THE VALIDATION OF WORKLOADS AT 180 AND 190 HEART RATE AS PREDICTORS OF MAXIMAL OXYGEN CONSUMPTION FOR COLLEGE WOMEN

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CHAPTER I

INTRODUCTION

There have been numerous studies attempting to predict and determine the maximum oxygen consumption (max $\dot{V}O_2$) of the male athlete. However, the literature reveals that very little research has been done to establish max $\dot{V}O_2$ rates for highly skilled female athletes, and still less information is available on this problem for the normal female population.

With trends pointing toward women becoming increasingly involved in physical activity, more concerned with physical fitness, and more inclined to participate in athletic competition, it is evident that more research should be conducted to determine what the physiological capabilities are for the female.

To emphasize the need for research involving women, Clayton Thomas (1) said:

> . . . the little interest investigators have in using women as subjects in studies by physical educators (is appalling). It is almost as if there were cultural or professional taboos against designing a research study involving women. Until this condition is altered, we will continue to be penalized by lack of information concerning half of the human race.

There is growing concern in our society about the increased mechanization of daily life and the resulting curtailment in physical exercise. There is much talk about this situation, but physical fitness continues to retain a low priority in our national life. Even though our culture is becoming more involved in leisure activities, fitness programs, and sports, the majority of Americans are still basically unfit.

The type of fitness we are concerned with in this study is cardiovascular-respiratory fitness. This is the capacity of the body to supply and deliver oxygen to the organs and tissues. Such a capacity involves the heart, the blood vessels and the lungs. Cardiovascular-respiratory fitness has progressively become a more important attribute as the amount of strain and pressure created by modern living and lack of activity has increased.

Maximum oxygen consumption seems to be the best single measure of cardiorespiratory fitness (2) (3) (4) (5). Maximum oxygen consumption, also referred to as maximum aerobic capacity, is the maximum amount of oxygen an individual can utilize while performing a workload (2). When the workload surpasses this oxygen maximum, the anaerobic process (without oxygen) takes over and continues for a brief period before exhaustion occurs and the work task is forced to cease.

In 1968 Dr. Ken Cooper stimulated the physical fitness programs of America when he published his book, Aerobics (6). "Aerobics" is defined as "with oxygen." The aerobic fitness program is designed to improve one's maximal oxygen intake capacity. Aerobic exercises utilize oxygen without producing intolerable oxygen debt. Cooper's program is based on aerobic activities that stimulate the heart and lungs for a continued and sufficient amount of time to produce beneficial changes in the body (7). Cooper's research program pre-determined oxygen consumption for various activities and correlated oxygen consumption and pulse rate with those activities (6).

Preventive medicine is no longer idle theory, and health is no longer defined as merely the absence of disease. After menopause, women begin to lose their natural resistance to cardiovascular disease, making it imperative that they increase their level of fitness.

Being able to predict max $\dot{V}O_2$, whether the prediction be from heart rates, ventilation volumes, or perhaps from other methods, can be a valuable tool for use in work capacity research. The direct method of measuring max $\dot{V}O_2$ is a laboratory procedure which is very time-consuming, requires an extensive amount of equipment, involves considerable expertise, and, overall is a very tedious process. This problem, then, seems to indicate a need for methods of predicting max $\dot{V}O_2$ from work tests of various kinds without doing the laboratory measurements, particularly the gas analysis work.

Balke has been the forerunner in presenting research pertaining to max $\dot{V}O_2$ for men. Balke and Ware (35) found that a sub-maximal heart rate of 180 beats per minute was a valid predictor of max $\dot{V}O_2$. Repeated studies by Balke and others have found that the time taken to reach 180 heart rate is a valid predictor of max $\dot{V}O_2$ for men. He noted that the sub-maximal tests avoid much of the discomfort and distress that the subjects are exposed to in an all-out run.

Later, Nagle and Bedecki (5) used the same treadmill procedure to reinforce the findings of Balke and add further knowledge to the test. Nagle and Bedecki concluded that 180 heart rate was a valid predictor of max $\dot{V}O_2$ using the all-out run on the treadmill. Physiological changes that resulted when max $\dot{V}O_2$ level was reached were an excessive volume of ventilation, a respiratory exchange ratio of unity, an acute decrease in the ratio of oxygen consumed to the work done, and a tendency for the oxygen consumption to level off indicating increased anaerobic work.

It seems that similar studies should be conducted for women.

Michael and Horvath (8) tested thirty female college students on the bicycle ergometer to determine max $\dot{V}O_2$. Heart rates ranged from 170 to 202 beats per minute. Average max $\dot{V}O_2$ was found to be 29.8 ml/kg/min. Predictions of max $\dot{V}O_2$ could not be made for individuals from any submaximal measurements. Humphrey and Falls (27) tested fifteen physical education majors at 180 heart rate to determine its validity as a predictor of max $\dot{V}O_2$. They found that workloads at 180 heart rate and max $\dot{V}O_2$ showed a relationship of .7 correlation. This, they concluded, would be an underestimate of max $\dot{V}O_2$.

The validity of a workload at 180 heart rate as predictor of max $\dot{V}O_2$ for women has been questioned as a result of evaluation in this area by A. B. Harrison in the Oklahoma State University Human Performance Laboratory (37). Currently when women are tested by Harrison using the Balke procedure and asked to stop the workload at 180 heart rate, the predicted max $\dot{V}O_2$ seems to be an underestimation when charted on the Balke regression line for men. When these women are tested to exhaustion and actual $\dot{V}O_2$ is measured, this score, when compared to the predicted max $\dot{V}O_2$ on the regression line, shows a 20-25% difference in men's and women's scores. This corresponds with the findings by Humphrey and Falls in which max $\dot{V}O_2$ was determined to be an underestimation of actual max $\dot{V}O_2$ when measured by gas analysis of those subjects worked to exhaustion. These findings gave this researcher a reason to believe that 190 might be a more valid predictor of max $\dot{V}O_2$ for women. These studies were steps in the right direction to find some answers about the maximum oxygen consumption for women.

Understanding, predicting, and determining maximum oxygen consumption can alleviate many of the question marks about female training methods, exercise prescription, and everyday activities beneficial to the average woman. Research regarding physiological processes to estimate maximum oxygen consumption from sub-maximal tests even if errors of measurement range from 10-15% are acceptable as a trade-off in favor of the savings of time and effort for both the subject and the investigator (3).

Statement of the Problem

The problem was to determine if workloads at 180 and 190 heart rates were valid predictors of maximal oxygen consumption in college women.

Hypotheses

1) The relationship between maximum oxygen consumption and the time to reach 180 heart rate on the treadmill will be sufficiently high to serve as a valid predictor of maximum oxygen consumption. A correlation coefficient of .7 or better will be an acceptable level for predictive validity.
2) The relationship between maximum oxygen consumption and the time to reach 190 heart rate on the treadmill will be sufficiently high to serve as a valid predictor of max $\dot{V}O_2$. A correlation coefficient of .7 or better will be an acceptable level for predictive validity.
3) There will be no difference in maximum oxygen consumption of HPELS majors, non-majors, and intercollegiate athletes.

Subproblems

1) To determine a valid regression line for predicting maximum oxygen consumption from treadmill test results.
2) To relate a valid regression line for women to the regression line developed by Balke for adult men.
3) To compare the maximum oxygen consumption for a normal population of college women with maximum oxygen consumption of those previously reported in the literature.
4) To compare maximum oxygen consumption of HPELS majors, non-majors, and intercollegiate athletes.

Limitations of Study

1) Apprehension of subjects due to the unfamiliarity of the testing equipment was anticipated, even though orientation of subjects to the equipment preceded the testing procedure.
2) There was no attempt to control diet, sleeping, or extra-curricular activities of the subjects.

Delimitations

The subjects for this study were limited to sixty Oklahoma State University college women between the ages of eighteen and twenty-eight years who were HPELS majors, non-majors enrolled in the School of HPELS, and members of female intercollegiate teams.

Assumptions

1) It was assumed that all subjects were in sound organic health and were fit to participate in physical activity.

2) The subjects exerted a maximum effort while being tested on the treadmill.

3) There was a wide range of physical conditioning present in the subjects tested.

4) The skill factor did not significantly effect this study since the only skills required were walking and breathing.

5) As oxygen consumption increased, heart rate increased proportionately until a maximum oxygen consumption was reached.

6) The Balke test procedure was a valid method of eliciting maximum work capacity, maximum oxygen consumption, and maximum heart rate.

Significance of the Study

The physical educator is concerned with the whole person. Therefore, it is important that we understand all realms of the human organism - psychological, sociological, and physiological. Cardiorespiratory fitness is a component of the total fitness program which is fundamental to all other aspects of the person. It, therefore, appears to this researcher that being able to predict max $\dot{V}O_2$ from sub-maximal heart rates will give the physical educator, the coach, the student, and the academician more advantageous and insightful knowledge about the physiological characteristics of the female.

Definition of Terms

1) Aerobic - A process by which work is accomplished in the presence of oxygen.

2) Anaerobic - A process by which work is accomplished in the

absence of oxygen.

3) Maximum oxygen consumption (max $\dot{V}O_2$) - The maximal amount of oxygen an individual can consume when performing a given workload expressed per minute. Also used synonymously with maximum aerobic capacity, oxygen uptake, and oxygen intake.

4) Oxygen debt - A deficit in oxygen intake during an activity that must be repaid during a recovery period.

5) Cardiorespiratory fitness - The efficiency of the heart, blood vessels, and lungs to supply and deliver oxygen to the organs and tissues.

6) EKG - Electrocardiography or record of the electrical potential of the heart.

7) Nomogram - A graph that enables one, by the aid of a straightedge, to read off the value of a dependent variable when the values of two or more independent variables are given.

8) Physical work capacity (PWC) - Amount of time, in minutes or percentage of grade on the treadmill, the subject walked before the heart rate reached 180 beats per minute (PWC 180) and 190 beats per minute (PWC 190).

9) Ml/kg/min - Milliliters per kilogram of body weight per minute. The preferred unit for expressing maximal oxygen intake since it takes into consideration body weight.

10) Balke Prediction for men - A nomogram devised by Balke to estimate maximum oxygen consumption from time to reach heart rate 180 on his treadmill test.

11) Percent oxygen - The amount of oxygen measured in the expired air.

12) Percent carbon dioxide - The amount of carbon dioxide measured in the expired air.

13) Corrected minute ventilation - Volume of air that is drawn into and expelled from the lungs per minute and corrected for STPD.

14) STPD - Gas volume reduced to standard conditions - barometric pressure 760 mm Hg, temperature $0^{o}C$, dry.

15) BTPS - Body temperature and ambient barometric pressure saturated with water vapor.

16) Respiratory quotient (RQ) - The ratio of the carbon dioxide output to oxygen consumed.

17) Systolic blood pressure - The surge of blood that is forced into the arteries when the left ventricle contracts.

18) Diastolic blood pressure - The drainage of the blood from the heart when the heart is in a resting state.

19) Open circuit - The process where a subject breathes ambient air, the exhaled respiratory gases are directed through tubing and a valve into a tissot tank or another collecting device.

Descriptions of Instruments

1) One-way breathing valve - A device which enabled the subject to take in atmospheric air and then to expel the air into a tissot tank for measurement of lung ventilation during exercise (Model - Double "J" Valve; Warren E. Collins, Inc., 220 Wood Road, Braintree, Mass.).

2) Physiograph - A multi-channel ink-writing recorder used to

monitor and record heart rate during work (Type PMP-4A; E and M Instrument Co., Inc., Houston, Texas).

3) Quinton Motorized treadmill - An apparatus with a continuously moving belt which can be made to run at various speeds and inclinations, thus standardizing workloads (Model 642; speed range 1.5-25 miles per hour; Elevation [percent grade] 0-40; Seattle, Washington).

4) Biotelemetry Transmitter - A unit that sent a signal by radio waves (no wires) from a small transmitter which was attached to the subject to a receiver (Model F. M. 1100-E-2, Part No. 98-100-71; Narco Bio-System, Inc., 7651 Airport Blvd., Houston, Texas).

5) Biotelemetry Receiver - A unit that received heart rate signals from a small wireless transmitter (Model F. M. 100-7; E and M Instrument Co., Inc., Houston, Texas).

6) Tissot tank - A large stainless steel tank which was used for collecting and measuring volumes of expired air during work (Warren E. Collins, Inc., 555 Huntington Avenue, Boston 15, Mass.; Capacity - 120 liters [0MM-720MM]; Serial No. 1440).

7) Surface Electrodes - Devices attached to the skin surface and adjacent the heart to transduce the electrical impulses of the heart into electrical signals (Part No. 710-0012; Narco Bio-Systems, Inc., 7651 Airport Blvd., Houston, Texas).

8) Godart Pulmo - Analyzer - An instrument used to determine the percentage of oxygen and carbon dioxide in samples of expired air utilizing the principle of thermal conductivity (Godart Instrumentation Association, New York, NY).

9) Nose clip - A device used to close off the nostrils and prevent nasal ventilation.

10) Sample bags - A one-liter rubber bag used to hold samples of subject's expired air.

CHAPTER II

REVIEW OF RELATED LITERATURE

This review of literature will be divided into five different phases: (1) methods for determining maximal oxygen consumption, (2) differences in men's and women's maximal oxygen intake measurements, (3) other physiological considerations related to oxygen intake, (4) related oxygen consumption studies, (5) summary.

Methods for Determining Maximal Oxygen Consumption

The literature that is available in the area of oxygen consumption for women indicates a serious lack of consistency in the testing procedures themselves and, in turn, in the actual prediction of max $\dot{V}O_2$.

Michael and Horvath (8) used a bicycle ergometer test to obtain maximum oxygen consumption for thirty college female students. The average max $\dot{V}O_2$ for the thirty subjects was 29.8 ml/kg/min. It was not possible to predict the maximum oxygen uptake from sub-maximal heart rates due to variability of the subjects' scores.

In another study with males, Molnar (9) suggested that the grade at which individuals run to attain max $\dot{V}O_2$ is an important factor in testing subjects. This study showed that higher max $\dot{V}O_2$ at proportionately steeper grades might indicate the usuage of greater muscle mass at those higher levels of incline. This idea was further substantiated by

Åstrand and Saltin (10). Molnar concluded that max $\dot{V}O_2$ was reached sooner at steeper grades.

Several studies found that the max $\dot{V}O_2$ measured on the treadmill consistently revealed higher scores than those on the bicycle ergometer (11) (12) (13). McArdle and others (32) tested thirty-five untrained females and six trained athletes on the treadmill and found the average max $\dot{V}O_2$ for trained to be 44.2 ml/kg/min and average max $\dot{V}O_2$ for untrained to be 37.1 ml/kg/min. Horvath (34) experimented with fourteen California coeds using the bicycle ergometer and found an average max $\dot{V}O_2$ of 31.0. This difference might be explained in terms of leg fatigue.

Faulkner (14) indicates that differences in max $\dot{V}O_2$ on bicycle and treadmill is due to reduced stroke volume. This can be explained in terms of biochemical factors of work which contribute to a greater impairment in blood flow from leg muscles during cycling.

The bicycle and treadmill are used most often to measure max $\dot{V}O_2$. Comparisons of different methods of achieving max $\dot{V}O_2$ using the continuous treadmill and bicycle and discontinuous treadmill and bicycle, indicates that the continuous treadmill similar to the Balke test seems to be the most advantageous from the standpoint of administering the test (12).

Motivating women to perform well on a single test for measurement of max $\dot{V}O_2$ has been a problem for some researchers (29), but others indicate that women seem to be highly suited subjects for a test of this nature (18) (29) (30). The psychological factor of motivation, and the state of mind of the subjects is important in the outcome of a successful physical performance.

Difference in Men's and Women's Maximal Oxygen Intake Measurements

When comparing men and women in oxygen consumption capacity, reporting scores in terms of per unit of fat-free body weight would give more accurate predictions. However, Drinkwater (17) believes that expressing scores in terms of fat-free body weight is immaterial when individuals must activate the whole body when performing workloads.

Some physiological information that seems pertinent to oxygen consumption was revealed in a study by Mitchell (18), who found both cardiac capacity and arterial-veninous difference both increase and become more efficient as oxygen capacity increases. Other factors related to max $\dot{V}O_2$ are body size, lean body mass, and cellular metabolic processes (4). Heart rate does not seem to effect aerobic capacity since maximal heart rate tends to be lower in a more fit individual (4) (12).

In 1927, A. V. Hill (43) described a theoretical limit of max $\dot{V}O_2$ to be 5.50 liters per minute. In actuality Hill observed oxygen uptake to be as high as 4.4 liters per minute when measuring a Cornell oarsman. A 1936 olympic two miler was recorded as having a 5.35 liters per minute oxygen uptake. Åstrand has reported the largest value for oxygen uptake of 5.88 liters per minute for a Swedish male skiing champion. In the resting state, oxygen uptake may vary from .200 to .350 liters per minute (36).

Other studies comparing males and females included testing twenty-seven males and seventeen female top swimmers from Japan on the treadmill commencing at 8.6 percent grade. The male swimmers elicited a mean max $\dot{V}O_2$ of 4.40 liters per minute while the female swimmers revealed a much lower mean max $\dot{V}O_2$ of 2.75 liters per minute (53).

Male and female athletes from the Swedish National team were tested to compare max $\dot{V}O_2$. As a team, the best five male cross-country skiers achieved a mean of 5.6 liters per minute. The ten top female athletes had a mean of 3.6 liters per minute (52).

Males tend to have 20-25% higher max $\dot{V}O_2$ than females (19). Macnab and others (20) found that average max $\dot{V}O_2$ measures of males were 50% higher than females when expressed in liters per minute. When these same measurements are expressed in ml/kg/min, the difference is only 23% and is still reduced further when expressed in relation to fat-free body weight. Costell and Winrow (16) found 8.6% difference between sexes when expressed in unit of fat-free and 15.9% when expressed in ml/kg/min.

