A Comparison of Continuous and Discontinuous Treadmill Tests for Maximum Oxygen Uptake in Sedentary College Females

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A COMPARISON OF CONTINUOUS AND DISCONTINUOUS TREADMILL TESTS FOR MAXIMUM OXYGEN UPTAKE IN SEDENTARY COLLEGE FEMALES

BY

MILES MARK METTLER

A thesis submitted in partial fulfillment of the requirements for the degree Master of Science Major in Physical Education South Dakota State University 1985
A COMPARISON OF CONTINUOUS AND DISCONTINUOUS TREADMILL TESTS FOR MAXIMUM OXYGEN UPTAKE IN SEDENTARY COLLEGE FEMALES

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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The purpose of this investigation was to determine if there was a significant difference in the elicitation of maximum oxygen uptake utilizing a continuous treadmill test versus a discontinuous treadmill test with sedentary college women. The study also attempted to determine if the subjects' perceptions of difficulty of the two protocols were equal utilizing rated perceived exertion. A total of 13 college females volunteered for the study. The order of the test protocols was randomly assigned. The continuous treadmill test was initiated at 6 mph on a 0% grade for 3 minutes. Elevation was increased by 2.5% after each successive 3 minute stage. The discontinuous test was initiated at 6 mph on a 2.5% grade for 3 minutes. The elevation was increased by 2.5% for each successive 3 minute bout of exercise. Each 3 minute run was followed by a 5 minute rest period. Metabolic measures were determined using the open-circuit method. Significant differences were determined by using a Correlated Group t test with a .05 alpha level. No significant difference in Max VO2 values between the continuous and discontinuous treadmill tests was found. A significantly
greater Max VO2 value was found on the discontinuous test for the 6 subjects who completed the discontinuous test first. The subjects rated the difficulty of the two tests similarly, however, they preferred the continuous test. (Note - Due to an uncorrectable error in the measuring devices used in the study, the Max VO2 values may have been consistently inflated above the normal MaxVO2 values for sedentary females.)
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Chapter One

INTRODUCTION

The widespread incidence of heart disease in the last 50 years has become a major concern for citizens living in Western society. Cardiovascular diseases constituted the leading cause of death in the United States in 1980; accounting for 51% of the total annual mortality. Death from cardiovascular diseases alone out-numbered the combined total of all other causes of death (Pollock, Wilmore, & Fox, 1984). These diseases are, to a great extent, attributable to the typical American lifestyle: a high-fat diet, cigarette smoking, psychological stress, and lack of physical exercise. It is widely believed that physical activity helps protect against cardiovascular diseases, although there continues to be considerable debate about this in the scientific community. Regular exercise has been shown to help regulate metabolism, help control weight, help regulate blood pressure, and help prevent the loss of bone mass. People who exercise are more likely to follow the general rules of good health and are likely to have a higher sense of self-esteem. Due to its many positive benefits, it appears that more and more people are beginning to
incorporate regular exercise into their lifestyle (Stamford, 1984).

The term physical fitness has several meanings and can be quantified in many ways. The main components associated with physical fitness are strength, cardiovascular endurance, muscular endurance, and flexibility. For the improvement and maintenance of overall health cardiovascular endurance is considered to be most important. The major variables of training for the development of cardiovascular endurance are the frequency (how often), the intensity (how hard), and the duration (how long) of the activity being completed. It is suggested that those who are planning to begin an exercise program or to drastically change the type, intensity, or duration of a program should first obtain an indication of their fitness level both for personal and medical records (Stamford, 1985). A good indicator of your cardiovascular fitness is the maximum volume of oxygen that can be consumed per minute during strenuous exercise (Max VO2). Miyamura and Honda (1972) have noted that "Max VO2 is generally considered to be the best indicator in man of aerobic work capacity which is determined by the capacity of the cardiorespiratory systems to deliver oxygen to the tissues" (p. 185). As a person's cardiovascular fitness improves there will be a similar increase in Max VO2.
Mitchell and Blomqvist (1971) defined Max VO2 as the greatest amount of oxygen a person can take in during physical work. It is a measure of his/her maximal capacity to transport and utilize oxygen. Maximum oxygen uptake is dependent on maximal cardiac output (amount of blood pumped by the heart in one minute) and the arterio-venous oxygen difference (amount of oxygen used by the cells). Max VO2 measurements are usually expressed in liters per minute (l/min) or milliliters per kilogram of body weight per minute (ml/kg/min) which facilitates the comparison of persons of different body weights. The mean Max VO2 in a population of moderately active, healthy 20 year old men is considered to be approximately 45 ml/kg/min. Women typically have a Max VO2 of 10% to 15% less than men. It is acknowledged that strenuous physical training may increase Max VO2 by as much as 25% (Mitchell & Blomqvist, 1971).

Maximum oxygen uptake is a highly stable and reproducible variable. Careful measurement should result in an error of 3% or less. Time of day, donation of one pint of blood, prolonged loss of sleep, or repeating the test with very little rest between tests were found not to influence Max VO2 (Weltman & Stamford, 1982). The type of exercise utilized for the test, however, will influence Max VO2, because the larger the muscle mass
employed, the greater will be the oxygen uptake (Weltman & Stamford, 1982).

The majority of the previous studies related to Max VO2 have not utilized females as subjects but concentrated primarily on fit males. Although many studies have indicated that there are no major differences in physiological function between males and females (Cunningham, 1975; Fringer & Stull, 1974; Edwards, 1974), others have noted a difference in response to maximal work and have suggested that initial level of fitness may affect the physiological response (Burke, 1976; and Diaz, Hagen, Wright, & Horvath, 1978). Thus there remains some question if the testing procedures validated with the use of fit male subjects will be appropriate for unfit females.

