numbers of Degrees of Freedom: 3 29 Critical F: 2.93**

Means.	2.77	3.68	2.11	2.38
		3		

22.5 Maximal Oxygen Consumption VO_2 max

Number of Degrees of Freedom, Sums of Squares and Mean Squares:

Among Groups	3	287.95	95.98
Within Groups	41	1069.22	26.08
Total	44	1357.17	

Value of F: 3.681

Numbers of Degrees of Freedom: 3 41 Critical F: 283**

Means.	57.2	60.9	55.9	54.1
		4		

22.6 Stair Run - Freestyle

Number of Degrees of Freedom, Sums of Squares and Mean Squares:

Among Groups	3	0.451	0.150
Within Groups	34	0.933	0.027
Total	37	1.384	

Value of F: 5.474
Numbers of Degrees of Freedom: 3 34 Critical F: 2.89**

Means. 2.00 2.11 2.29 2.20
3
4

Table 23.1 To 23.7 **One-Way Analysis of Variance Summary Tables and Newman-Keuls Post Hoc Tests[a] on Significant Differences Between Football Players by Position.** (**$p < 0.05$).

23.1 Cybex $30^{\circ}/s$ Max. Torque Quadriceps

Number of Degrees of Freedom, Sums of Squares and Mean Squares:

Among Groups	7	41509.17	5929. 88
Within Groups	36	78359.83	2176.66
Total	43	119869	

Value of F: 2.724

Numbers of Degrees of Freedom: 7 36 Critical F: 2.28**

Means.	203.8	213.7	184.0	182.0	200.4	228.5	286.0	252.7
							3 4	

23.2 Cybex $30^{\circ}/s$ Fatigue Slope Quadriceps

Number of Degrees of Freedom, Sums of Squares and Mean Squares:

Among Groups	7	0.913	0.130
Within Groups	36	1.618	0.045
Total	43	2.531	

Value of F: 2.903

Number of Degrees of Freedom: 7 36 Critical F: 2.28**

Means.	.396	.569	.401	.601	.559	.541	.971	.768
							1 3	

---

[a] Means are ordered in sequence (1. Wide Receivers, 2. Inside Receivers, 3. Quarterbacks, 4. Running Backs, 5. Defensive Backs, 6. Linebackers, 7. Defensive Lineman, 8. Offensive Lineman). The numbers below a mean indicate that the mean designated by the number is significantly different from the mean below which it appears.

23.3 Cybex 30°/s **Fatigue Slope Hamstrings**

Number of Degrees of Freedom, Sums of Squares and Mean Squares:

Among Groups	7	0.418	0.060
Within Groups	36	0.865	0.024
Total	43	1.284	

Value of F: 2.485
Numbers of Degrees of Freedom: 7 36 Critical F: 2.28**

Means. .251 .385 .223 .313 .267 .252 .575 .394
3

23.4 Cybex 180°/s Max. Torque Quadriceps

Number of Degrees of Freedom, Sums of Squares and Mean Squares:

Among Groups	7	6912.78	987.54
Within Groups	36	11727.22	325.76
Total	43	18640	

Value of F: 3.032
Numbers of Degrees of Freedom: 7 36 Critical F: 2.28**

Means. 99.8 108.0 91.5 88.3 87.6 102.7 126.3 112.6
4
5

23.5 Cybex 180°/s Max. Torque Hamstrings

Number of Degrees of Freedom, Sums of Squares and Mean Squares:

Among Groups	7	3344. 49	477.78
Within Groups	36	7444.31	206.79
Total	43	10788.80	

Value of F: 2.311
Numbers of Degrees of Freedom: 7 36 Critical F: 2.28**

Means. 73.5 78.7 72.5 66.8 64.9 80.5 95.3 72.4
5

23.6 **Maximal Oxygen Consumption** VO_2 **max**

Number of Degrees of Freedom, Sums of Squares and Mean Squares:

Among Groups:	7	452.69	64.67
Within Groups	37	904.48	24.45
Total	44	1357.17	

Value of F: 2.646
Numbers of Degrees of Freedom: 7 37 Critical F: 2.27**

Means. 57.8 56.6 59.8 59.9 60.9 54.7 53.2 53.3
7
8

23.7 Percent Body Fat

Number of Degrees of Freedom, Sums of Squares and Mean Squares:

[illegible] Groups	7	269.42	38.49
[illegible] Groups	35	452.68	12.93
[illegible]tal	42	722.09	

Value of F: 2.976
Numbers of Degrees of Freedom: 7 35 Critical F: 2.29**

Means. 5.80 9.61 9.64 9.85 8.93 13.27 12.98 13.54
1 1

Table 21.10 To 21.22 **One-Way Repeated Measures Analysis of Variance Summary Tables for Significant Pre versus Post Test Differences by Position.** (*p<0.10, **p<0.05, ***p<0.01).

21.10 Defensive Backs - Cybex 30°/s Fatigue Slope Hamstrings

Sums of Squares, Numbers of Degrees of Freedom and Mean Squares:

```
Among Subjects
   S       0.154 5 0.031
Within Subjects
   T       0.015 1 0.015
   TS      0.013 5 0.003
```

Mean Square Within Subjects: 0.005

Value of F: 5.708
Numbers of Degrees of Freedom: 1 5 Critical F: 4.06*

21.11 Offensive Lineman - Cybex 180°/s Max. Torque Quadriceps

Sums of Squares, Numbers of Degrees of Freedom and Mean Squares:

```
Among Subjects
   S       8822.429 6 1470.405
Within Subjects
   T       480.29 1 480.29
   TS      490.71 6 81.79
```

Mean Square Within Subjects: 138.71

Value of F: 5.872
Numbers of Degrees of Freedom: 1 6 Critical F: 3.78*