An interesting study by Hermansen and others (23) noted the max $\dot{V}O_2$ difference in males and females is greater in trained athletes than in those measured between inactive men and women. The highly active female seems to be equivalent in oxygen consumption to the average male. According to Sinning and Adrian (24) the female athlete has a higher max $\dot{V}O_2$ than non-athletes. Åstrand (21) explained this phenomena in terms of hemoglobin concentration. Several other studies (22) (4) agree with Åstrand's analysis and, in addition, add the occurrence of subcutaneous tissue in females. Women tend to have a smaller heart and less blood volume than men (2). The hemoglobin concentration varies with adult males and females. The hemoglobin-to-blood ratio in males is about 15 gm/100/ml and for females the ratio is about 13 gm/100/ml blood (36). As activity is increased cardiac output also increases in women to compensate for the lower hemoglobin level and thus, lower oxygen availability in the arterial blood occurs. The lower arterial blood volume causes the female to have a lower maximal oxygen uptake than males indicate (2).

Several studies have compared ventilation efficiency of males and females (15) (22) (23). In a study by Wells and others (15) girls were found to have a significantly higher ventilation ($VeVO_2$) equivalent than boys. This they explained in terms of boys needing fewer liters of respired air for each liter of oxygen consumed, resulting in greater respiratory efficiency. Hermansen and Anderson (23) surmised that females have a higher pulmonary ventilation even before hyperventilation is begun, indicating that perhaps females breathe more shallowly. As workload is increased, the female athlete increases in pulmonary efficiency.

Other Physiological Considerations Related to Oxygen Intake

Another factor having an effect on oxygen uptake capacity is age. There seems to be a positive relationship between age and aerobic capacity. Aerobic capacity seems to increase up to age eighteen for men and to age fifteen for women (4) (11). From age fifteen to eighteen to approximately twenty-six there seems to be a leveling off period, and both studies (4) (11) agree that about thirty years of age is the time that aerobic capacity begins to decline in both males and females. Knuttgen (4) as well as Wilmore and Brown (19) attribute this decrease in aerobic capacity with age to an instability of tissues and change to a more sedentary lifestyle.

Thirty-five females and thirty-one male subjects performed maximal tests on the treadmill in 1949. Approximately twenty-one years later another test was performed by the same subjects to determine the effects of age on max $\dot{V}O_2$. Maximal oxygen consumption had declined by 20% in males and 22% in females over the timer period (54).

Several studies (11) (25) have noted that the amount of physical activity that a nation or population is engaged in has a direct relationship to their max $\dot{V}O_2$ average. It was reported that Norwegian and Swedish women have a higher average max $\dot{V}O_2$ than either Japanese or American women. The population of Ainus, a once active and now somewhat sedentary group, has $\dot{V}O_2$ closely related to those more urbanized cultures. This environmental factor seems to be a more valid reason for explaining higher max $\dot{V}O_2$ as opposed to genetic differences.

Klissouras (41) performed an interesting study to determine the influence of hereditary on an individuals aerobic capacity. Fifteen monozygous and ten dizygous male subjects, ages seven to thirteen were tested for variability of aerobic capacity. It was concluded that 93% of the subject's aerobic capacity was determined by genetic factors.

In another study closely aligned with Klissouras comparisons were made between trained and untrained monozygous twins. The aerobic capacity of the trained twins were superior by 37%, but the absolute value after training was only average. This indicated that training can improve aerobic capacity, but the ceiling is determined in genetic factors (42).

Women, as well as men, can improve their cardiorespiratory fitness through training. The end result of training - lower heart rate, increased hemoglobin, increased heart volume, and arterial-veinous difference - seems to develop regardless of the sequence of duration or intensity of exercise. A study by Hermansen and Anderson (23) revealed that female non-athletes have a 5% lower fat-free body weight than the female athlete. With training the athlete can increase the density of the capillaries, thus allowing more oxygen to the muscles to perform the workload required.

The higher the aerobic capacity, the longer lactate build-up is delayed and, in turn, the more work can be accomplished before fatigue sets in. According to Drinkwater (26) this lactate build-up is thought to begin when an individual reaches 67% max $\dot{V}O_2$.

Related Oxygen Consumption Studies

Balke, some years ago, devised the Balke Treadmill Procedure and validated 180 heart rate as a predictor of max $\dot{V}O_2$ for men (31). As a result of this study, a nomogram was constructed consisting of a regression line to estimate max $\dot{V}O_2$ for various times required to reach 180 on the treadmill. In 1963 Nagle and Bedecki (5) verified 180 heart rate as a predictor of max $\dot{V}O_2$ in men. They concluded that max $\dot{V}O_2$ was a valid measure of circulatory-respiratory fitness. One of the earliest studies to test females for max $\dot{V}O_2$ was by Metheny and others (49). Seventeen health and physical education majors were tested on the treadmill. They found a mean max $\dot{V}O_2$ of 40.9 ml/kg/min.

Madsud and others (44) investigated twenty-six female athletes on the treadmill to determine max $\dot{V}O_2$. They found a mean max $\dot{V}O_2$ of 41 ml/kg/min. The highest mean max $\dot{V}O_2$, 42.9 ml/kg/min, was attained by the field hockey players. Eisenman and Golding (46) tested eight females after a fourteen week training program and found a max $\dot{V}O_2$ of 44.8 ml/kg/min.

A study by Yoriko and Miyashita (47) tested one hundred and two sedentary and forty-six active adult Japanese females ranging from twenty to sixty-two years of age. The sedentary group ages twenty to twenty-nine had a mean max $\dot{V}O_2$ of 32.4, which the same age group of active women recorded a max $\dot{V}O_2$ of 37.5 ml/kg/min. These subjects were tested on the bicycle ergometer.

Higgs (58) tested twenty female physical education majors while running on the treadmill and concluded a mean max $\dot{V}O_2$ of 41.32 ml/kg/min. One hundred and nine females were tested from ages ten to sixty-eight. Those women within the college age group showed a mean max $\dot{V}O_2$ of 40.36 ml/kg/min (49).

Thirty females ages twenty to forty years of age were tested on the bicycle ergometer by Bell and Hinson (55). Average max $\dot{V}O_2$ was 29.74 ml/kg/min. The group was heterogeneous with regards to training levels, ranging from sedentary housewives to moderately active participants in a city softball league. Twenty-eight college women enrolled in a required physical education class were tested on the treadmill and a mean max $\dot{V}O_2$ of 44.43 ml/kg/min was revealed. Investigators of this study were unable to predict max $\dot{V}O_2$ from sub-maximal measures (57).

Flint and others (56) tested three non-trained females to determine the effects of a six week training program on max $\dot{V}O_2$. It was found that after the training program, max $\dot{V}O_2$ values increased 12%.

Other studies utilizing female athletes included seventeen Norwegian female cross-country skiers who were compared to nine sedentary women in regards to max $\dot{V}O_2$ using the bicycle ergometer. It was concluded that the athletes had a mean max $\dot{V}O_2$ of 55 ml/kg/min, while the sedentary group showed a mean of 38 ml/kg/min (23). McArdle and others

(48) tested six female varsity basketball players and found a mean max $\dot{V}O_2$ of only 35.75 ml/kg/min. Wilmore and Brown (19) studied female distant runners and found a considerably higher max $\dot{V}O_2$ than other values cited in the literature. This value was 59.1 ml/kg/min. Forty athletes and forty non-athletes were tested on the bicycle ergometer by Conger and Macnab (51). The athlete group showed a mean max $\dot{V}O_2$ of 40.7 ml/kg/min and the non-athletes a mean max $\dot{V}O_2$ of 34.0 ml/kg/min. These figures tend to support other studies that state the bicycle ergometer consistently reveals 8-19% lower values than on the treadmill (11).

Horvath and Michael (8) tested thirty female subjects seventeen to twenty-two years of age on the bicycle ergometer. As the subjects peddled the workload was increased each minute until the subject could no longer work. Heart rate was monitored as well as expired air collected in a Tissot Tank and was analyzed for oxygen. Subjects were all given a retest. The maximal heart rate was 184 BPM and max $\dot{V}O_2$ was 29.8 ml/kg/min. Max $\dot{V}O_2$ predictions could not be made at any sub-maximal measurement.

Humphrey and Falls (27) tested fifteen college female physical education majors at near heart rates of 180 to determine a valid predictor using the progressive treadmill test. Treadmill speed was 3.5 MPH at 0 grade for the first two minutes and each subsequent minute the grade was raised one degree until the subject ceased exercise. Expired air was collected at mean heart rate of 182 and at mean heart rate of 193 for the final minute of walk. This study found that work-load at 180 was a valid predictor of max $\dot{V}O_2$ at .7 correlation coefficient.

Another study by McArdle and others (32) tested the interrelationship among maximum oxygen consumption, physical work capacity, and step test scores of forty-one college women. The Balke Treadmill Procedure was used to determine max $\dot{V}O_2$ and physical work capacity. PWC was the time that the subject reached heart rates of 150 and 170. Max $\dot{V}O_2$ was found to be 37 ml/kg/min. It was found that the three minute step test is just as valid a predictor of max $\dot{V}O_2$ as is the Balke treadmill test. Custer and Chaloupka (59) tested forty college age females on the bicycle ergometer to determine max $\dot{V}O_2$. The purpose of this study was to determine the predictability of max $\dot{V}O_2$ from the running performance of six, nine, and twelve minutes. The twelve minute run has in some cases been customarily used as a measure of cardiorespiratory fitness. It was concluded that the six minute run could be used in lieu of the twelve minute run to determine cardiovascular fitness.

Getchell and others (60) tested twenty-one experienced female joggers (mean age twenty and one tenth years) to determine the predictability of maximal oxygen uptake from a 1.5 mile running performance. Using a continuous treadmill run to exhaustion, a mean maximum $\dot{V}O_2$ of 46.2 ml/kg/min was found. The authors concluded that for young adult joggers with no problem of excess body fat or weight, the 1.5 mile run tended to be a suitable distance for estimating cardiovascular endurance.

One of the most recent studies predicting oxygen consumption was completed by K. D. Campbell (39). She tested thirty-eight endurance type athletes from four sports that seemed to stress cardiorespiratory attributes to determine if time to reach 180 and 190 heart rate was a valid predictor of max $\dot{V}O_2$. Mean max $\dot{V}O_2$ was 46.95 ml/kg/min. She found the Balke regression line using time to reach 180 heart rate was a valid predictor of max $\dot{V}O_2$ for trained female athletes. There was no significant difference found within the four groups of athletes with respect to oxygen intake or time to reach heart rates on the treadmill.

This researcher utilized the Balke procedure to determine the time it takes to reach 180 and 190 heart rates and correlate this time with max $\dot{V}O_2$ scores.

Summary

Most of the studies in this review indicated a serious lack of consistency in the testing procedures and in predicting maximum oxygen consumption. There is some agreement, however, that the Balke procedure consistently reveals higher max $\dot{V}O_2$ scores than the bicycle ergometer. The treadmill test that seems to be the most advantageous from the standpoint of administering is the Balke procedure.

There also seems to be some general agreement in the literature that indicates that men do have a higher maximal oxygen intake when measured in ml/kg/min. This range is from 10-30% with most studies indicating about 25%. When max $\dot{V}O_2$ scores are expressed in terms of fat-free body weight, the difference gap appears to narrow. However, most of the max $\dot{V}O_2$ studies are expressed in ml/kg/min. Other factors which seem to have an influence on the oxygen consumption level in women are age, environment, and amount of training in which they are engaged.

The Balke Treadmill Procedure has been used extensively in testing maximum oxygen consumption in men. Since the trend now is toward women engaging in physical activity, fitness programs and athletics, more concern has been focused on physiological considerations in the area of maximum oxygen consumption. There have been a few studies in this area using women as subjects, but not enough to draw a valid conclusion.

CHAPTER III

METHODS AND PROCEDURES

The purpose of this study was to determine if the workloads at 180 and 190 heart rates are valid predictors of maximum oxygen consumption in college women. This chapter outlines the methodology and procedures used in assessing maximum oxygen consumption on the treadmill.

Selection of Subjects

The subjects in this study consisted of sixty Oklahoma State University female students. These subjects were selected from Health, Physical Education, and Leisure Services (HPELS) majors, non-majors enrolled in HPELS classes and intercollegiate athletes. A total of twenty HPELS female majors were randomly selected from the total Oklahoma State HPELS major population (two hundred students); twenty subjects were randomly selected from sixty volunteer non-majors enrolled in HPELS classes; and twenty subjects were selected from the nine intercollegiate teams by the following procedure: six names were randomly selected each from the nine varsity teams (Basketball, Field Hockey, Golf, Gymnastics, Softball, Swimming, Tennis, Track and Field, and Volleyball) - one hundred and forty-two students. From these fifty-six names twenty subjects were randomly selected so each team would have equal opportunity to be chosen. The number of subjects selected from each sport was as follows: Basketball - three, Field Hockey - three, Golf - two, Gymnastics - three, Softball - two, Swimming - one, Tennis - two, Track and Field - two, and Volleyball - two.

Selection of Test for Assessing Maximum Oxygen Consumption

The test used in this study was the treadmill test as described by Balke and Ware, with a treadmill speed of 3.4 MPH (36). Subjects walked at 0% grade for the first two minutes. The grade was then raised to 2% and increased 1% a minute until the subject stopped walking. A study in 1972 by McArdle (32) found the Balke treadmill test provides a highly reproducible means for assessing aerobic capacity in women.

Test Procedure

Subjects reported to the Oklahoma State University Physiology Laboratory dressed in activity clothes - shorts, shirt, and tennis shoes. Data, such as age, height, and weight, was recorded for each participant. The subject was asked to lie down on the laboratory table so that electrodes could be attached over the upper sternum and lower left rib cage areas (V-5 lead). The telemetry transmitter was taped to the side just behind the rib electrode. The telemetry receiver was checked to determine if the EKG signal was being picked up by the physiograph. At this time, subjects were asked to rest quietly for an additional two minutes. A resting heart rate was monitored on the physiograph and continued to be monitored throughout the exercise during the last fifteen seconds of each minute.

Next, the subjects were instructed to sit up and listen to and watch an explanation-demonstration by the researcher of the proper procedure for mounting and dismounting the treadmill. Also at this time subjects were familiarized with the mouthpiece and nose clip to be used later to collect air samples. Subjects were then instructed to mount the treadmill. Subjects were observed until the researcher was satisfied that a normal walking pace had been achieved. Immediately following this adjustment the treadmill test was begun. Subjects walked at 0% grade for two minutes and the workload was increased 1% each minute. During the early part of the test the subject was handed the one-way valve to place in her mouth so she could become accustomed to breathing through the valve while walking before the expired air was actually collected. Subjects were encouraged to continue the workload as long as possible.

Gas samples were collected during the last thirty seconds of the workload at heart rates of 180, 190, and maximal. By collecting a sample of air in the tissot tank at 180 BPM and 190 BPM, one could determine if $\dot{V}O_2$ was leveling off, indicating maximum oxygen consumption had been reached. When the subject felt she was on her last minute of the test, she was asked to indicate this to the researcher so a thirty second expired air sample could be collected in the Collins Tissot Tank. After volume readings were recorded, gas samples were transferred to the Godart Pulmo-analyzer in one liter rubber bags in order to analyze the expired air for oxygen and carbon dioxide. The Pulmo-analyzer had been calibrated against a modified Haldane and then a calibration curve was prepared for the oxygen readings. Oxygen uptake was calculated according to the open circuit method as described by Ricci (36).

A nomogram devised by Dill and Folling (45) was used to calculate the respiratory quotient and true oxygen. Temperature was recorded from a gauge secured on the top of the Collins Tissot Tank. Barometric pressure was obtained each day from the Stillwater Municipal Airport altimeter setting. Temperature correction was then determined by using the nomogram devised by Robert C. Darling (45).

At the completion of the test, subjects dismounted the treadmill and sat on the laboratory table. Heart rate continued to be monitored for approximately five minutes after the workload was completed. An assistant was used to help oversee the physiograph and treadmill while the researcher was collecting and analyzing gas samples.

Grouping and Analysis of Data

At the completion of the test, means and standard deviations were computed for heart rates at 180, 190, and maximal, time to reach heart rate 180, 190, and maximal, oxygen uptake at 180, 190, and maximal, percent oxygen, percent carbon dioxide, corrected ventilation, respiratory quotient, and the Balke prediction and Balke prediction plus 25%.

A Pearson Product-moment was calculated to show the relationship between time to reach heart rate 180, 190, and maximum oxygen consumption.

An ANOVA was calculated to determine difference between groups in oxygen uptake at heart rate 180, 190, and maximum, time to reach heart rate 180, 190, and maximum, maximum heart rate, and corrected ventilation at heart rate 180, 190, and maximum.

Reliability of the test procedures and maximum oxygen consumption measures was determined by correlating test-retest scores on twelve randomly selected subjects. A product-moment correlation was calculated between max $\dot{V}O_2$ and time to reach 180 heart rate. Additionally, a product-moment correlation was calculated between max $\dot{V}O_2$ and time to reach 190 heart rate in order to determine which was the best predictor of maximum oxygen consumption.

Regression lines were constructed by using both the 180 and 190 heart rate as a predictor of max $\dot{V}O_2$. An additional regression line was constructed for the major group using time to reach heart rate 190 and maximal oxygen consumption. The two variables used in constructing these lines were the time it takes to reach 180 and 190 heart beats and maximum oxygen uptake. A calculation was made to determine the relationship of the present regression line constructed by Balke for men, and the regression line devised in this study. In the Oklahoma State University Physiology of Exercise class, the regression line for men, as validated by the Balke test, was being used with a correction factor being applied to the men's scores to predict a woman's maximum oxygen uptake score.

The statistical analysis for this study was completed at the Oklahoma State University computer center. The program used to compute the Pearson Product-moment correlation, analysis of variance, and the regression equation were designed by North Carolina State University as part of the Statistical Analysis System (SAS).