The treadmill test is popular because Max VO2 can be accurately determined under controlled conditions. Another advantage is that treadmill test performance is usually independent of strength, speed, body size, and skill of the performer. Also, researchers have standardized the tests establishing norms for aerobic fitness for both sexes and for various age and fitness levels.

There are two main classifications of treadmill protocols: the continuous test and the discontinuous test. The continuous treadmill test has no rest periods
between work increments and continues until the subject reaches exhaustion. The discontinuous treadmill test allows for rest periods between stages of increased work and the stages are continued until a maximal value has been elicited. There are both advantages and disadvantages for both of the major treadmill protocols. It would be ideal if all subjects would be able to reach the desired maximal levels using the continuous test because of reduced test time. There is some concern, however, of the increased need for motivation required for the completion of the continuous test. Although the discontinuous test requires more time for completion, the need for high levels of motivation may be less demanding. The research team of McArdle, Katch, and Pechar (1973) conducted a study comparing continuous and discontinuous treadmill tests with healthy male subjects. They reported that the "subjects seemed to 'tolerate' the continuous test quite well and preferred the shorter time period for testing" (p. 159). Meanwhile, research completed by Fardy and Hellerstein (1978) has questioned the ability of sedentary people to complete the continuous test due to its greater cardiorespiratory cost. Their study involved 12 male subjects being tested using both the continuous and discontinuous testing methods. The researchers also noted that their subjects perceived the discontinuous test as less strenuous than
The continuous test possibly adding a psychological advantage.

The motivational levels of the subjects is an important determinant to how they will perform on the tests for maximum oxygen uptake. Since society has, in the past, placed restrictions on female participation in activities involving maximal effort, many females remain inactive and unfamiliar with high intensity work. The physiological and psychological responses of sedentary individuals when subjected to maximal workloads will determine how they perform on Max VO2 tests. As a result of these factors, there remains a need to evaluate the methods for obtaining Max VO2 in sedentary college females.

STATEMENT OF THE PROBLEM

The purpose of this study was to determine if there was a significant difference in the elicitation of maximum oxygen uptake using a continuous treadmill test versus a discontinuous treadmill test with sedentary college women. The study also attempted to determine if the subjects' perceptions of difficulty of the two protocols are equal utilizing ratings of perceived exertion.
DEFINITION OF TERMS

Continuous Treadmill Test: Treadmill tests which have no rest periods and continue until the subject reaches exhaustion. There is a gradual increase in workload throughout the test (McArdle et al., 1973).

Discontinuous Treadmill Test: Treadmill tests which allow for rest periods between stages of increasing work (McArdle et al., 1973)

Maximum Oxygen Consumption: The greatest volume of oxygen used by the cells of the body per unit of time. It may be expressed either in l/min or in ml/kg/min (Lamb, 1984). It will be abbreviated as Max VO2 throughout this thesis.

Rated Perceived Exertion: The subjective rating of the intensity of physical activity by the subject on a continuous scale with a value of 6 reflecting the easiest work and 20 reflecting maximal work (Borg, 1982).

Sedentary College Females: Females of college age (18 to 23 years) who have not been engaged in intercollegiate sports or involved in a regular, structured fitness program (30 minutes of continuous activity three times per week) for the past two years.
ASSUMPTIONS UNDERLYING THE RESEARCH

It is assumed that all the subjects meet the requirements for being classified as sedentary and have not engaged in regular physical activity for the last two years. It also assumed that each subject is fully motivated to achieve her maximal work capacity.

LIMITATIONS OF THE STUDY

The Max VO2 values obtained in this study should be used with caution when comparing to other studies. Based on other completed research, these Max VO2 values are somewhat above the norm for sedentary females. Every attempt was made to determine the cause of the apparently inflated values, however, none was found.

SCOPE OF THE STUDY

The study compared continuous and discontinuous treadmill tests for measuring Max VO2 in 13 college females. The subjects were female volunteers attending South Dakota State University. Data collection was conducted between April 9th and May 30th, 1985 between the hours of 7:00am - 4:30pm. The continuous and discontinuous protocols were variations of the protocol
implemented by McArdle et al., (1973). The continuous protocol used in the McArdle study had the subjects run for 2 minutes at 6 mph on a 0% grade. Elevation was then increased by 2.5% for each successive 2 minute period until the subject stopped. This procedure was altered in the present study by having the subjects begin at 6 mph on a 0% grade for 3 minutes. Elevation was increased by 2.5% after each successive 3 minute stage. The discontinuous test conducted by McArdle et al. (1973) had the subjects run for 5 minutes at 6 mph at a 2.5% grade. The grade was then increased for each successive 5 minute bout by 2.5%. Each run was followed by a 10 minute rest period. This procedure was altered for the present study by having the subjects begin running at 6 mph on a 2.5% grade for 3 minutes. The elevation was increased by 2.5% for each successive 3 minute bout of exercise. Each three minute run was followed by a five minute rest period. A familiarization test was given each subject to answer any questions and relieve any anxiety the participants may have initially had. The testing order was randomly assigned.
SIGNIFICANCE OF THE STUDY