CHAPTER IV

RESULTS AND DISCUSSION

A total of sixty undergraduate college women participated in a study to determine if time to reach 180 and 190 heart rate was a valid predictor of maximum oxygen consumption. Subjects were tested on the treadmill utilizing the Balke procedure. The total population of subjects were divided into three groups which consisted of athletes, physical education majors, and non-majors enrolled in HPELS activity classes.

Reliability

Reliability was tested both for the Balke treadmill test and maximum oxygen consumption by a test-retest procedure. Four subjects were selected at random from each of the three individual groups and retested approximately one month after the initial testing. The results of the test-retest calculations are found in Tables I and II.

Means for the initial test for max $\dot{V}O_2$ was 44.38 ml/kg/min and the retest mean showed 45.14 ml/kg/min. The time to reach maximum heart rate showed a mean of 17.58 minutes for the initial test and 18.73 minutes recorded for the retest.

A Pearson Product-moment correlation was calculated for time to reach maximum to determine the reliability of the Balke procedure. A relationship of r=.84 was found. The same correlations r=.84 were

TABLE I

TEST-RETEST MAX VO_2

Group	Mean Max $\dot{V}O_2$ (ml/kg/min)	Mean Max $\dot{V}O_2$ ml/kg/min re-test	Correlation
Total population (N=12)	44.38	45.14	.84
Athletes (N=4)	45.98	46.85	
Majors (N=4)	45.16	44.77	
Non-Majors (N=4)	41.99	43.70	

TABLE II

TEST-RETEST-PERCENT GRADE

Group	Mean Max Percent Grade	Mean Max Percent Grade Retest	Correlation
Total population (N=12)	17.58	18.73	.84
Athletes (N=4)	19.40	18.75	
Major (N=4)	17.81	17.33	
Non-Majors (N=4)	15.42	16.75	

calculated with max $\dot{V}O_2$ to test for reliability. According to Mathews (40) these correlations are considered fair. Reliability correlations might have shown a higher relationship if subjects had been retested closer to the initial testing period.

Means and Standard Deviation of Oxygen Uptake and Heart Rate

The maximum oxygen consumption for the entire population tested using the Balke treadmill test revealed a mean of 44.38 milliters per kilogram of body weight per minute (ml/kg/min). This figure was larger than those found in the literature; however, few studies have been done using both trained and untrained women subjects together. Katch et al. (38), tested athletes, physical education majors and non-majors and found an overall mean max $\dot{V}O_2$ of 38.9 ml/kg/min. Humphrey and Falls (27) determined mean max $\dot{V}O_2$ for fifteen women physical education majors to be 38.50 ml/kg/min. This author speculates that as women become more physically active and engage in strenuous fitness programs, max $\dot{V}O_2$ will continue to rise.

The mean for the female population using the Balke prediction for men was 34.61 ml/kg/min and when 25% was added to this figure as Dr. A. B. Harrison at OSU has done to compensate for apparent underestimations, a mean max $\dot{V}O_2$ of 41.09 ml/kg/min was revealed. Both of these values are underestimations of the actual max $\dot{V}O_2$ found in this study.

The mean max $\dot{V}O_2$ for the athlete group was found to be 45.98 ml/kg/min. This figure was slightly lower than the mean produced in the Campbell (39) study of 46.95 ml/kg/min; however, the Campbell study was concerned with specific endurance type athletes. McArdle et al. (32), found a figure of 45.0 ml/kg/min while investigating six varsity coeds in swimming, field hockey, basketball, and track. In 1973, Katch (38) discovered a mean for max $\dot{V}O_2$ of 43.7 ml/kg/min when comparing athletes with physical education majors and non-majors. The mean max $\dot{V}O_2$ for athletes in this study were similar to those found for other athletes in America. Many of the foreign athletes, such as those found in Norway and Sweden (32) have produced mean max $\dot{V}O_2$ of 55 ml/kg/min and 61.8 ml/kg/min, respectively. These large figures are probably due, not only to genetic factors, but the intensity of the European training programs as well as the motivation possessed by these women to excell.

Using the Balke regression equation for men, the mean for the athlete group was 34.61 ml/kg/min and 43.26 ml/kg/min when 25% was added to the former figure. Again this indicated an underestimation of the actual max $\dot{V}O_2$ of 45.98 ml/kg/min for this group.

The mean max $\dot{V}O_2$ for the major group showed a value of 45.16 ml/kg/min. This value was similar to the mean max $\dot{V}O_2$ found in the athlete group, but was considerably higher than the literature indicates for this particular group. In 1972, a study by McArdle (32) tested thirty-five non-athletic women on the treadmill and reported a max $\dot{V}O_2$ of 37.3 ml/kg/min. In 1956, Åstrand (21) tested forty-four Swedish women physical education students and found a max $\dot{V}O_2$ of 48.4 ml/kg/min.

The maximum oxygen consumption for the non-major group was calculated to be 41.99 ml/kg/min. This figure was also larger than most of the studies indicated in the literature. Michael (8) tested thirty California coeds and revealed a maximum oxygen uptake of only 29.8 ml/kg/min. One explanation for the higher values found in the present study might have been the fact that all non-major subjects were participants in physical education classes at the time of the testing.

Table III expresses a comparison of max $\dot{V}O_2$ scores of the subjects in the present study with data reported in the literature for trained and untrained women. Figure 1 graphically displays O_2 uptake at heart rate 180, 190, and maximal.

The mean maximal heart rate for the total population tested was 194.53 beats per minute, which was similar to the findings cited in the literature (27) (32). When the maximum heart rate was isolated and included only those rates above 190 heart rate, a higher mean value of 197.71 beats per minute was found. The mean maximum heart rate for the athlete group was 195.20 beats per minute. This value was similar to heart rate values found in other studies using women subjects (38) (24) (29). Mean maximum heart rate for the major group was 195 beats per minute. When maximum heart rate for this group was isolated and included only those values above 190 beats per minute, a slightly higher average of 196 beats per minute was found. The maximum heart rate mean for the non-majors group was 194 beats per minute. This figure was not significantly different from either the athlete or the major group. Figure 2 displays maximal heart rate for total population and individual groups.

The mean maximum percent grade reached on the treadmill or time to reach maximum heart rate was 17.58 minutes for the total population. The athlete group revealed a mean of 19.4 minutes as the time to reach maximum heart rate. The figures for this group ranged from fifteen minutes to an extremely high value of twenty-seven minutes to reach maximum heart rate.

TABLE III

COMPARISON OF MAX $\dot{V}O_2$ SCORES OF THE PRESENT SUBJECTS WITH DATA REPORTED FOR TRAINED AND UNTRAINED WOMEN

Year	Author	Country	N	Subject	Max $\dot{V}O_2$ L/min	Max $\dot{V}O_2$ Ml/Kg/Min	Method
1956	Astrand (21)	Sweden	44	P.E. Students	2.90	48.4	Bicycle
1965	Michael and Horvath (8)	U.S.A.	30	Untrained	1.78	29.8	Bicycle
1970	Horvath and Michael (34)	U.S.A.	14	Untrained	1.93	31.0	Bicycle
1971	Drinkwater (33)	U.S.A.	2	Athletes	2.76	51.1	Treadmill
1972	McArdle (32)	U.S.A.	6	Athletes	2.70	45.0	Treadmill
1972	McArdle (32)	U.S.A.	35	Untrained	2.16	37.3	Treadmill
1973	Katch (38)	U.S.A.	36	Athletes, Majors, and Non-majors	2.29	38.90	Treadmill
1976	Humphrey	U.S.A.	15	Physical Education Majors	3.60	38.50	Treadmill
1977	Campbell (39)	U.S.A.	28	Athletes	2.92	46.95	Treadmill
1977	Present Study	U.S.A.	60	Athletes, Majors and Non-majors	2.64	44.38	Treadmill

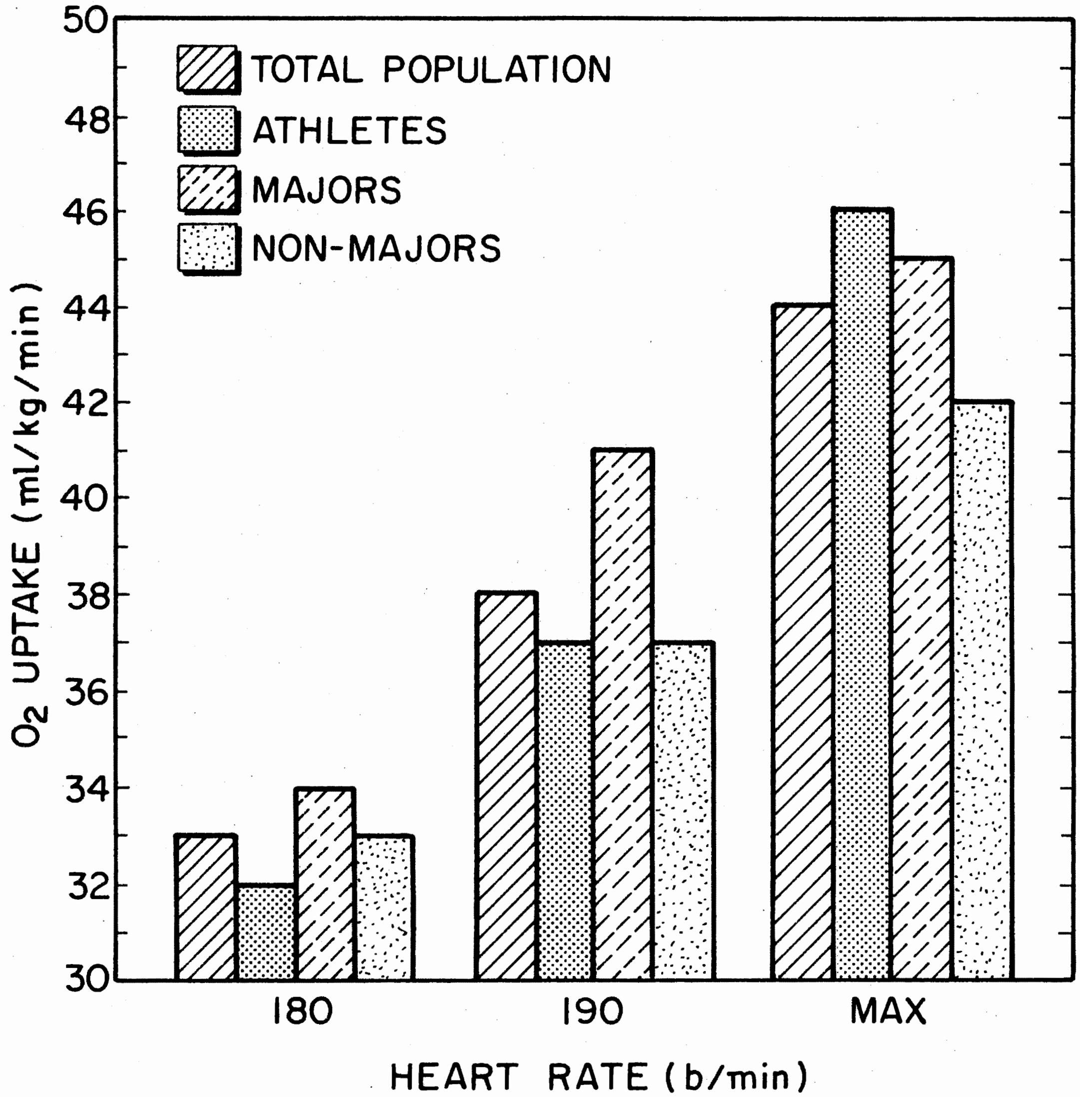

Figure 1. Mean O_2 Uptake ml/kg/min at Heart Rate 180, 190, and Maximal

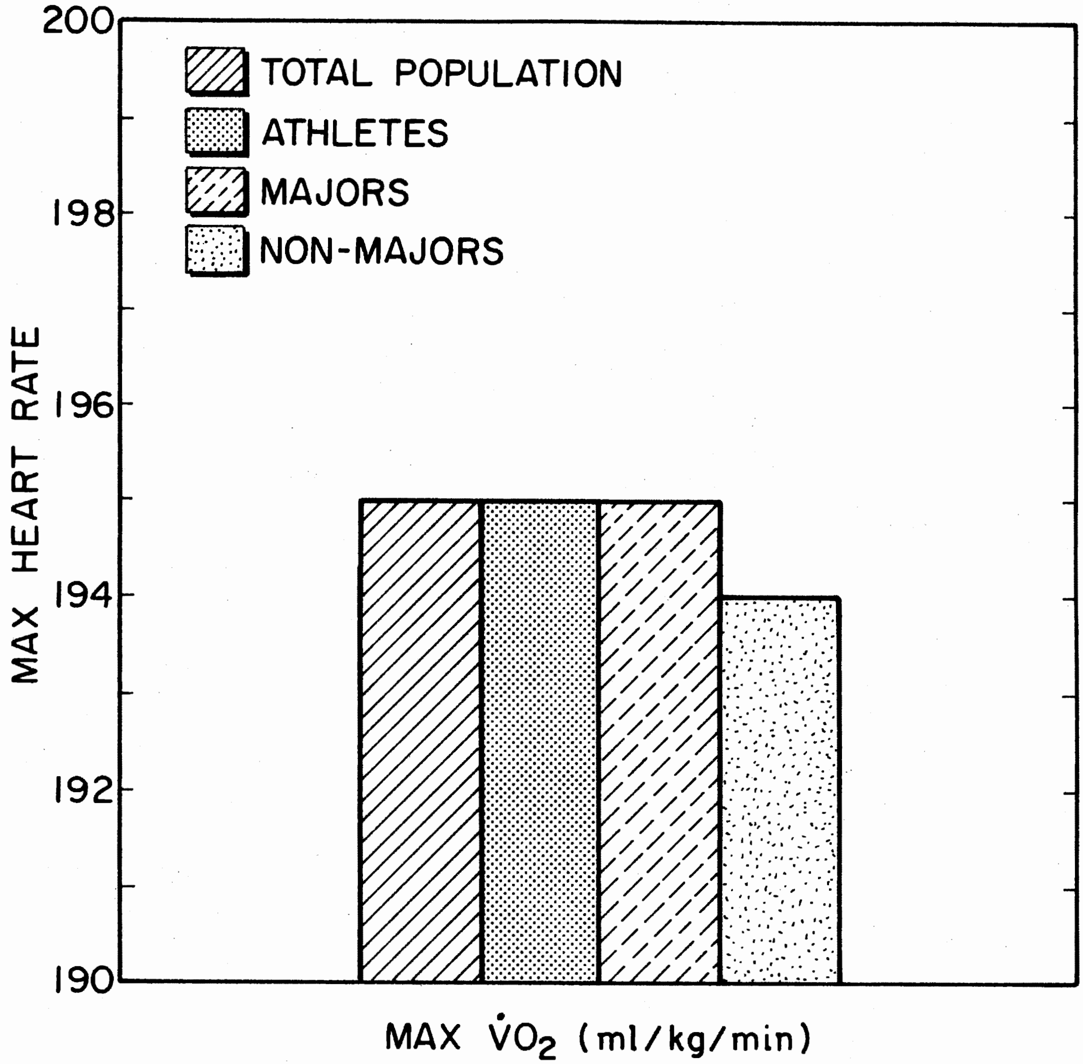

Figure 2. Maximum Heart Rate

The mean for time to reach maximum heart rate for the major group was 18.00 minutes. The mean time to reach heart rate 180 was 13.20 minutes and time to reach heart rate 190 was 15.20 minutes. The time to reach heart rate 180, 190, and maximum increased from a mean of 13.89 minutes at 180 to 19.40 minutes at maximum heart rate for the non-major group. Figure 3 expresses means for time to reach 180, 190, and maximum heart rate for total population and individual groups.

Means and standard deviation for O_2 uptake, heart rate, and time to reach heart rates are found in Tables IV, V, VI, and VII.