Maximum oxygen uptake testing is considered by most researchers to be the best indicator of cardiovascular fitness. The current emphasis on fitness in our society would suggest a need for the appropriate method of determining true Max VO2 in sedentary individuals. Much testing has been done to determine Max VO2 values. However, a large number of the investigations reviewed utilized healthy male subjects. The studies conducted by Maksud and Coutts (1971), McArdle et al. (1973), and Fardy and Hellerstein (1978) have found no significant difference in Max VO2 values obtained via continuous and discontinuous treadmill testing in fit male subjects. Questions have been raised as to whether sedentary individuals are capable of reaching the required levels necessary during continuous testing. Also, it needs to be determined whether the lack of experience with maximal efforts in untrained individuals will affect the results of maximum oxygen uptake testing. Since few studies have been completed with females, more studies need to be conducted with sedentary females to see what findings will emerge. It will also be important to determine which method the subjects prefer, should the Max VO2 values be equal. The current trends indicate that Max VO2 testing
will be used extensively in the future for determining fitness levels. The following study is an attempt to determine which method, continuous or discontinuous treadmill testing, is best for measuring Max VO\textsubscript{2} in sedentary college females.
Chapter Two

REVIEW OF LITERATURE

This chapter reviews the published literature which is relevant to this study. The chapter is divided into five major areas: (a) modes of testing, (b) Max VO2 testing in females, (c) continuous versus discontinuous treadmill testing, (d) rated perceived exertion, and (e) summary of the review of literature.

Modes of Testing

Many modes have been utilized for measuring maximum oxygen intake. However, not all of these are recognized as being able to produce true Max VO2 values. Two of the most common testing modes used today are the bicycle ergometer and the motor-driven treadmill.

The two basic types of bicycle ergometers are the mechanically braked ergometer and the more precise electromagnetic ergometers (Smodlaka, 1982). Testing with the bicycle ergometer may involve the constant load or increment loading techniques such as those used by Miyamura and Honda (1972), maximal and submaximal tests used by Diaz, Hagen, Wright, and Horvath (1978), or the continuous and discontinuous method that McArdle et al. (1973) incorporated into their investigation.
The study conducted by Diaz et al. (1978) consisted of 12 subjects participating in maximal and submaximal exercise tests. Each subject performed two maximal bicycle tests consisting of work being performed at progressively increasing intensities. All subjects maintained a pedaling speed of 60 rpm throughout the test with the initial loads being 720 kpm/min for males and 540 kpm/min for females. The workload was then increased 180 kpm/min every two minutes until the subject reached exhaustion. One bicycle test was performed in the upright position and the other was performed in the low sitting position. Max VO2 was also determined by having the subjects complete a modified Balke treadmill test. The subjects initially walked on a level surface, men at 3.5 mph and women at 3.4 mph, and continued while the grade was increased 1% each minute until exhaustion. The results showed the the Max VO2 values for men and women combined during the treadmill test were 4.0% and 11.2% higher than for upright and low sitting positions, respectively. The results also revealed significantly higher Max VO2 levels for men (57.5 ml/kg/min) on the treadmill tests compared to the women (52.3 ml/kg/min).

Keren et al. (1980) conducted a similar study comparing treadmill running, bicycle ergometer pedalling and step climbing tests. Fifteen healthy young men were tested using the modified Bruce multistage treadmill
tests which consisted of having the subjects begin walking at 1.2 mph on a 10% grade. The speed and grade were then increased during the next five stages to 2.5 mph and 12% grade, 3.4 mph and 14% grade, 4.2 mph and 16% grade, 5.0 mph and 18% grade, and 5.5 mph and 20% grade, with the increase occurring every three minutes until exhaustion. Also administered was a bicycle ergometer test with the resistance increased 300 kpm every three minutes, from an initial load of 600 kpm, until the subject was unable to continue. Finally, a step test was completed using a bench 32.5 cm high and a stepping rate of 24 steps/min with the pace increased to a maximum of 40 to 60 steps/minute. Results revealed that the greatest mean Max VO2 was obtained on the treadmill tests (63.0 ml/kg/min), while the bicycle ergometer and step test were 60.2 ml/kg/min and 59.6 ml/kg/min, respectively.

Seventeen healthy male students participated in Miyamura and Honda's (1972) study measuring oxygen intake and cardiac output during maximal treadmill and bicycle ergometer exercise. The study incorporated both the constant loading and the increment loading procedures. With the constant loading method the treadmill tests were conducted at a grade of 8.6% and the speed was set so the subjects became exhausted within 4 to 8 minutes after the initiation of work. Using the increment loading
technique the treadmill was kept at the same speed for two minutes. The treadmill speed was increased by 10 m/min once every minute until the subject reached exhaustion. The bicycle ergometer test was also regulated so the subjects reached exhaustion within 4 to 8 minutes after initiation of exercise for the constant loading technique. The increment loading technique had the subject begin with a constant load and the work intensity began increasing 180 kgm/min once every minute up to exhaustion. Significantly higher values for Max VO2 were obtained from the treadmill exercise than from the ergometer exercise, 3.95 l/min to 3.37 l/min, respectively.

A study conducted by Stamford (1975) revealed that the Balke test elicited lower values than running treadmill tests in three different fitness groups. The 19 male students were classified as average fitness, high fitness, or as competitive race walkers. All subjects completed six maximal tests which were all discontinuous in nature except for the Balke test. Three discontinuous tests, conducted at 3.5, 4.5, and 5.5 mph were initiated on a grade of 5%. The remaining two discontinuous tests were conducted at 7.0 mph and 8.5 mph and were initiated on a 0% grade. Workbouts of three minutes in duration were alternated with 10 minute rest periods. Grade elevation was increased 2.5% for each successive bout.
The walking test elicited values of 45.7 ml/kg/min, 60.1 ml/kg/min, and 63.6 ml/kg/min for the low to high fit groups, respectively. This compared to the running results of 48.4 ml/kg/min, 65.9 ml/kg/min, and 65.2 ml/kg/min for the low to high fit groups, respectively. The differences were all significant.

A total of 15 male students participated in a study by McArdle, Katch, and Pechar (1973) comparing continuous and discontinuous treadmill and bicycle tests for measuring maximum oxygen uptake. There were six different tests given. In the continuous bicycle test the subject pedaled at 60 rpm with the workload increased 0.5 kg every two minutes until the subject was unable to maintain the required rpm. In the discontinuous bicycle test the subject pedalled at 60 rpm at 2 kg workload for 5 minutes. The subject was then given 10 minute rest intervals after which 0.5 kg workloads were added. The subjects continued until they were unable to maintain the rpm level. The Balke treadmill test was conducted with a treadmill speed of 3.4 mph and 0% grade. After two minutes the grade was increased 1% per minute until the subject fatigued. The Mitchell, Sproule, Chapman (MSC) treadmill test started at a 10% grade for ten minutes at 3 mph. The subject was then given 10 minutes of rest after which the grade increased by 2.5% and the subject continued to run for 2.5 minutes at 6 mph. The grade
increases and rest intervals continued until the subject reached exhaustion. The continuous treadmill test was initiated for at 6 mph with a 0% grade for 2 minutes followed by the grade being increased by 2.5% for each 2 minute interval until the subject stopped. The discontinuous treadmill test was initiated with a 2.5% grade with the subjects running at 6 mph for 5 minutes. They were then given 10 minute rest intervals after which the grade was increased 2.5% during each 5 minute run.

The results showed the mean values for Max VO2 on the ergometer tests were significantly lower than the treadmill values, 49.9 ml/kg/min and 56.6 ml/kg/min, respectively. No significant differences were shown among the treadmill tests or the bicycle ergometer tests.

In an effort to explain observed differences in maximum oxygen uptake values between bicycle ergometer and treadmill tests, Smolak (1982) has suggested that, "the smaller muscle mass used while cycling on the bicycle fatigues faster and prevents the subject from reaching a higher Max VO2" (p. 77). He also notes that a larger muscle mass is being used while running on a treadmill especially uphill. A common complaint of the subjects who were tested on the bicycle ergometer was the feeling of intense local discomfort in the thigh muscle during maximal workloads (McArdle et al., 1973). This was perceived as a limiting factor in their ability to
perform more work.

A related factor which may contribute to lower Max VO2 values on the bicycle ergometer, as noted by Miyamura and Honda (1972), is that Max VO2 is correlated with cardiac output. Cardiac output is considered to be an important determinant for oxygen transport capacity. In their study, the average values of cardiac output were higher during treadmill testing than during bicycle ergometer exercise, 24.6 l/min to 23.2 l/min, respectively. The authors state that "the somewhat lower cardiac output in ergometer exercise was assumed to be caused by decreased venous return from excessively contracted muscles" (p. 188).

Consideration must also be given, when testing for Max VO2, to whether the person being tested is involved in a specific activity that has trained a particular group of muscles. Should this be the case, the principle of specificity applies and the maximum testing done for that individual should involve the trained group of muscles in order to obtain the person's true maximum oxygen uptake. For sedentary individuals it is generally considered that a larger muscle group is needed to attain Max VO2 values, as was noted earlier by Smodlaka (1982). The treadmill is considered to be a valid method for utilizing a large group of muscles.
Shepard (1984) has outlined some other advantages and disadvantages of treadmill and bicycle ergometer testing for attaining Max VO2 values. He points out that an advantage of treadmill testing is that the pace is set by the machine rather than by the subject as is the case for bicycle ergometers. Shepard also notes that the maximal oxygen uptake average is 7% to 8% higher than the bicycle ergometer values. The main disadvantage of treadmill testing is the mechanical efficiency in running which is different for all subjects and which may be improved upon during the stages of testing. This factor is offset through bicycle ergometer testing because the weight of the individual is not a factor and because the cycling motion is the same for everyone.

Max VO2 Testing in Females

Although considerably more maximum oxygen uptake testing has been done with male subjects than female subjects, the results of various investigations using female subjects show similar physiological responses to maximal work. McArdle, Katch, Pechar, Jacobson, and Ruck (1972) found that trained female athletes had significantly higher Max VO2 values than those of untrained women. Their study consisted of 41 female college students, six of whom were considered active and
physically fit. The treadmill test began at a speed of 3.4 mph and the subjects walked at a 0% grade for the first two minutes. The grade was then increased by 1% per minute until the subject stopped walking. The results showed that the trained women had a mean Max VO2 of 44.2 ml/kg/min compared with the untrained women who had a mean Max VO2 if 37.2 ml/kg/min. The difference was significant.

The study completed by Horvath and Michael (1970) also revealed a relationship between Max VO2 and fitness levels. Fourteen female subjects between the ages of 18 and 37 years were tested for maximum oxygen uptake using a bicycle ergometer. The workload was initially set at 300 kpm/min and was increased 150 kpm/min each minute until the subject stopped due to exhaustion. The bicycle was pedaled at 50 rpm timed by a metronome. The Max VO2 values ranged from 22.2 ml/kg/min to 35.2 ml/kg/min using the step increment method and from 23.5 ml/kg/min to 38.1 ml/kg/min with the constant load method. The results also showed that the higher work load achieved, which may be an indication of fitness levels, also resulted in higher Max VO2 levels. The authors noted that the step increment exercises resulted in Max VO2 measurements only if the subjects were more capable of hard work or had strong motivational drives. It is also possible that an untrained subject will continue exercising at a constant
heavy workload more readily than attempt an additional workload when he/she doesn’t know what the next higher load will feel like. It was suggested that psychological motivation is possibly an important deterrent to exercise and the attainment of maximal physiological measures (Horvath & Michael, 1970).