Analysis of Variance Between Groups

Differences between groups were calculated for oxygen uptake at 180, 190, and maximal heart rate, maximum heart rate, time to reach rate 180, 190, and maximal heart rate. A summary of the ANOVA between groups is displayed in Table VIII. Means for significant variables are shown in Table IX. When analyzing the oxygen uptake at heart rate 180, 190, and maximal, the only significant difference between groups was found in maximum oxygen consumption when expressed in liters. This difference appeared between athletes and non-majors at both .01 level and .05 level of significance and between majors and non-majors at the .05 level. No significant difference was found between groups when oxygen uptake was expressed in ml/kg/min. Significant differences were also found between groups at time to reach heart rate 180, 190, and maximum. Again this difference was found between athletes and non-majors and majors and non-majors. Significant differences in corrected ventilation at maximum heart rate were calculated between the same groups as mentioned above. The data in this study indicates very little difference in subjects in

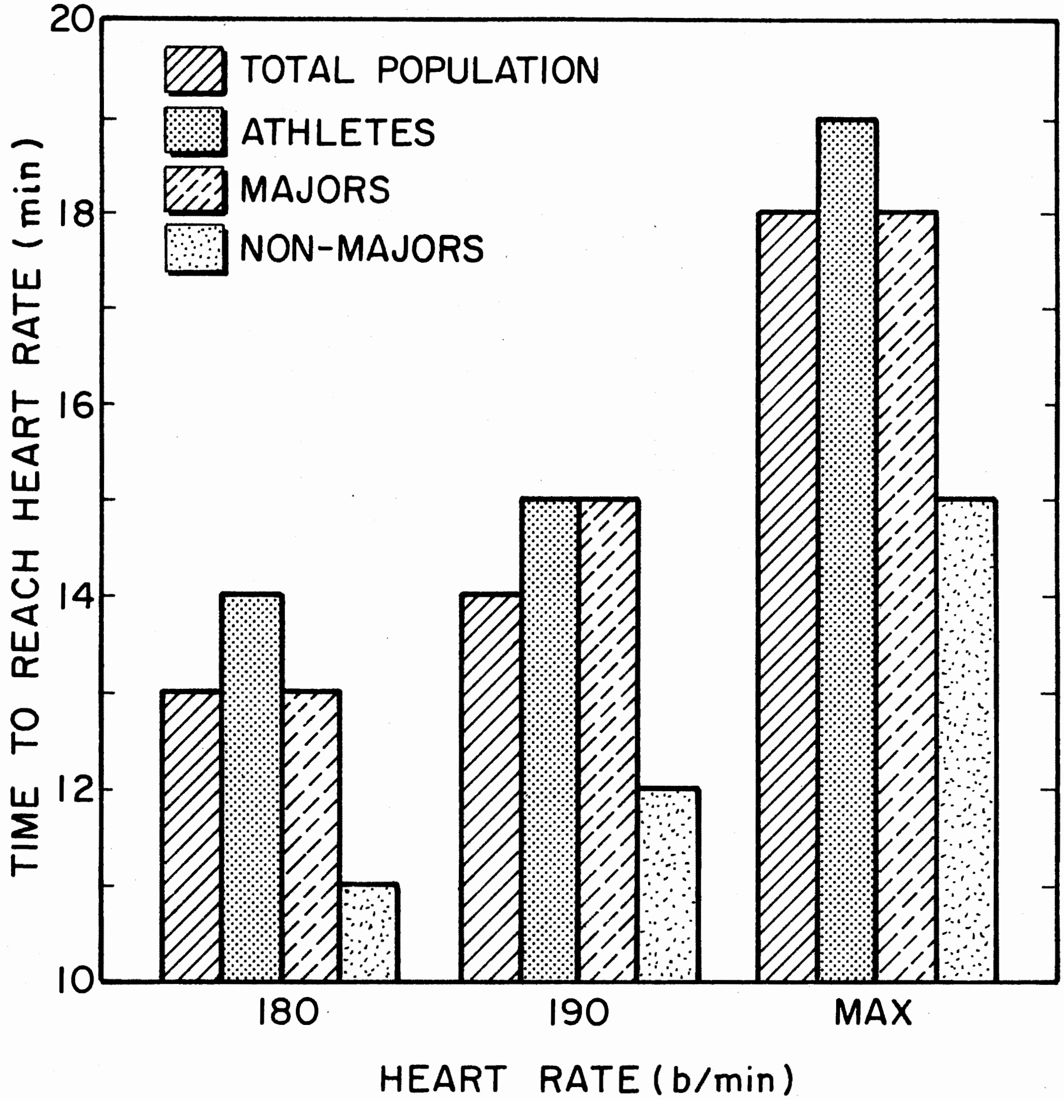

Figure 3. Means for Time to Reach 180, 190, and Max Heart Rate

TABLE IV

MEANS AND STANDARD DEVIATIONS FOR TOTAL POPULATION

Variable	N	Mean	Standard Deviation
Max $\dot{V}O_2$ (L/min)	60	2.64	.489
Max $\dot{V}O_2$ (ml/kg/min)	60	44.38	6.60
Balke Prediction (ml/kg/min)	55	32.87	5.17
Balke Prediction plus 25%	55	41.09	6.46
Max heart rate (b/min)	60	194.53	8.44
Time to reach max heart rate (min)	60	17.58	3.15

TABLE V

MEANS AND STANDARD DEVIATIONS FOR ATHLETE GROUP

Variable	N	Mean	Standard Deviation
Max $\dot{V}O_2$ (L/min)	20	2.86	.431
Max $\dot{V}O_2$ (ml/kg/min)	20	45.98	5.66
Balke Prediction (ml/kg/min)	18	34.61	6.13
Balke Prediction plus 25%	18	43.26	7.67
Max heart rate (b/min)	20	195.20	9.66
Time to reach max heart rate (min)	20	19.40	2.95

TABLE VI

MEANS AND STANDARD DEVIATIONS FOR MAJOR GROUP

Variable	N	Mean	Standard Deviation
Max $\dot{V}O_2$ (L/min)	20	2.69	.535
Max $\dot{V}O_2$ (ml/kg/min)	20	45.16	7.77
Balke Prediction (ml/kg/min)	20	33.74	4.00
Balke Prediction plus 25%	20	42.17	5.00
Max heart rate (b/min)	20	194.80	5.29
Time to reach max heart rate (min)	20	17.08	.289

TABLE VII

MEANS AND STANDARD DEVIATIONS OF NON-MAJORS

Variable	N	Mean	Standard Deviation
Max $\dot{V}O_2$ (L/min)	20	2.364	.374
Max $\dot{V}O_2$ (ml/kg/min)	20	41.99	5.80
Balke Prediction (ml/kg/min)	17	30.00	4.25
Balke Prediction plus 25%	17	37.50	5.32
Max heart rate (b/min)	20	193.60	9.94
Time to reach max heart rate (min)	20	16.95	.2806

TABLE VIII

ANOVA BETWEEN GROUPS

Variable	Level Of Significance	LSD.01	LSD.05
Oxygen uptake 180 (L/min)	.6667	.440	.330
Oxygen uptake 180 (ml/kg/min)	.5406	5.27	3.96
Oxygen uptake 190 (L/min)	.1763	.398	.297
Oxygen uptake 190 (ml/kg/min)	.1274	5.85	4.37
Oxygen uptake max (L/min)	.004	.381	.286
Oxygen uptake max (ml/kg/min)	.128	5.46	4.10
Heart rate max (b/min)	.830	7.22	5.42
Time to reach 180 heart rate (min)	.009	2.47	1.85
Time to reach 190 heart rate (min)	.007	2.55	1.90
Time to reach max heart rate (min)	.0002	2.27	1.71
Corrected ventilation at 180 (L/min)	.580	10.97	8.23
Corrected ventilation at 190 (L/min)	.3022	11.96	8.92
Corrected ventilation at max (L/min)	.010	10.14	7.62

the athlete and major group. Their similarity might be attributed to the extensive program of physical activity in which these groups participate.

TABLE IX

MEANS FOR SIGNIFICANT VARIABLES

Variable	Athletes		Majors	Non-majors
O_2 uptake max (^{L}/min)	2.86**	--------	2.69*	2.36
Time to reach 180 (min)	13.89**	--------	13.20*	11.00
Time to reach 190 (min)	15.07**	--------	15.20**	12.25
Time to reach max (min)	19.40**	--------	18.00**	15.35
Corrected ventilation max (^{L}/min)	69.23*	--------	69.06*	58.69

*Significant at .05 between group indicated and non-majors.

**Significant at .01 between group indicated and non-majors.

--Connecting lines indicate no significant differences between groups.

Correlations Between Variables

The author of this study expressed a level of .7 as a measure to be used as validation. The time to reach 180 and 190 heart rate were correlated with the actual maximum oxygen consumption to determine if one or both measures would be a valid predictor of max $\dot{V}O_2$ without having to work the subject to exhaustion. This study revealed for the total population, a correlation of .50 when time to reach 180 heart rate and max $\dot{V}O_2$ were compared. The correlation between time to reach 190 heart rate and max $\dot{V}O_2$ expressed a higher value of .57. Both of these values produced a slightly higher correlation when expressed in liters per minute. When the Balke predicted max $\dot{V}O_2$ for men was correlated with the actual max $\dot{V}O_2$ found in this study, a relationship of only .51 was recorded. Although none of these correlations proved to be very high (.7 or above), the time to reach 190 heart rate appeared to be the better predictor of max $\dot{V}O_2$ for the entire population when expressed in ml/kg/min.

Correlations in the athlete group for time to reach 180 heart rate and max $\dot{V}O_2$ revealed an r=.53. A smaller relationship (.44) existed between time to reach 190 heart rate and max $\dot{V}O_2$. The Balke prediction for men showed a .55 relationship with max $\dot{V}O_2$. Although not significant, the Balke prediction appears to be the best predictor of max $\dot{V}O_2$ for the athlete group. Campbell (39) found a valid correlation of .81 between the actual max $\dot{V}O_2$ of female athletes and that predicted from Balke's equation for men.

Significant correlations were found in the major group between time to reach 190 heart rate and max $\dot{V}O_2$ (ml/kg/min). This correlation was computed to be .84 and consequently could be used as a valid predictor of max $\dot{V}O_2$. Correlations between time to reach 180 heart rate and max $\dot{V}O_2$ (ml/kg/min) revealed a .55 relationship. This was also the identical value found when testing the relationship of the Balke prediction and actual max $\dot{V}O_2$. The majors were the only group that revealed a valid relationship between time to reach either 180 or 190 heart rate and max $\dot{V}O_2$.

The correlations found within the non-major group was different compared to the other groups. The relationship between time to reach heart rate 180 and max $\dot{V}O_2$ was r=.26. When correlations were made between time to reach heart rate 190 and max $\dot{V}O_2$, the relationship was only r=.02. The relationship between the Balke prediction and actual max $\dot{V}O_2$ revealed an r=.25. The best predictor, of max $\dot{V}O_2$ in L/min, for the non-major group was time to reach heart rate 190. This correlation was .56, not high enough for validity of prediction. This author observed that the weight mean for the non-major group was less than those in either the athlete or major group. This could be an explanation for the higher correlation when expressed in liters as opposed to ml/kg/min. Correlations expressing calculations of data are found in Tables X, XI, XII, and XIII.

Means and Standard Deviations of Additional Variables

Means and standard deviations were calculated for percent oxygen, carbon dioxide percent, corrected minute ventilation and respiratory quotient at heart rate 180, 190, and maximum.

The means for oxygen percent in the expired air for the total population of subjects was 16.66 at 180 heart rate and gradually increased to a mean of 16.96 at maximum workload. These readings indicated the subject was reaching close to her maximum workload and oxygen percent was beginning to stabilize. When oxygen percent at

TABLE X

CORRELATIONS FOR TOTAL POPULATION

Variable	Max $\dot{V}O_2$ ($^L/min$)	Max $\dot{V}O_2$ (ml/kg/min)
Time to reach 180 HR	.628	.4973
Time to reach 190 HR	.610	.571
Balke Prediction	----	.498

TABLE XI

CORRELATION FOR ATHLETE GROUP

Variable	Max $\dot{V}O_2$ ($^L/min$)	Max $\dot{V}O_2$ (ml/kg/min)
Time to reach 180 HR	.526	.531
Time to reach 190 HR	.267	.439
Balke Prediction	----	.533

TABLE XII

CORRELATIONS FOR MAJOR GROUP

Variable	Max $\dot{V}O_2$ (^{L}/min)	Max $\dot{V}O_2$ (ml/kg/min)
Time to reach 180 HR	.708	.545
Time to reach 190 HR	.755	.843
Balke Prediction	----	.545

TABLE XIII

CORRELATIONS FOR NON-MAJOR GROUP

Variable	Max $\dot{V}O_2$ (^{L}/min)	Max $\dot{V}O_2$ (ml/kg/min)
Time to reach 180 HR	.423	.258
Time to reach 190 HR	.560	.019
Balke Prediction	----	.251

maximum workload was isolated and only included those percentages over 190 heart rate, there was only a .08 decrease in the value thus indicating extreme scores were not significantly affecting the maximal figure.

The mean for oxygen percent in the expired air increased as the workload increased in the athlete group. Mean oxygen percent at heart rate 180 was 16.54 and at heart rate 190 a mean of 16.57 was recorded. The oxygen percent at maximum heart rate was 16.85.

The percent oxygen in the expired air for the major group, similar to the athlete group, increased as the workload increased. Oxygen percent means ranged from 16.76 at heart rate 180 to 16.85 at maximum heart rate.

The percent oxygen in the expired air of the non-major group was similar to the athlete and majors group in that as workload increased oxygen percent in expired air increased. Mean oxygen percent at 180 heart rate was 16.68, and 16.90 at maximum heart rate. Figure 4 shows oxygen percent means for total population and individual groups.

The mean carbon dioxide percent in the expired air for the total population stabilized as the workload increased. This data, is interesting, since one would expect the carbon dioxide percent to increase in the expired air as the body consumed more oxygen. The carbon dioxide percent in the expired air stabilized at 180 and 190 heart rate, but then declined slightly at maximum heart rate in the athlete group. In the major group, the carbon dioxide percent decreased slightly at each heart rate level. The mean ranged from 3.90 at 180 heart rate to 3.65 at maximum heart rate. The explanation this author has for this phenomenon is that subjects are able to work longer with increased levels of carbon

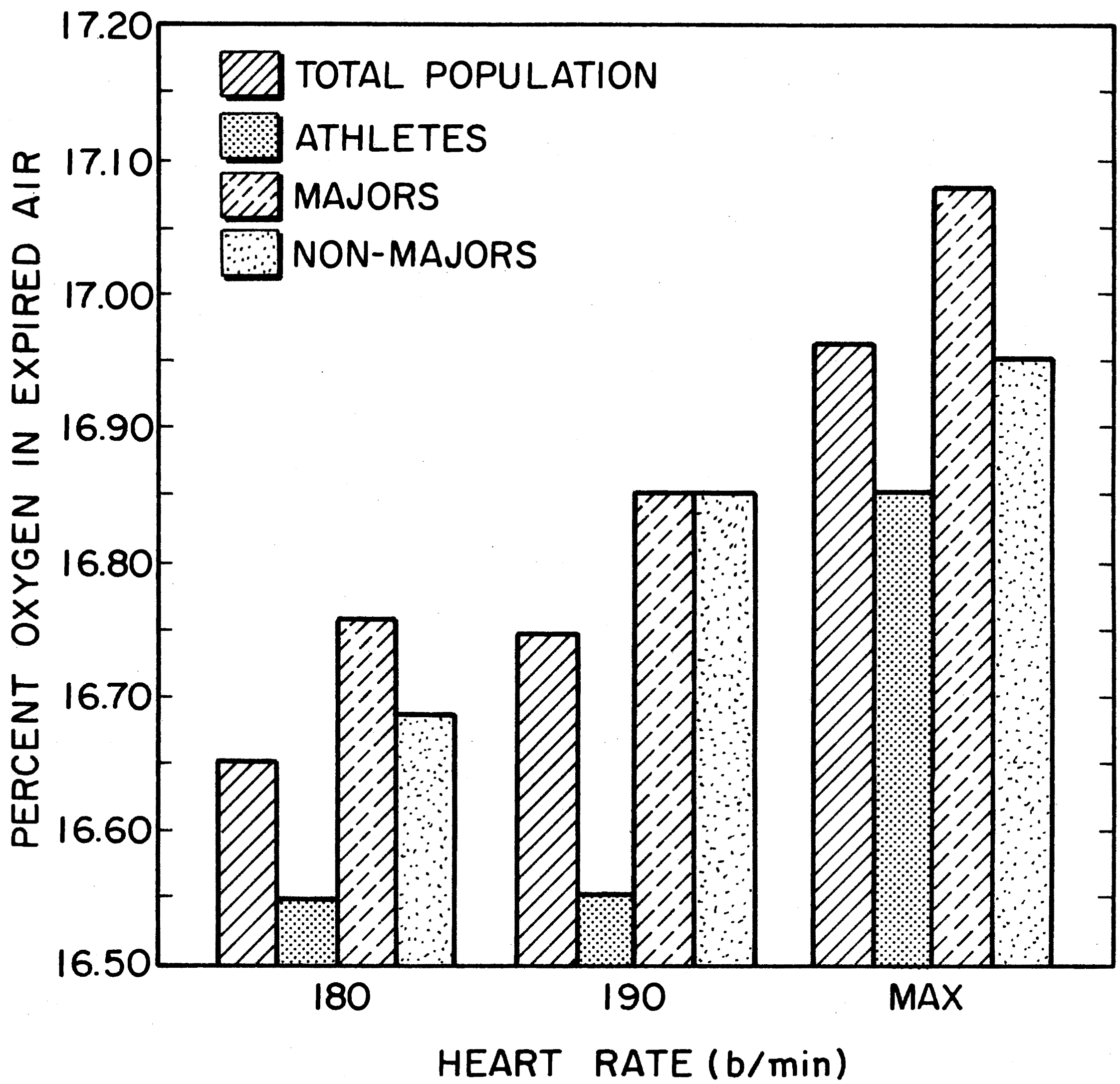

Figure 4. Mean O_2 Percent in Expired Air

dioxide. The carbon dioxide means in the non-major group also stabilized as workload increased. The athlete and major groups tended to produce more carbon dioxide than non-majors thus indicating that the former group are able to continue the workload longer without extracting more oxygen. Carbon dioxide percent mean ranged from 3.79 at 180 heart rate to 3.78 at maximum heart rate. Figure 5 displays means for total population and individual groups.

Corrected ventilation for total population at heart rate 180, 190, and maximum increased as expected, commencing at a mean of 48.59 L/min at 180 heart rate, 56.31 L/min at 190 heart rate, and at maximum workload a mean of 69.06 L/min. The figures recorded in this study are lower than the ventilation average of subjects cited by Humphrey and Falls of 91.12. These differences might be explained by difference in body size or levels of training. The corrected ventilation mean for the athlete group increased progressively at all three heart rate levels. Ventilation at maximum heart rate was calculated at 69.23 L/min. Corrected ventilation means for both the major and non-majors group were normal in that they increased as workload increased, but were lower than those reported for other female studies (32) (44). Figure 6 shows means of corrected ventilation at all three heart rate levels.