Falls and Humphrey (1973) compared alternative methods for determining maximum oxygen uptake in college females. They examined three alternate procedures to the standard Balke protocol. The standard Balke test is initiated with the subject walking for 2 minutes at 3.4 mph at 0% grade. The grade is then raised to 2% and subsequently increased 1% per minute until the subject is exhausted. The first method was a shortened version of the Balke in which the subject walked the first 2 minutes at a 10% grade which was then increased 1% per minute until exhaustion. The second method involved having the subject work for two minutes at light work then increasing the work load to the maximum load. The third method started out as the conventional Balke, however, after 2 minutes the grade was raised 3% per minute rather than the 1% per minute increments for the next 4 to 6 minutes. Upon reaching the maximum workload, the 1% per minute increments were initiated and continued to exhaustion. Results showed that subjects achieved higher heart rates in both the Balke and short Balke,
however, this was not shown to effect the Max VO2 achieved. They concluded that any of the four methods will apparently yield good results in estimating maximum oxygen uptake in fit, motivated college women. The subjects stated that the Balke test did not hurt as much, therefore, if time of testing is not an important consideration the longer Balke test was recommended.

In comparing the treadmill test to bicycle ergometer tests, Diaz et al. (1978) found higher Max VO2 values with the treadmill tests for men and women. The results for the women revealed the mean Max VO2 levels at 2.4 l/min and 52.3 ml/kg/min for the treadmill testing and 2.21 l/min and 41.6 ml/kg/min for the bicycle ergometer tests. Maximum oxygen uptake express in terms of lean body mass was found to be 9.0% higher in males than in females. Diaz et al. (1978) indicated this comparison was similar to those of other studies, however, it was suggested that the findings may indicate differences between the sexes for Max VO2 expressed as ml/kg of lean body weight/min may be due to the fitness level of the individual subject.
Continuous versus Discontinuous Treadmill Testing

As reported by Froelicher, Brammell, Davis, Noquera, Stewart, and Lancaster (1974), the first use of treadmill testing was to evaluate functional work capacity. The first treadmill exercise protocols for measuring oxygen uptake consisted of intermittent progressive workloads separated by a period of several days. This was considered necessary since near maximal work is fatiguing and may influence subsequent efforts. The aim of the protocol was to achieve a work load at which there was no increase in oxygen uptake from a previous work load of lower intensity. However, more recent investigations have discovered that Max VO2 is a highly stable and reproducible variable and that factors such as the time of day, donation of one pint of blood, prolonged loss of sleep, and repeating the test with very little rest between stages will not significantly influence the Max VO2 values (Weltman & Stamford, 1982).

Continuous treadmill testing refers to tests completed without any stopping until the subject reaches exhaustion. The speed of the treadmill and percent of grade varies with the protocol. In contrast, discontinuous treadmill testing involves the subject reaching the state of exhaustion through work periods separated by rest periods. The specific work and rest
interval variables varies from one study to another.

The research team of Maksud and Coutts (1971) compared the Max VO2 values attained during a single session continuous protocol and the values achieved in a discontinuous protocol. Twenty young adult males volunteered for their study. The continuous test consisted of a 10 minute warm-up at 3.5 mph and 0% grade. After a brief rest period the subject began running at 7 mph on a 0% grade. At the end of each minute the grade was increased 2.5% until the subject could no longer continue. The discontinuous procedure had the subjects warm-up by walking for 10 minutes at 3.5 mph on a 10% grade followed by 5 minutes of rest. The subject then ran at 7 mph for a period of 3 minutes at each randomly ordered treadmill grade. The results revealed Max VO2 values of 55.6 ml/kg/min for the continuous test and 55.2 ml/kg/min for the discontinuous test. The difference was not statistically significant.

The study conducted by McArdle et al. (1973) also compared continuous and discontinuous treadmill tests. Fifteen male college students volunteered for the study. In the continuous protocol, the subjects ran for 2 minutes at 6 mph on a 0% grade. Elevation of the treadmill was then increased by 2.5% for each successive two minutes until the subject reached exhaustion. The discontinuous protocol involved the subject running for 5
minutes at 6 mph on a 2.5% grade. The grade was then increased for each successive five minute bout by 2.5%. Each run was followed by a 10 minute rest period. The results of the treadmill tests revealed that Max VO2 values were not significantly different on the discontinuous test (56.6 ml/kg/min) compared to the continuous test (55.5 ml/kg/min).

Fardy and Hellerstein (1978) also conducted a study comparing the physiological responses to continuous and discontinuous multistage exercise of identical intensities using a motor-driven treadmill. Both the continuous and discontinuous treadmill protocols consisted of 10 three minute exercise stages of identical speed and grade (2.0 mph & 0% grade, 2.0 mph & 3.5% grade, 2.0 mph & 7.0% grade, 2.0 mph & 10.5% grade, 2.0 mph & 14.0% grade, 2.0 mph and 17.5% grade, 3.0 mph & 12.5% grade, 3.0 mph & 15.0% grade, 3.0 mph & 17.5% grade, and 3.0 mph & 20.0% grade). The continuous test required the subject to proceed through the stage in progression without resting. The discontinuous test incorporated 3 minutes of sitting rest between the stages. The results of the testing revealed Max VO2 values of 40.7 ml/kg/min for the continuous test and 39.5 ml/kg/min for the discontinuous test. The difference was not significant.
As a result of their work, Fardy and Hellerstein (1978) have proposed some advantages to discontinuous treadmill testing, when working with unfit subjects. They found that some of their subjects were unable to complete the continuous test because of greater cardiorespiratory cost than for the discontinuous method. It may, therefore, be assumed that a greater physical work capacity is attained with discontinuous testing. They also revealed that "all subjects perceived the discontinuous test as less strenuous than the continuous test possibly adding a psychological factor. Physiologically this was substantiated by a lower heart rate, ventilation rate and respiration rate, and a greater oxygen pulse at the same exercise stage" (Fardy & Hellerstein, 1978, p. 11).

**Rated Perceived Exertion**

In recent years, researchers have become more interested in how people feel, what aches and pains they have, and how difficult they perceive their work to be. Most practitioners in the health field agree it is important to understand subjective symptoms and how they relate to objective findings. Therefore, it became necessary to develop methods which could quantify these subjective symptoms which are applicable to most people,
regardless of gender, age, circumstances, and national origin (Borg, 1982). Pandolf (1982) reported that "Ekblom and Goldbarg were the first to formally propose that the subjective evaluation of physical effort during exercise was based on two categories of factors: a local factor related to the feelings of strain in the exercising muscles and/or joints and a central factor related primarily to sensations or feelings from the cardiopulmonary systems" (p. 397). And Gunnar Borg (1982) has stated that "in my opinion perceived exertion is the single best indicator of the degree of physical strain. The overall perceived exertion rating integrates various information, including the many signals elicited from the peripheral working muscles and joints, from the central cardiovascular and respiratory functions, and from the central nervous system" (p. 377).

There have been various rating of perceived exertion (RPE) scales devised to determine subjective feelings. The "Ratio - Scaling" method was developed with the same metric qualities as methods used in physics and physiology, e.g., methods with absolute zero and with the same distance between all scale values. One major drawback with ratio - scaling methods is that they do not provide any direct "levels" for interindividual comparisons. Good general functions for a group of subjects can be obtained, but it is difficult
to compare the subjects with each other because subjects are asked only to make relative comparisons. To demonstrate this principle, Borg (1982) notes, "one subject may rate a 1-pound weight a '10' and a 2 pound weight '25' while another may assign '4' and '10' to the same weights. However, the subject assigning the '25' rating to the 2 pound weight does not mean that he perceives it to be heavier than the subject who has rated it '10'" (p. 378).

A category scale for ratings of perceived exertion was constructed by Borg to increase linearly with the exercise intensity for work on the cycle ergometer. Because oxygen uptake and heart rate increase linearly with work load, this was a convenient means of constructing a scale. The scale values range from 6 to 20 and can be used to denote heart rates ranging from 60 - 200 beats/minute. This was intended to make the scale easier to use because a certain value on the scale, e.g., 13, would match approximately a heart rate of 130 b/min for 30 - 50 year-old subjects. However, this close relationship was not intended to be taken too literally because the meaning of a certain heart rate value as an indicator of strain depends upon age, type of exercise, environment, anxiety, and other factors. The advantage of not having to refer to a table to interpret the meaning of a rating value has been great and has
overshadowed the disadvantages of the scale. The scales also have the term "moderate" placed in the middle of the scale, and the terms "strong" and "weak" with the addition of "rather" or "very" placed symmetrically on each side of moderate (Borg, 1982). The subject is asked how he/she would rate the work load based on the corresponding word cues.

The research team of Noble, Metz, Pandolf, Bell, Cafaelli, and Sime (1973) conducted a test utilizing Borg's ratings of perceived exertion while walking and running. Twenty male students participated in the study which utilized a motor driven treadmill. The subjects walked at each of four randomly assigned velocities: 2.5, 3.5, 4.5, and 5.5 mph. Each velocity lasted three minutes with heart rate and perceived exertion recorded at the end of the second and third minute. The Borg scale numbered from 6 - 20 was used to interpret perceived exertion. The results revealed that perceptions of exertion while running are greater than for walking at velocities lower than approximately 4.0 mph. The reverse was observed at higher velocities. The Perceived Exertion Intersection Point was identified as the point where walking and running is subjectively equal and also the point at which one should decide to change from a walking to a running mode. In untrained walkers this point occurred around 4.0 mph.
In 1983 Mihevic completed a study comparing the perceptual responses to absolute exercise intensities of individuals differing in fitness levels using the RPE scale. A total of 41 women (21 high fit and 20 low fit) and 34 men (21 high fit and 13 low fit) completed the study. The subjects were classified as either high or low fit based on a maximum oxygen uptake test. In the study, subjects cycled for six minutes of increasing workloads until a heart rate of 160 - 170 bpm was attained or until the subject reported leg muscle fatigue. The results of the study revealed that the RPE values did not differ significantly between the high and low fit groups at any work load. However, at each workload heart rates were significantly higher for the low fit subjects (150 bpm for high fit - 165 bpm for low fit, women).

Summary of Review of Literature

Although there are various modes of testing available for obtaining maximum oxygen uptake, treadmill testing appears to be the most desired method for obtaining optimal Max VO2 values. Treadmill testing is popular because it employs a large muscle mass necessary when testing for VO2, especially in sedentary individuals. Also, the researchers are able to
accurately control the speed and grade of the test, thus allowing for the reproduction of procedures. Shepard (1984) notes that the maximum oxygen uptake average from treadmill testing is 7% - 8% above the bicycle ergometer values.