The respiratory quotient for the total population at 180 and 190 heart rate increased and then leveled off at maximum heart rate. The mean for the respiratory quotient at 180 heart rate was .91 and at heart rate 190 and maximum a mean of .93 was recorded. During heavy exercise, it is not unusual for respiratory quotients to rise above 1.00 and possibly reach values as high as 1.30. During the recovery process, the respiratory quotient is normally below .70. This lowering of respiratory

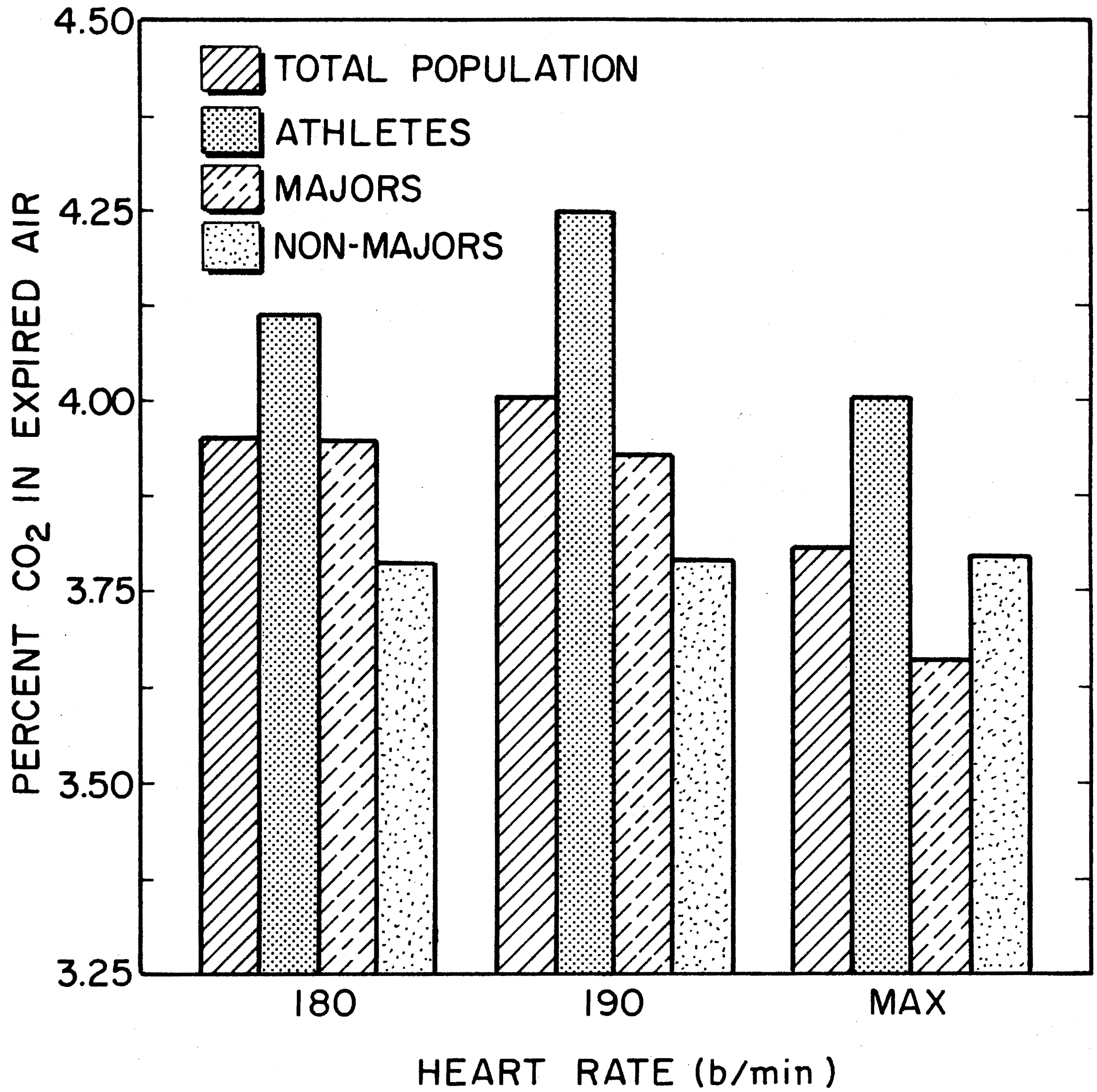

Figure 5. Mean Carbon Dioxide Percent in Expired Air

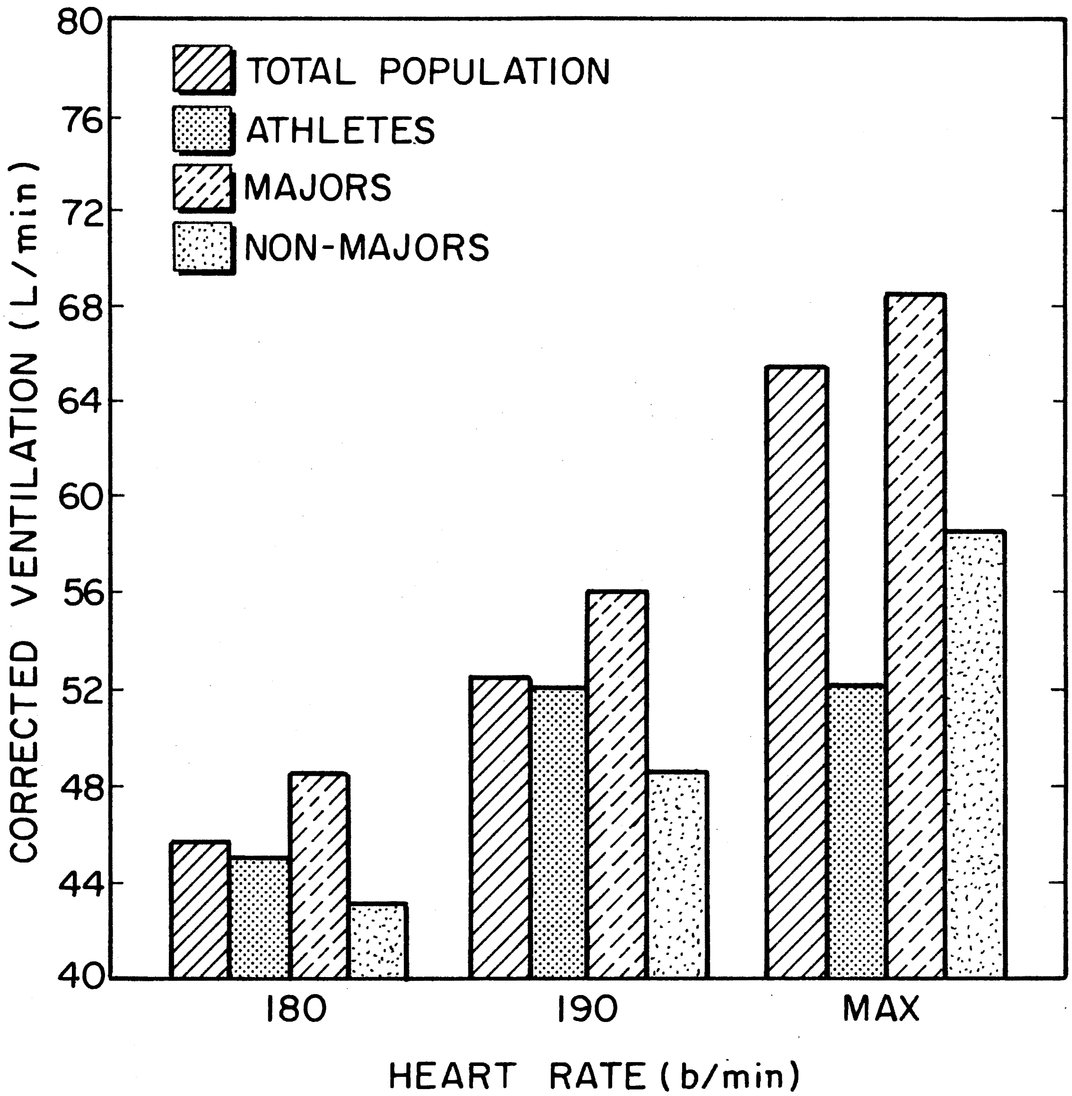

Figure 6. Mean Corrected Ventilation

quotient indicates the lactate has decreased from the circulation system. The respiratory quotient means for the athlete group were normal and ranged from .92 at 180 heart rate to .96 at maximum heart rate. The mean respiratory quotients recorded for the major group ranged from .90 at 180 heart rate to .93 at heart rate maximum. The non-major group showed the lowest means for respiratory quotient of .86 at heart rate 180 and .90 at 190 heart rate and .92 at maximum heart rate. The low respiratory quotients could indicate the inefficiency of the tissues to utilize the oxygen needed to perform the workload. Respiratory quotient means are graphically displayed in Figure 7. Data relating to variables discussed above are presented in Tables XIV, XV, XVI, and XVII.

Recovery Variables

Systolic and diastolic blood pressure were monitored each minute for a total of five minutes following the exercise. One minute following the exercise bout, the mean blood pressure for the total population was 164/71 mm Hg.; after three minutes blood pressure mean had reduced to 130/67 mm Hg.; and after five minutes blood pressure readings had almost approached normal levels with a mean recorded of 113/65 mm Hg. Recovery blood pressure means for the athlete group declined normally after one, three, and five minutes. Systolic and diastolic blood pressure means for major group decreased normally as did the blood pressure for the non-major group. Figures 8 and 9 present blood pressure means for total population and individual groups.

Recovery heart rates declined normally for the total population of subjects ranging from 133 beats per minute after one minute to 102 beats

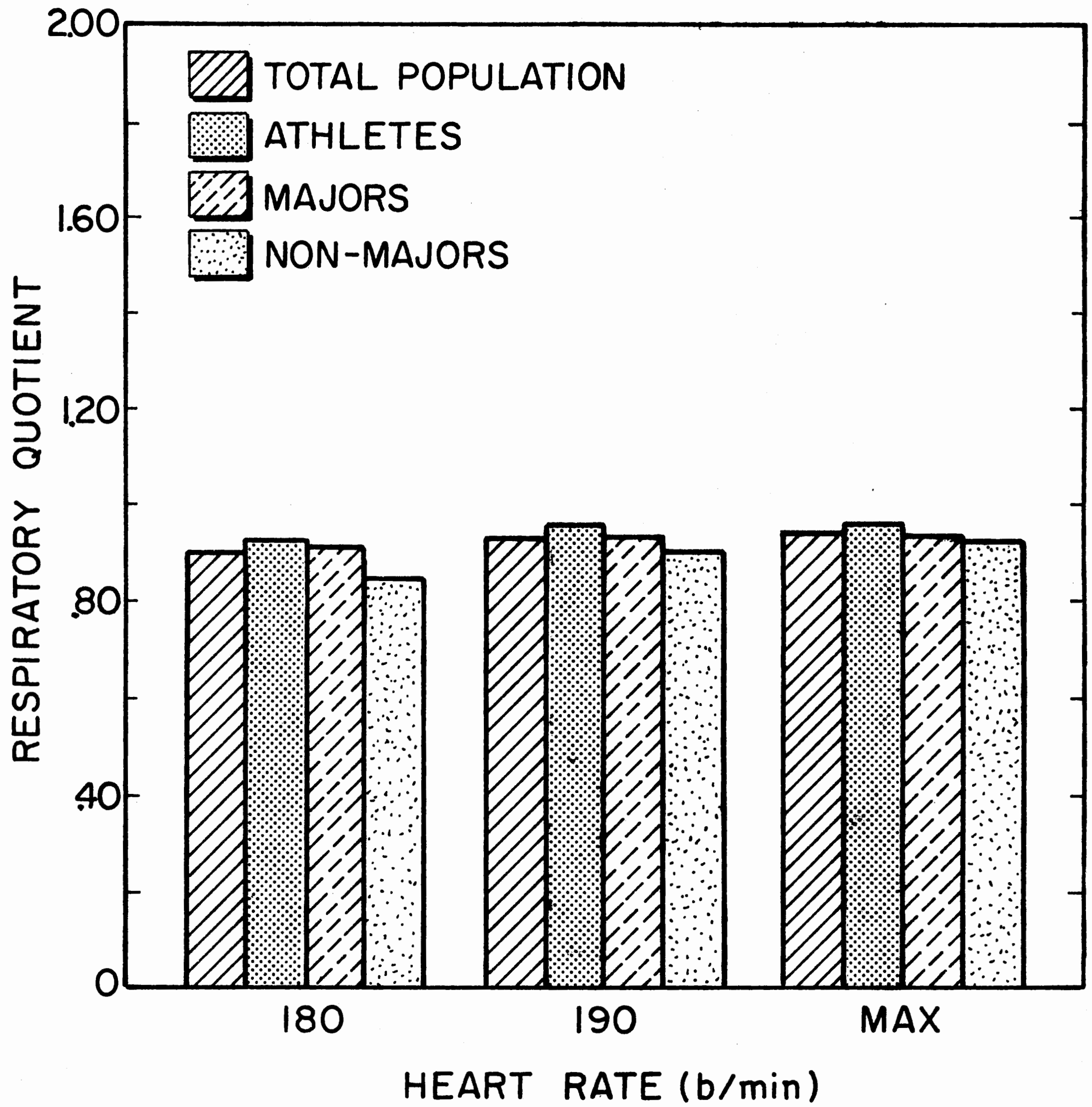

Figure 7. Mean Respiratory Quotient

TABLE XIV

MEANS AND STANDARD DEVIATIONS OF ADDITIONAL VARIABLES FOR TOTAL POPULATION

Variable	N	Mean	Standard Deviation
O_2 percent 180 HR	55	16.66	.346
O_2 percent 190 HR	39	16.74	.313
O_2 percent max HR	60	16.96	.269
CO_2 percent 180 HR	55	3.94	.419
CO_2 percent 190 HR	39	4.00	.430
CO_2 percent max HR	60	3.81	.411
Corrected Ventilation 180 (L/min)	55	45.84	12.28
Corrected Ventilation 190 (L/min)	39	52.67	11.28
Corrected Ventilation mas (L/min)	60	65.66	12.83
Respiratory quotient 180 HR	55	.897	.081
Respiratory quotient 190 HR	39	.933	.066
Respiratory quotient max HR	60	.936	.068

TABLE XV

MEANS AND STANDARD DEVIATIONS OF ADDITIONAL VARIABLES FOR ATHLETE GROUP

Variable	N	Mean	Standard Deviation
O_2 percent 180 HR	18	16.54	.277
O_2 percent 190 HR	15	16.57	.200
O_2 percent max HR	20	16.85	.181
CO_2 percent 180 HR	18	4.12	.286
CO_2 percent 190 HR	15	4.25	.192
CO_2 percent max HR	20	3.99	.288
Corrected ventilation 180 (L/min)	18	45.18	11.53
Corrected ventilation 190 (L/min)	15	52.07	9.20
Corrected ventilation max (L/min)	20	69.23	10.40
Respiratory Quotient 180 HR	18	.918	.051
Respiratory Quotient 190 HR	15	.9600	.052
Respiratory Quotient max HR	20	.9620	.060

TABLE XVI

MEANS AND STANDARD DEVIATIONS OF ADDITIONAL VARIABLES FOR MAJOR GROUP

Variable	N	Mean	Standard Deviation
O_2 percent 180 HR	20	16.76	.451
O_2 percent 190 HR	13	16.85	.360
O_2 percent max HR	20	17.08	.289
CO_2 percent 180 HR	20	3.906	.487
CO_2 percent 190 HR	13	3.898	.362
CO_2 percent max HR	20	3.65	.442
Corrected ventilation 180 (^{L}/min)	20	48.59	
Corrected ventilation 190 (^{L}/min)	13	56.31	
Corrected ventilation max (^{L}/min)	20	69.062	13.730
Respiratory Quotient 180 HR	20	.909	.085
Respiratory Quotient 190 HR	13	.93	.052
Respiratory Quotient max HR	20	.926	.077

TABLE XVII

MEANS AND STANDARD DEVIATION OF ADDITIONAL VARIABLES FOR NON-MAJOR GROUP

Variable	N	Mean	Standard Deviation
O_2 percent 180 HR	17	16.68	.233
O_2 percent 190 HR	11	16.85	.293
O_2 percent max HR	20	16.95	.281
CO_2 percent 180 HR	17	3.79	.404
CO_2 percent 190 HR	11	3.79	.489
CO_2 percent max HR	20	3.78	.432
Corrected ventilation 180 (L/min)	17	43.30	10.29
Corrected ventilation 190 (L/min)	11	49.18	12.84
Corrected ventilation max (L/min)	20	58.69	11.73
Respiratory Quotient 180 HR	17	.862	.094
Respiratory Quotient 190 HR	11	.900	.085
Respiratory Quotient max HR	20	.920	.063

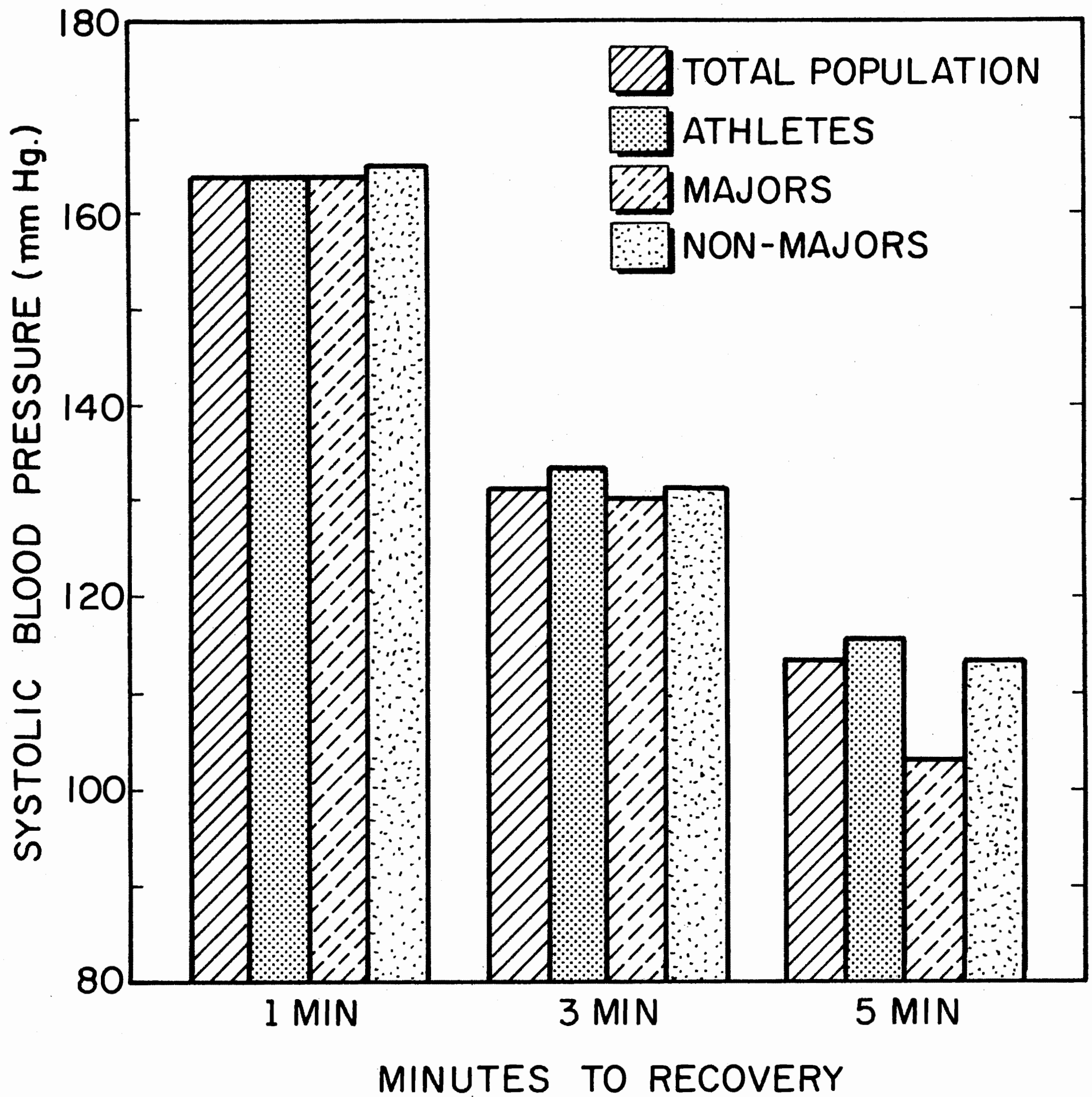

Figure 8. Recovery Systolic Blood Pressure

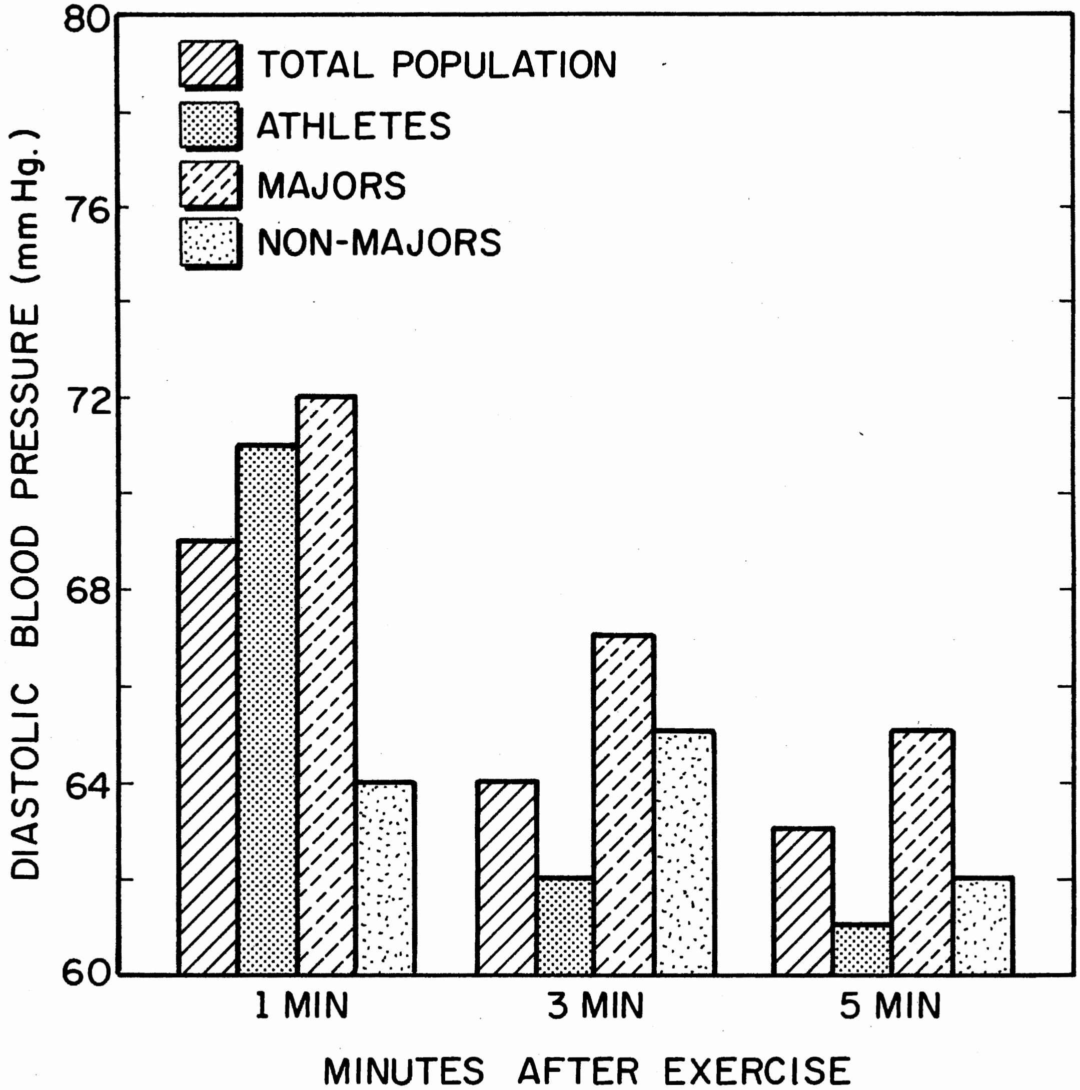

Figure 9. Recovery Diastolic Blood Pressure

per minute after five minutes following the exercise bout. The mean recovery heart rate for the athlete group declined immediately after exercise ceased and returned to a normal mean level of 99.40 beats per minute after five minutes of recovery. Recovery heart rate mean for the major group was 135 beats per minute after one minute and declined to 104 beats per minute after five minutes following the exercise bout. The mean heart rate for the non-major group had dropped to 134 beats per minute following the exercise bout. The mean heart rate after three minutes was 111 beats per minute and a mean of 105 beats per minute after five minutes was found. Figure 10 shows recovery heart rate at one, three, and five minutes following the termination of the exercise bout.

Tables XVIII, XIX, XX, and XXI express recovery variables for total population and individual groups.

Two regression lines were calculated and constructed for the total population to predict maximum oxygen consumption using time to reach heart rate 180 and 190. A third regression line was constructed for the major group to predict maximum oxygen consumption using time to reach heart rate 190. These regression lines are displayed in Figures 11, 12, and 13.

Summary of Results

The purpose of this study was to determine if the time to reach 180 and 190 heart rate was a valid predictor of maximum oxygen consumption for college women. The data in this study revealed that time to reach 180 or 190 heart rate cannot be a valid predictor of maximum oxygen consumption for a normal population of college women. A correlation of

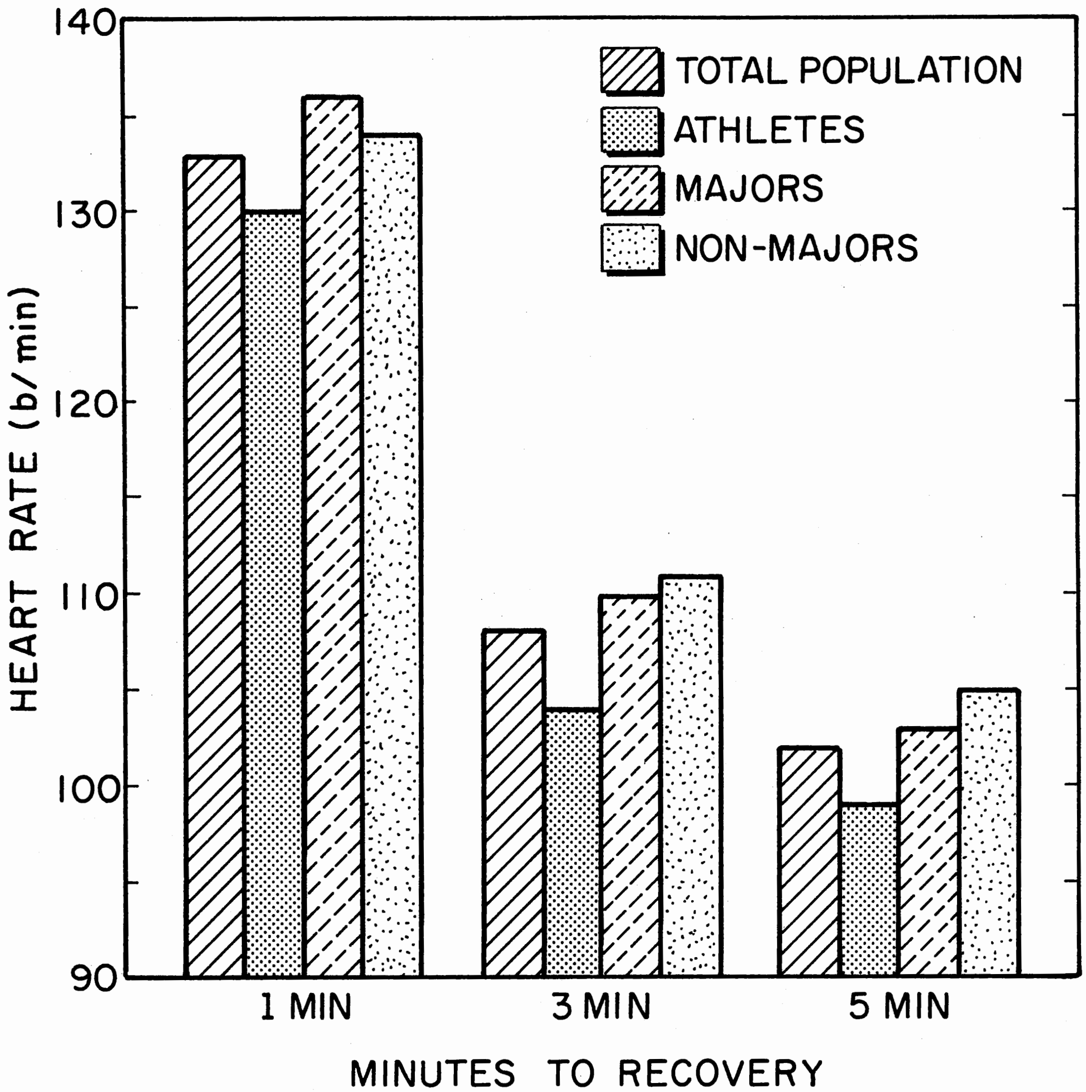

Figure 10. Recovery Heart Rate

TABLE XVIII

RECOVERY VARIABLE FOR TOTAL POPULATION

Variable	Time	Mean	Standard Deviation
Systolic BP	1	164.00	17.77
Diastolic BP	1	68.50	10.71
Systolic BP	3	130.00	16.09
Diastolic BP	3	64.17	7.87
Systolic BP	5	113.25	13.33
Diastolic BP	5	62.58	7.04
Heart Rate	1	133.10	14.17
Heart Rate	3	108.40	10.98
Heart Rate	5	102.53	9.70

TABLE XIX

RECOVERY VARIABLES FOR THE ATHLETE GROUP

Variable	Time	Mean	Standard Deviation
Systolic BP	1	163.50	16.63
Diastolic BP	1	71.00	9.68
Systolic BP	3	132.75	17.43
Diastolic BP	3	61.50	8.75
Systolic BP	5	113.25	13.33
Diastolic BP	5	114.75	61.00
Heart Rate	1	129.90	14.07
Heart Rate	3	104.10	10.89
Heart Rate	5	99.00	10.38

TABLE XX

RECOVERY VARIABLES FOR MAJOR GROUP

Variable	Time	Mean	Standard Deviation
Systolic BP	1	164.00	18.75
Diastolic BP	1	71.00	11.19
Systolic BP	3	130.50	15.04
Diastolic BP	3	67.00	7.33
Systolic BP	5	113.00	11.74
Diastolic BP	5	65.25	7.52
Heart Rate	1	135.60	11.25
Heart Rate	3	109.80	7.05
Heart Rate	5	103.50	6.42

TABLE XXI

RECOVERY VARIABLE FOR NON-MAJOR GROUP

Variable	Time	Mean	Standard Deviation
Systolic BP	1	164.50	18.77
Diastolic BP	1	63.50	9.88
Systolic BP	3	129.50	16.38
Diastolic BP	3	64.00	6.81
Systolic BP	5	112.00	12.81
Diastolic BP	5	61.50	5.87
Heart Rate	1	133.80	16.76
Heart Rate	3	111.30	13.27
Heart Rate	5	104.70	11.26

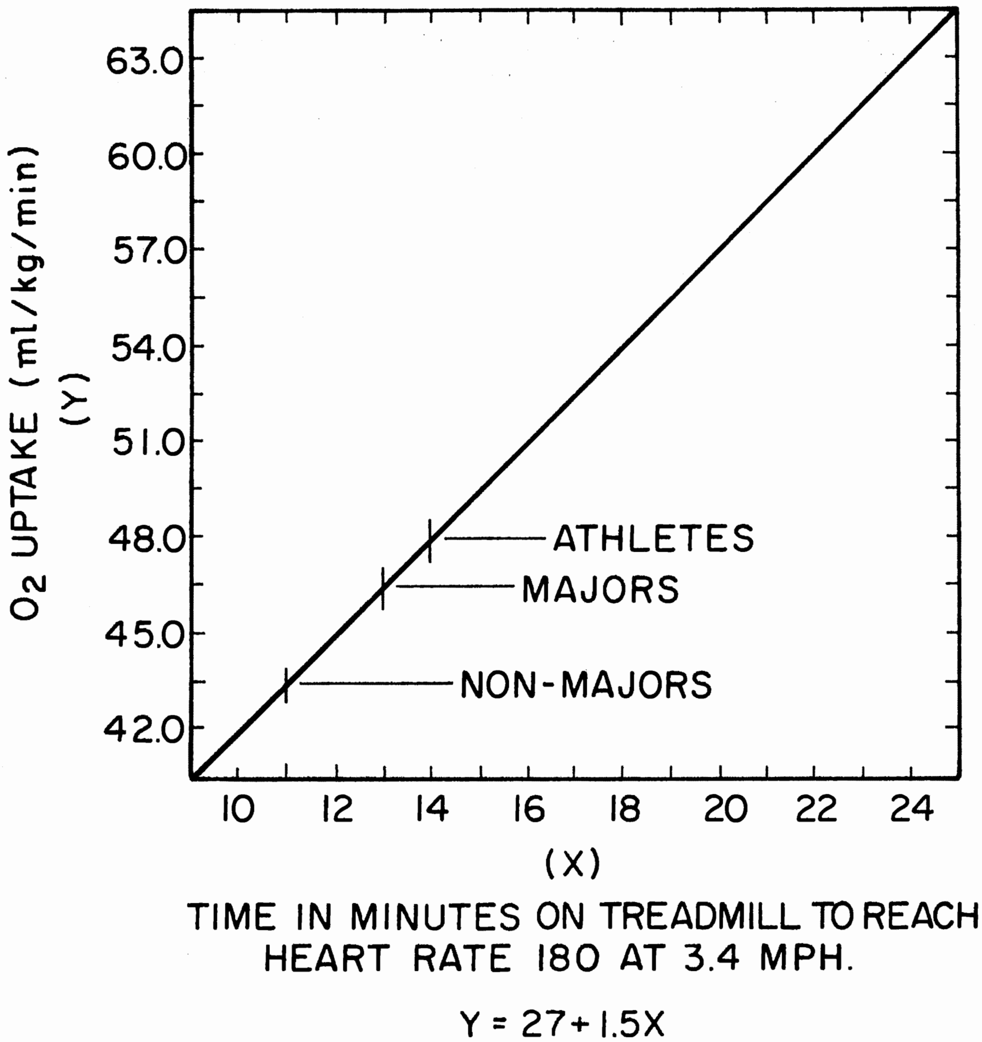

Figure 11. Edgley Regression Chart - Grade 180 HR - Correlation: r=.63 - Total Population