Maximum oxygen uptake testing with females has also shown higher Max VO2 values resulting from treadmill tests compared to the bicycle ergometer (Diaz et al. 1978). Researchers have noted that psychological motivational levels of subjects will be an important determinant in the amount of work individuals are able to perform and in their resultant maximal physiological measures.

As noted earlier, various studies cited have shown that treadmill testing may be the best measure for measuring Max VO2. Maksud and Coutts (1971) and McArdle et al. (1973) maintain that, from the standpoint of administration efficiency for measuring Max VO2 in a large number of healthy subjects, the continuous treadmill test is preferred since only one testing session is required. They also pointed out that "these findings reflect the responses of young male subjects in relatively good condition. Maximum responses to these tests may vary with the subjects tested depending on factors such as age, sex, health, and state of training" (McArdle et al., 1973, p. 6). Various studies have

Although theory would indicate that individuals who are less fit would perceive strenuous exercise as more difficult than the highly fit, research has not supported this concept (Mihevic, 1983). Results indicate that individuals differing in cardiovascular fitness rate their perceived exertion at absolute work loads similarly, even though the less fit subjects exhibit significantly greater cardiovascular strain. These findings are consistent for both men and women.
Chapter Three

METHODS AND PROCEDURES

This chapter contains a description of the subjects, facilities, equipment, testing procedures, and statistical analyses which were used in the study.

Subjects

The subjects were 13 sedentary college women attending South Dakota State University during the spring semester of 1985. Subjects were considered sedentary if they had not been engaged in intercollegiate sports or involved in 30 minutes of continuous activity three times per week for the past two years. The subjects had a mean height of 166.47 centimeters with a standard deviation of 2.97 centimeters and a mean weight of 59.93 kilograms with a standard deviation of 8.30 kilograms. Initial contact was made with individuals who were enrolled in Physical Education classes at South Dakota State University to be possible subjects for the study. All of the subjects were volunteers consenting to all factors represented in the informed consent form (appendix A).
Facilities

All testing sessions were conducted in the South Dakota State University Human Performance Laboratory located in the Stanley J. Marshall HPER Center. Environmental factors should not have affected the results of the study since the room was air conditioned. The air temperature in the lab ranged from 21 to 23 degrees centigrade and the relative humidity ranged between 40% and 68%.

Equipment

All treadmill testing was completed on a variable speed and grade Collins treadmill, model 148. Metabolic measurements were determined utilizing an open circuit method of gas collection and analysis. The expired gas collection was facilitated by a Hans - Rudolph two-way valve model 2700 with a headgear support. Air was prevented from entering or leaving the nose using a spring-type nose clip. Volume was measured on the inspired side by passing through a Parkinson - Cowan dry air gas meter, model P - 249. Expired gases were directed into 150 L meterological ballons with the use of a three way valve and a section of hose four feet in length and one inch in diameter. The oxygen analyzer, model S - 3A, and carbon dioxide analyzer, model CD - 3A,
made by Applied Electrochemistry, Inc. were used to
determine the percent of the respective gases. Expired
air samples were taken from the ballons and passed
through the oxygen and carbon dioxide analyzers at a rate
of 500 ml/min. The analyzers were calibrated regularly
throughout the testing session with known concentrations
of gas. The calibration gas had been verified using the
micro-Scholander technique. Heart rates were monitored
with the use of an Exersentry III heart rate monitor
distributed by Respirationics, Inc. A computer program was
written to calculate metabolic variables based on
standard formulae. The program was generated on the
spreadsheet portion of Lotus 1-2-3 by the Lotus
Development Corporation and run on an IBM Personal
Computer (appendix B).

Testing Procedures

Familiarization Session:
An orientation session was performed by all
subjects prior to the initial testing in order to
familiarize them with the equipment and procedures, to
relieve any anxiety, and to answer any questions the
subjects may have had. Previous to this session informed
consent forms were distributed to the subjects for
approval and signature.
The introduction of the subjects to the treadmill was preceded with verbal instructions on the procedures which would follow. The subjects were asked to step onto the treadmill with their feet to the sides of the belt and their hands on the railing. With the treadmill set at 2 mph the subjects were asked to follow the belt along with one foot sensing the speed and motion of the belt. They were then asked to step onto the treadmill belt and to walk as normally as possible with their arms along their sides in a normal gait. The speed of the treadmill was slowly increased to 6 mph. The subjects ran at this speed for 2 minutes after which the treadmill speed was decreased and the subjects again put their hands on the rail and their feet to the sides of the belt. The treadmill was stopped and the subjects were asked to step off.

Subsequent to this initial phase of the testing familiarization, the continuous protocol for determination of maximum oxygen uptake was simulated. The headgear and nose clip were placed on the subject, and the protocol was explained. The subjects ran at 6 mph for the initial 3 minutes at 0% grade. This was followed by an increase in grade of 2.5% every 3 minutes thereafter. When the subject could no longer continue, she was told to place her hands on the rail and her feet to the side of the treadmill belt. At this time the
head gear and nose clip were removed and the treadmill speed was reduced to 3 mph and the subject stepped onto the belt again to walk for several minutes to prevent the pooling of venous blood in the capacitance vessels of the legs and possible syncope.

Preparation for Testing:

Upon arrival for the actual testing session, the subject's height and weight were recorded. Readings for barometric pressure (mm Hg), temperature (centigrade), and relative humidity (percent) were also recorded. The subject then walked at 3 mph at a 0% grade for 3 minutes followed by a run at 6 mph and 0% grade for one minute. This warmup period was followed by five minutes of sitting rest.