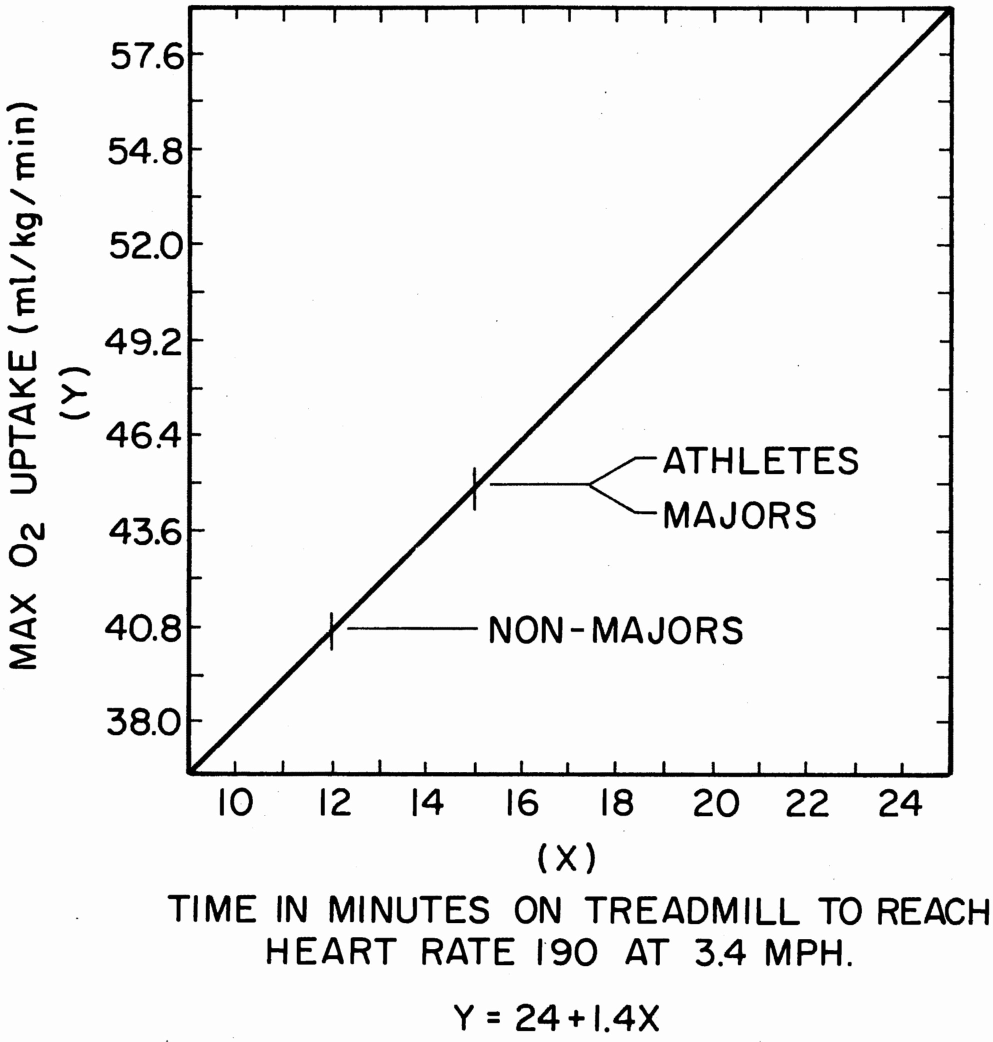

Figure 12. Edgley Regression Chart - Grade 190 HR - Correlation: r=.61 - Total Population

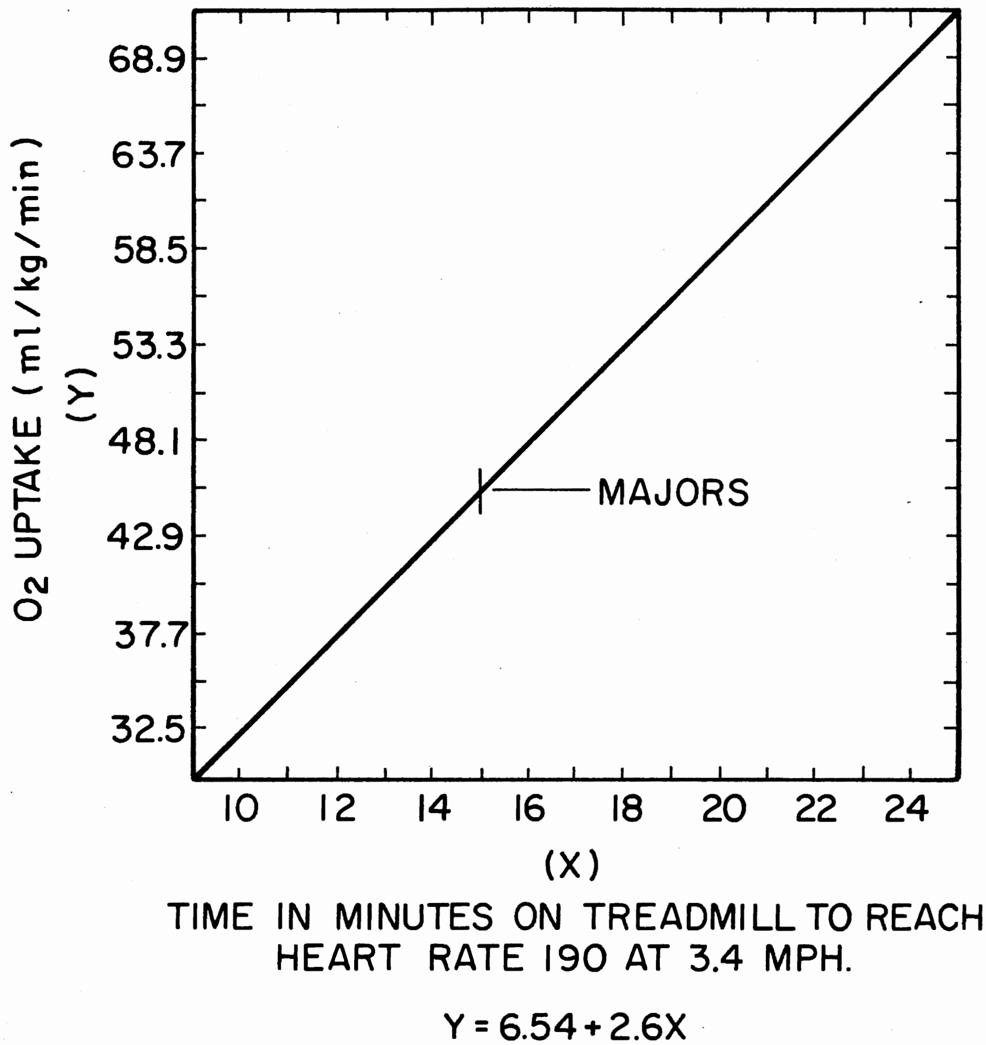

Figure 13. Edgley Regression Chart - Grade 190 HR - Correlation: r=.84 - Major Group

.7 or above was the determinant of a valid predictor for this study. The Balke prediction for men was not found to be a valid predictor of max $\dot{V}O_2$ when a normal population of college women were considered. Maximum oxygen consumption was found to be greater than most of the studies indicate in the literature.

When individual groups were isolated from the total population, it was found that time to reach 190 heart rate was a valid predictor of max $\dot{V}O_2$ for the major group. A relationship of r=.84 was calculated. No significant difference existed between groups in oxygen uptaken when expressed in milliters per kilogram per minute; but when these figures were expressed in liters per minute, a significant difference was recorded between athletes and non-majors, and also between majors and non-majors. Other variables such as oxygen percent and carbon dioxide in the expired air appeared normal.

Regression lines were constructed for the time to reach 180 and 190 heart rate for the total population and the time to reach 190 heart rate for the major group only.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

For many years, most of the studies conducted in the area of exercise physiology and fitness testing were done utilizing male subjects. Within the past ten years, a growing concern for the understanding and prediction of potentialities of the female athlete has arisen. Since that time untrained females have gradually been used as subjects in various studies to determine their physiological capabilities. Adequate information and testing results for the female are still lacking. More studies are needed in order to assess accurately the female physiological processes so that better training programs for the women athlete can be devised and exercise and fitness programs for the non-athlete can be improved.

The literature revealed few studies using female subjects in predicting maximal oxygen consumption from sub-maximal heart rates. Most of the early physiological studies that used women subjects were performed in Norway and Sweden. Åstrand, from Sweden, was one of the early pioneer investigators in testing women subjects in respect to oxygen uptake.

When women have been tested at Oklahoma State University to determine maximal oxygen consumption from sub-maximal heart rates, the Balke regression line for men has been used with some modifications. The accuracy of this method was questionable and continued research was needed to assess properly the physiological attributes of the female.

The purpose of this study was to determine if the time to reach heart rate 180 and 190 were valid predictors of maximal oxygen consumption for college women.

Conclusions

Within the limits of this study and based on the hypotheses stated the following conclusions were made.

1) THE RELATIONSHIP BETWEEN MAXIMUM OXYGEN CONSUMPTION AND TIME TO REACH HEART RATE 180 ON THE TREADMILL WILL BE SUFFICIENTLY HIGH TO SERVE AS A VALID PREDICTOR OF MAXIMUM OXYGEN CONSUMPTION. A CORRELATION COEFFICIENT OF .7 OR ABOVE WAS THE ACCEPTABLE LEVEL FOR PREDICTIVE VALIDITY. This hypothesis was rejected. A correlation of only .50 was calculated between the time to reach heart rate 180 and maximum oxygen consumption.

2) THE RELATIONSHIP BETWEEN MAXIMUM OXYGEN CONSUMPTION AND TIME TO REACH 190 HEART RATE ON THE TREADMILL WILL BE SUFFICIENTLY HIGH TO SERVE AS A VALID PREDICTOR OF MAXIMUM OXYGEN CONSUMPTION. A CORRELATION COEFFICIENT OF .7 OR ABOVE WAS THE ACCEPTABLE LEVEL FOR PREDICTIVE VALIDITY. This hypothesis was also rejected. A correlation of .57 was found. However, when individual groups were isolated and tested separately, the major group showed a relationship of .84 when time to reach the heart rate of 190 was correlated with maximum $\dot{V}O_2$. No other groups showed a significant relationship at either 180 or 190 heart rate.

3) THERE WILL BE NO DIFFERENCE IN MAXIMUM OXYGEN CONSUMPTION OF HPELS MAJORS, NON-MAJORS, AND INTERCOLLEGIATE ATHLETES. This hypothesis was rejected. An ANOVA indicated that there was a significant difference in max $\dot{V}O_2$ between athletes and non-majors and between majors and non-majors when max $\dot{V}O_2$ was expressed in liters per minute. No significant difference was found between athletes and majors.

Subproblems

1) A subproblem of this study was to determine a valid regression line for predicting maximum oxygen consumption from treadmill test results. The only valid regression line constructed was within the majors group in time to reach 190 heart rate and max $\dot{V}O_2$.

2) Another subproblem stated in this study was to relate a valid regression line for women to the regression line developed by Balke for adult men. The valid regression line constructed from this study within the majors group indicated a better predictor of maximum oxygen consumption than did the Balke or the Balke plus 25%. A relationship of .54 was revealed for both the Balke and the Balke plus 25% and max $\dot{V}O_2$.

3) A third subproblem was concerned with comparing the maximal oxygen consumption for a normal population of college women with max $\dot{V}O_2$ of those subjects previously reported in the literature. Few studies have been concerned with subjects from all three groups as was presented in this study. Compared with studies cited in the literature, the mean max $\dot{V}O_2$

in the present study was greater. This could be partially attributed to the increase in activity and fitness programs participated in by todays college age women.

4) A final subproblem investigated in this study was to compare maximum oxygen consumption of HPELS majors, non-majors, and intercollegiate athletes. There was a significant difference found in this study for max $\dot{V}O_2$ between athletes and non-majors, and between majors and non-majors when expressed in liters per minute. However, specific endurance athletes chosen and compared with majors showed a greater max $\dot{V}O_2$ than those athletes in this study who were randomly selected from nine sports.

Additional results of this study indicated a significant difference between athletes and non-majors, and between majors and non-majors in time to reach heart rates 180, 190, and maximum. Also significant differences were found between the same pairs in corrected ventilation at maximum heart rate.

Recommendations

It has been assessed that more studies testing female subjects are needed to determine maximal oxygen consumption and also various means to predict this component from sub-maximal variables such as heart rate.

One of the greatest deterrents, although not a limiting factor of this study, was the lack of motivation exhibited by many of the female subjects. Perhaps various means could be devised to enhance motivation.

This author would suggest that the retest be conducted closer to the initial testing period. One month had elapsed before the test was repeated in this study which allowed changes in intensity of training programs and activity classes as well as some fluxuation in weight.

Close observation should be made of subjects' degree of difficulty while breathing through the one-way-valve. Some subjects in the present study complained that air was difficult to extract through the valve. This problem might have been psychological.

When a subject reached a max $\dot{V}O_2$ at 180 or 190 heart rate in this study, her score was only recorded in the maximal O_2 column. A recommendation would be to include those scores in both the 180 or 190 O_2 uptake figures as well as the max $\dot{V}O_2$ numbers.

A stratified method of selecting subjects in the athlete group is suggested to insure all sports being represented. A more representative population of college females would entail selecting subjects at random from the entire University female enrollment or determine the percentage of female athletes in the University population and then include this percentage in subject selection.

A third person to assist the testing process would have been beneficial especially when subjects were nearing the end of the exercise bout. Pictures of equipment as well as pictures of telemetry attached to a subject would help enlighten the understanding of the test procedure.

Other suggestions for studies similar to this study are to determine max $\dot{V}O_2$ for women and then determine their oxygen debt. Another study suggested would be to compare a group of highly motivated women with a group that was less motivated. A study could be devised to compare a large group of non-majors participating in activity classes of intramurals and another group of non-majors who were considered sedentary.

And finally a study could investigate the differences of maximal oxygen consumption for various sports.

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APPENDIX A

RAW DATA FOR VARIABLES

RAW DATA

Subject	Group	180(ml/kg/min) O_2 uptake	190(ml/kg/min) O_2 uptake	max(ml/kg/min) O_2 uptake	180(min) time to reach	190(min) time to reach	max(min) time to reach	180 O_2%	190 O_2%	max O_2%	180 CO_2%
1	A	29.46	35.40	59.12	13	15	18	15.75	16.13	16.87	4.68
2	A	27.43	32.50	46.06	12	14	20	16.57	16.40	16.96	4.15
3	A	26.84	35.48	38.03	9	11	15	16.38	16.40	16.71	4.22
4	A	31.22	36.62	50.68	13	15	22	17.00	16.75	17.15	3.85
5	A	29.57	31.04	46.48	10	13	16	16.83	16.62	16.83	3.54
6	A	36.45	43.40	44.39	16	19	22	16.60	16.75	16.71	4.22
7	A	29.38	41.94	51.32	17	19	22	16.38	16.25	16.51	3.85
8	A	30.31	39.62	50.33	13	15	19	16.33	16.45	17.08	4.37
9	A	27.10	34.95	39.13	13	15	16	16.37	16.68	16.80	4.26
10	A	28.08	34.72	39.00	11	13	16	16.90	16.75	16.98	3.65
11	A	39.80	---	46.00	19	--	20	16.45	---	16.55	4.42
12	A	34.70	38.23	47.18	14	16	20	16.62	16.66	17.00	4.15
13	A	46.90	---	56.03	23	--	27	16.70	---	16.75	4.19
14	A	---	---	42.70	--	--	22	---	---	17.00	----
15	A	---	---	43.76	--	--	22	---	---	16.75	----
16	A	28.06	34.44	42.82	11	13	19	16.55	16.70	17.05	3.92
17	A	32.37	36.95	40.96	13	15	16	16.60	16.60	16.60	4.15
18	A	39.98	---	47.62	15	--	18	16.80	---	16.91	3.92
19	A	29.23	35.23	42.18	13	15	18	16.55	16.80	17.00	4.37
20	A	29.77	41.79	48.57	15	18	20	16.40	16.60	16.75	4.30
21	M	20.47	27.40	33.01	8	11	16	16.39	16.58	16.74	4.07
22	M	38.80	45.02	49.62	16	18	20	16.15	16.50	16.82	4.52
23	M	36.62	---	47.35	14	--	17	17.50	---	17.29	3.39
24	M	44.92	---	47.28	15	--	18	17.25	---	17.45	3.47
25	M	32.23	34.00	38.32	10	11	15	16.79	16.90	17.27	3.85
26	M	25.88	36.95	45.02	12	14	17	16.45	16.58	16.90	3.85
27	M	24.15	33.87	37.70	11	14	17	15.90	16.28	16.80	4.75
28	M	31.72	38.02	43.79	12	14	17	17.18	17.10	17.20	4.22
29	M	39.62	---	42.89	16	--	18	16.69	---	16.84	4.49
30	M	33.69	42.40	53.88	14	18	19	16.56	16.79	17.05	4.34
31	M	34.70	38.89	39.16	12	14	16	16.95	17.08	17.20	3.85
32	M	25.82	38.28	52.33	13	15	19	16.72	16.89	17.26	3.85
33	M	23.59	---	27.83	11	--	14	16.58	---	16.85	4.15
34	M	31.92	43.13	51.64	11	14	17	17.27	17.23	17.40	3.39
35	M	42.61	44.05	56.32	17	20	26	15.95	16.44	16.84	4.22
36	M	36.23	---	37.05	16	--	18	16.52	---	16.45	4.22
37	M	39.37	52.34	52.90	16	19	21	17.00	17.20	17.33	3.54
38	M	38.04	52.52	55.58	13	18	20	17.20	17.50	17.55	3.47
39	M	38.49	---	45.67	13	--	17	17.22	---	17.36	2.71
40	M	39.19	---	45.77	14	--	18	16.85	---	17.03	3.77
41	N	36.66	39.68	46.72	13	15	18	16.65	16.80	16.90	3.96
42	N	45.37	---	51.79	17	--	19	16.71	---	17.00	3.85
43	N	---	---	44.40	--	--	19	---	---	16.55	----
44	N	36.08	---	44.64	15	--	19	16.45	---	16.75	3.40
45	N	---	---	33.94	--	--	11	---	---	16.88	----
46	N	29.98	32.41	36.73	8	10	12	16.73	16.82	16.98	3.77
47	N	39.74	---	39.77	11	--	14	16.63	---	16.85	3.85
48	N	38.93	---	41.12	12	--	14	16.95	---	17.11	3.77
49	N	---	---	41.86	--	--	13	---	---	16.72	----
50	N	34.73	50.48	50.60	11	15	16	17.02	17.55	17.80	2.64
51	N	27.26	32.48	48.03	9	10	17	16.90	16.88	17.25	3.54
52	N	25.06	31.38	37.74	9	12	16	16.59	16.45	16.75	4.22
53	N	32.15	36.35	41.37	7	8	11	16.70	16.71	17.05	3.92
54	N	34.22	37.40	50.76	10	11	16	16.90	17.11	17.18	3.54
55	N	27.45	32.16	32.24	13	15	17	16.68	16.70	16.71	4.30
56	N	32.39	---	35.37	10	--	13	16.13	---	16.51	4.15
57	N	31.38	36.10	39.07	10	12	14	16.58	16.85	17.05	4.00
58	N	31.48	---	35.22	12	--	14	16.74	---	16.92	4.11
59	N	31.55	37.90	43.53	11	14	18	16.98	16.90	17.08	3.40
60	N	29.52	35.82	44.96	9	12	16	16.38	16.55	16.90	4.07

RAW DATA

190	max	180	190	max	180	190	max	Recovery Heart Rate			Recovery Blood Pressure		
CO_2%	CO_2%	Corr. Vent	Corr. Vent.	Corr. Vent.	RQ	RQ	RQ	1 min.	3 min.	5 min.	1 min.	3 min.	5 min.
4.60	3.92	35.24	46.52	70.72	.87	.94	.95	138	114	108	160/60	130/50	120/50
4.30	3.77	37.86	43.09	70.24	.93	.93	.93	150	114	106	180/50	160/60	120/60
4.45	4.30	28.86	38.90	45.17	.90	.97	1.02	132	102	90	170/80	130/70	110/70
4.30	3.85	44.93	50.17	76.63	.96	1.03	1.02	144	114	110	150/80	115/60	110/60
4.07	4.15	40.35	41.10	65.76	.83	.93	1.01	150	126	116	150/70	140/60	110/60
4.22	4.30	54.76	67.84	69.07	.96	1.00	1.02	108	96	90	170/70	130/70	110/70
4.15	3.92	29.57	41.16	53.46	.81	.85	.85	120	90	96	140/70	100/60	90/50
4.30	3.77	40.89	58.61	81.54	.93	.94	.96	150	120	120	160/70	120/60	120/70
4.22	4.07	37.91	53.32	61.14	.92	.98	.96	126	96	108	140/70	120/60	90/60
3.85	3.77	40.02	47.97	57.42	.87	.89	.93	126	96	90	170/80	120/60	110/60
----	4.45	57.23	---	68.13	.97	---	1.01	126	108	108	170/60	160/60	140/60
4.30	3.40	47.47	53.40	68.97	.95	1.00	.83	144	114	102	180/90	160/80	150/70
----	4.30	73.53	---	89.95	.98	---	1.02	114	96	90	180/80	140/40	110/50
----	3.62	---	---	65.16	---	---	.89	120	96	96	180/70	150/60	140/60
----	4.15	---	---	62.01	---	---	.98	102	84	78	150/60	120/50	110/50
4.07	3.70	44.59	57.54	77.71	.86	.94	.93	144	102	96	190/70	160/70	130/70
4.30	4.30	56.29	68.73	76.19	.94	.98	.98	132	102	90	180/80	130/60	110/60
----	3.77	61.40	---	81.25	.93	---	.92	126	96	96	170/80	130/60	110/60
4.07	3.88	43.60	55.99	75.39	.99	.97	.97	120	114	102	130/60	120/70	95/70
4.52	4.34	38.65	56.74	68.63	.93	1.05	1.06	126	102	96	150/70	120/70	100/70
4.07	3.40	27.17	38.44	46.52	.86	.91	.77	156	114	108	180/70	130/70	100/70
4.45	4.07	46.70	59.59	70.29	.93	1.00	.98	150	108	96	180/60	130/70	110/70
----	3.24	61.56	---	72.84	.97	---	.85	138	108	102	180/60	120/70	120/60
----	3.17	63.65	---	70.39	.92	---	.88	114	102	102	150/70	130/60	100/50
3.77	3.39	41.62	45.09	55.99	.90	.91	.90	138	114	108	180/80	130/80	120/70
4.00	3.77	26.44	39.53	52.16	.82	.89	.91	144	108	102	180/80	150/80	130/70
4.68	4.45	31.43	48.44	61.91	.93	1.00	1.09	150	120	108	100/90	150/50	120/70
3.77	3.54	44.14	49.87	58.35	1.05	.96	.92	126	108	102	170/70	120/60	100/60
----	4.34	84.09	---	94.42	1.06	---	1.06	138	108	102	170/80	150/70	140/70
4.11	3.85	40.38	53.51	72.34	.98	.98	.98	138	102	96	160/90	120/70	110/70
3.62	3.62	59.13	67.96	71.15	.95	.92	.95	138	114	102	160/80	110/60	100/65
4.00	3.40	38.64	60.97	90.01	.88	.97	.90	138	108	108	160/60	130/60	120/50
----	3.92	36.19	---	45.93	.94	---	.95	132	108	96	180/60	130/60	110/60
3.39	3.09	43.53	58.19	72.15	.90	.88	.84	126	102	114	160/50	120/60	100/50
4.37	2.92	54.49	64.80	90.25	.81	.96	.94	132	108	96	160/80	130/70	110/70
----	4.46	65.80	---	67.29	.94	---	1.02	126	102	102	170/70	150/70	130/70
3.39	3.32	47.87	66.96	70.44	.87	.87	.89	120	126	108	170/60	160/70	120/70
3.05	2.94	52.92	78.63	84.37	.90	.84	.83	138	108	102	140/60	100/70	100/70
----	3.47	45.93	---	60.25	.67	---	.95	150	120	120	170/80	130/70	110/70
----	3.62	60.18	---	74.18	.89	---	.90	120	96	96	160/70	120/70	110/70
4.03	3.92	45.09	51.81	60.03	.90	.95	.95	126	102	96	180/60	120/60	110/60
----	3.77	57.63	---	71.75	.88	---	.94	108	90	84	170/70	140/70	100/60
----	4.45	---	---	60.08	---	---	1.02	90	90	84	140/70	120/70	110/60
----	4.00	37.74	---	52.51	.70	---	.93	132	126	120	140/50	130/60	100/60
----	3.88	---	---	41.28	---	---	.93	126	114	102	180/50	140/50	110/50
3.70	3.54	34.97	38.69	45.69	.86	.86	.86	132	108	102	140/60	120/60	100/60
----	3.69	55.29	---	58.41	.86	---	.87	138	114	108	120/60	110/60	110/60
----	3.62	69.86	---	76.45	.93	---	.93	132	96	96	180/50	140/60	140/70
----	4.07	--	---	56.86	---	---	.94	120	102	102	180/60	160/60	120/60
2.80	2.56	46.58	81.51	88.20	.61	.79	.77	150	120	108	170/60	130/70	110/60
3.77	3.47	27.19	32.63	53.15	.84	.91	.92	156	138	120	160/70	110/70	120/60
4.64	4.52	36.98	45.48	59.22	.95	1.04	1.01	138	108	102	160/80	120/60	120/60
3.40	3.62	34.61	38.07	48.70	.90	.76	.91	162	126	114	180/50	130/70	110/70
3.40	3.39	46.93	53.63	74.49	.84	.85	.87	138	114	114	170/70	130/70	130/70
4.30	4.37	43.59	51.31	51.81	1.01	1.01	1.04	138	108	102	180/80	130/70	110/60
----	4.00	35.70	---	42.94	.83	---	.87	120	96	90	140/60	110/60	90/60
3.77	3.47	44.52	54.54	61.54	.89	.90	.85	132	120	108	160/60	110/50	90/50
----	3.92	44.02	---	51.43	.96	---	.96	144	114	108	180/60	160/70	130/70
3.85	3.70	40.39	48.87	58.60	.83	.94	.94	138	108	108	180/80	120/70	110/70
4.03	3.70	35.01	44.47	60.56	.86	.86	.89	156	132	126	180/70	160/70	120/60

APPENDIX B

ADDITIONAL DATA

I would like to elicit your help in conducting a research study involving a normal female population. This population will include randomly selected individuals, from the HPELS classes and also participants from intercollegiate athletic teams ages 18-28 years.

You will be asked to walk on the treadmill one time until you can no longer continue. A random few may be asked to walk the test twice. Heart rate will be monitored throughout the test as well as air samples being collected at specified heart rates to determine your oxygen consumption level. Height, weight, blood pressure, and skin-fold measurement will be taken prior to the test. The entire test procedure will take approximately one hour. No meals should be consumed within 3 to 4 hours prior to the test period. Also, vigorous activity should be held to a minimum 24 hours before you are scheduled to test. Dress should include shorts, T-shirt, shoes and socks. Long hair should be tied back for safety reasons.

The purpose of this study is to correlate the time it takes to reach 180 and 190 heart rate with maximum oxygen consumption so that we might use 180 heart rate and/or 190 heart rate as a possible predictor of your maximum oxygen consumption. Maximum oxygen consumption is a valid measure of cardio-vascular fitness.

Testing will begin Nov. 1 and continue throughout the semester. Please fill out the following information and return it to me. I will contact you and set up a date for you to test.

Name ______________________________ Age __________

Address ______________________________ Phone __________

Do you have any medical problems? ______________________________

HPELS class or intercollegiate team you are now enrolled in or a member of

______________________________ Instructor __________

Please circle the approximate time and day you prefer to be tested.

Monday	Morning	Afternoon	Evening
Tuesday	Morning	Afternoon	Evening
Wednesday	Morning	Afternoon	Evening
Thursday	Morning	Afternoon	Evening
Friday	Morning	Afternoon	Evening
Saturday	Morning	Afternoon	Evening
Sunday	Morning	Afternoon	Evening

Your help with this study is <u>greatly</u> appreciated.

Betty Edgley
Office: 115A Colvin Center
Phones: Office: 624-5508
Home: 372-7180

OKLAHOMA STATE UNIVERSITY
HUMAN PERFORMANCE LABORATORY
HPELS RESEARCH STUDIES
CONSENT FORM

Subject's Name____Date__________________

I hereby authorize ______________________________________ and her assistant to perform the following procedures and investigations:

A maximal oxygen uptake test will consist of walking on the treadmill at 3.4 miles per hour. The treadmill grade will begin at 0% for two minutes, then raised to 2% for one minute and then increased 1% a minute until the subject can no longer continue the test. Heart rate will be monitored throughout the test and 30 second air samples will be collected at heart rates of 180, 190, and the last 30 seconds of the test.

The procedures and investigations have been explained to me by_______________

______________________________ and her assistant.

I understand that this study involves the following possible risks and discomforts:

Subjects will walk continuously at progressive grade increases until they no longer can continue. The last few minutes of the test will be quite strenuous and exhausting, but should pose no danger if the subject is in good medical conditions.

I also understand that all results will be tabulated for research purposes as group data and in no case will a subject's personal identity be associated with test results without expressed permission.

I understand that the benefits of this research study are as follows:

The results of this study will give the subject an accurate measurement of maximal oxygen capacity which in turn will indicate the subject's cardiovascular fitness level.

I understand that I may terminate my participation in this study at any time.

____
Subject's Signature

____
Witness

LABORATORY METABOLIC CALCULATION SHEET

Subject__________________ Date________ Age______ Surface Area____________ Sq.M.

Temp.__________ degrees C. Barometric Pressure________ mm Hg. Corr. Factor_______

SITTING (Non basasl)

1. Oxygen %______ CO_2%______ True O_2______ R.Q.______ (from nomogram)
2. Ventilation/min. = $\frac{\_\_\_\_\_\_\_\_}{10}$ Kym mm. = ________ x 1.332 = ________ l/Min
3. Corr. Vent. = Vent. x Corr. Factor = ________ x ________ = ________ L/Min
4. Oxygen Intake = $\frac{\text{Corr. Vent. x True } O_2}{100}$ = $\frac{\text{x}}{100}$ = ________ L/Min
5. S.M.R. = $\frac{\text{x5 x60}}{\text{sq. M. S.A.}}$ = ______________ Cal/Hr. Sq. M.

EXERCISE:

SPEED_____________ HEIGHT_____________ TIME_____________

1. Oxygen %_______ CO_2%_______ True O_2_______ RQ_______ (from nomogram)
2. Ventilation/min. = $\frac{\_\_\_\_\_\_\_\_}{10}$ KYM mm. = ________ x 1.332 = ________ L/Min
3. Corr. Vent. = Vent. x Corr. Factor = ________ x + ________ = ________ L/Min
4. Oxygen Intake = $\frac{\text{Corr. Vent. x True } O_2}{100}$ = $\frac{\text{x}}{100}$ = ________ L/min
5. EMR = $\frac{\text{x5 x60}}{\text{Sq. M. SA}}$ = ____________ Cal. hr/ Sq. N.

EXERCISE:

SPEED_____________ HEIGHT_____________ TIME_____________

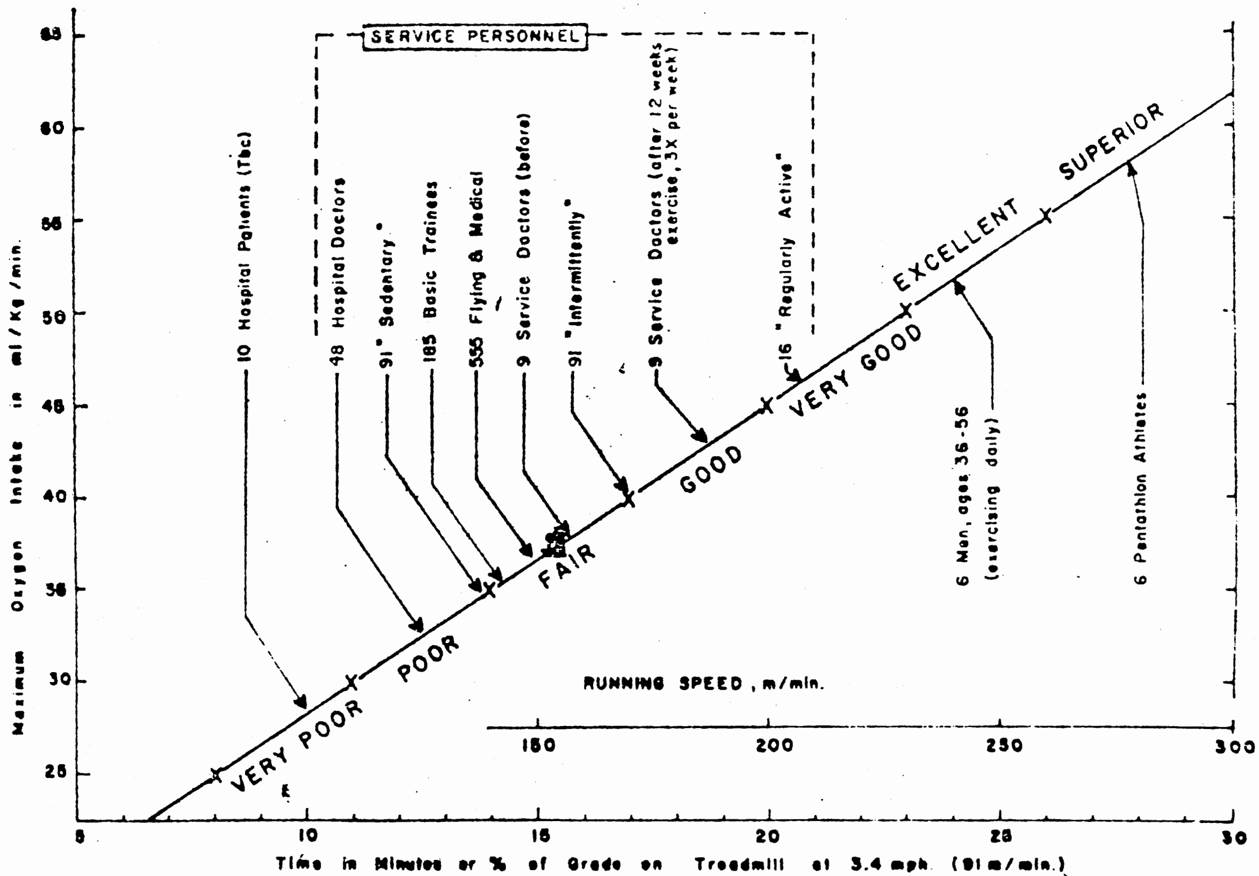
1. Oxygen %________ CO_2%________ True O_2________ RQ________(from nomogram)
2. Ventilation/Min. = $\frac{\_\_\_\_\_\_\_\_}{10}$ kym mm. = ________ x 1.332 = ________ L/min
3. Corr. Vent. = Vent. x Corr. Factor = ________ x ________ = ________ L/min
4. Oxygen Intake = $\frac{\text{Corr. Vent. x True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

EXERCISE:

SPEED_____________ HEIGHT_____________ TIME_____________

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

Maximum Oxygen Intake as Criterion of Functional Potential



Source: Balke, Bruno, and R. T. Clark, "Cardio-Pulmonary and Metabolic Effects of Physical Training, "Health and Fitness in Modern World, Athletic Institute (1961).

VITA

Betty Marie Edgley

Candidate for the Degree of

Doctor of Education

Thesis: THE VALIDATION OF WORKLOADS AT 180 AND 190 HEART RATE AS PREDICTORS OF MAXIMAL OXYGEN CONSUMPTION FOR COLLEGE WOMEN

Major Field: Higher Education

Minor Field: Health, Physical Education, and Recreation

Biographical:

Personal Data: Born in Tonkawa, Oklahoma, April 19, 1941, the daughter of Mr. and Mrs. Murray Scott. Married Charles K. Edgley, August 22, 1964.

Education: Attended elementary, junior high, and high school in Tonkawa, Oklahoma; graduated from Tonkawa High School in 1959; received the Bachelor of Science degree from Wayland Baptist College, Plainview, Texas, in 1963; received the Master of Education degree from the University of Oklahoma, Norman, Oklahoma, in 1970; and completed requirements for Doctor of Education degree in July, 1977.

Professional Experience: Taught physical education and coached tennis at Del City High School, Del City, Oklahoma, 1963-1964; taught physical education and coached basketball at junior and senior high school in Abernathy Public Schools, Abernathy, Texas, 1964-1966; taught physical education in the Kenmore Public Schools, Kenmore, N.Y., at all three levels, 1966-1969; received graduate assistantship from the University of Oklahoma while working toward the Master's degree, 1969-1970; served as intramural director and taught physical education at Oklahoma Baptist University, Shawnee, Oklahoma, 1972-1974; received graduate assistantship from Oklahoma State University to work toward Ed.D. degree, 1975-present. Member of OAHPER, American Alliance of Health, Physical Education, and Recreation.