Maximum Oxygen Uptake Test:

Following the five minute rest period the subject was asked to assume the starting position on the treadmill. The adjustable headgear with breathing apparatus and the nose clip were placed on the subject and properly adjusted. The intake hose extending from the dry gas meter was connected to one side of the two-way valve and the exhaust hose leading to the three-way valve was attached to the opposite side. At this point the
test protocol was reviewed with the subject.

Two different treadmill protocols were completed by each subject. The protocols used in the study were modifications of the protocols used by McArdle et al. (1973). The reduction in exercise stage length from 5 minutes to 3 minutes was due to the utilization of sedentary females as subjects. Also, this study was interested in establishing more uniform procedures for the continuous and discontinuous test thus allowing for between test comparisons. The continuous treadmill test was conducted at six miles per hour and began at a zero percent grade. The grade was increased by 2.5% every three minutes until the subject could no longer continue. Expired gases were collected between the second and third minute of each exercise stage. Heart rates were recorded immediately upon completion of exercise. Each subject received verbal encouragement from the researcher during the testing session to continue as long as possible. In some instances, gas collection was interrupted before a full minute sample was collected due to cessation of exercise by the subject. The time into the stage was recorded and calculation adjustments were made. Immediately upon cessation of exercise the headgear and nose clip were removed and the speed and grade of the treadmill was reduced to 2.0 mph and 0% grade, respectively, as the subject was encouraged to walk for
a few minutes.

The discontinuous treadmill test was also conducted at 6 mph but was initiated at 2.5% grade. The subject ran for 3 minutes and was then given a 5 minute rest. The treadmill grade was then increased by 2.5% and the subject ran for three more minutes followed by another five minute rest period. This process was continued until the subject could not complete a stage or until the increase in oxygen uptake was 2.1 ml/kg/min or less between stages. Expired gases were collected between the second and third minute of each exercise stage. If a full minute sample was interrupted due to cessation of exercise by the subject, the time into the stage was noted and the appropriate adjustment was made. Heart rates were recorded immediately after each stage was completed.

Statistical Analysis:

The SPSSX computer analysis package was used to calculate the statistical information. The means, standard deviations, and standard errors, were identified for the following variables: maximum oxygen uptake (l/min) and (ml/kg/min), respiratory exchange ratio, rated perceived exertion, and the number of work stages entered. To determine if there was a significant
difference between the continuous and discontinuous
treadmill tests a correlated groups $t$ - test was
utilized with the alpha level set at .05. Analyses were
carried out on the following variables: maximum oxygen
uptake (l/min) and (ml/kg/min), respiratory exchange
ratio, rated perceived exertion, and the number of work
stages entered. In order to determine whether test order
may have affected the results, the data were also
analyzed comparing the results of those who completed the
continuous test first to those who completed the
discontinuous test first.
Chapter Four

RESULTS AND DISCUSSION

Presented in this chapter are the results and a discussion of the comparison of maximum oxygen uptake achieved during continuous and discontinuous treadmill tests with 13 sedentary college females.

Results

The means, standard deviations, and the standard errors of the means for maximum oxygen uptake (l/min) and (ml/kg/min), respiratory exchange ratio, rated perceived exertion, and the number of stages entered by the 13 subjects are presented in Table 1. The descriptive statistics for the seven subjects who completed the continuous test first are presented in Table 4. The descriptive statistics for the six subjects who completed the discontinuous test first are presented in Table 5. The results of the correlated groups t-test for the respective groups are presented in Tables 2, 3, and 6–8.

Maximum Oxygen Uptake:

Data analysis was performed on maximum oxygen uptake expressed in both liters per minute (l/min) and milliliters per kilogram of body weight per minute (ml/kg/min).
TABLE 1

Descriptive Statistics for All Subjects

<table>
<thead>
<tr>
<th>Variable</th>
<th>Continuous Test</th>
<th></th>
<th>Discontinuous Test</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>x</td>
<td>s</td>
<td>sx</td>
<td>x</td>
</tr>
<tr>
<td>Max VO2:</td>
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<td>.43</td>
<td>.12</td>
<td>3.10</td>
</tr>
<tr>
<td>(l/min)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Max VO2:</td>
<td>50.31</td>
<td>2.55</td>
<td>.71</td>
<td>51.60</td>
</tr>
<tr>
<td>(ml/kg/min)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RER:</td>
<td>.88</td>
<td>.04</td>
<td>.01</td>
<td>.85</td>
</tr>
<tr>
<td>RPE:</td>
<td>17.62</td>
<td>1.71</td>
<td>.47</td>
<td>17.92</td>
</tr>
<tr>
<td>Stages:</td>
<td>3.34</td>
<td>.96</td>
<td>.27</td>
<td>4.15</td>
</tr>
</tbody>
</table>
TABLE 2

Summary for Correlated Group t - tests for
Max VO2 (1/min)

<table>
<thead>
<tr>
<th>Source:</th>
<th>df</th>
<th>t Value</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Subj.:</td>
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<td>-1.49</td>
<td>.163</td>
</tr>
<tr>
<td>Cont. First:</td>
<td>6</td>
<td>-.35</td>
<td>.739</td>
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<tr>
<td>Disc. First:</td>
<td>5</td>
<td>-3.54</td>
<td>.017</td>
</tr>
</tbody>
</table>

TABLE 3

Summary for Correlated Group t - tests for
Max VO2 (ml/kg/min)

<table>
<thead>
<tr>
<th>Source:</th>
<th>df</th>
<th>t Value</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
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<td>-1.37</td>
<td>.197</td>
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<tr>
<td>Cont. First:</td>
<td>6</td>
<td>-.23</td>
<td>.825</td>
</tr>
<tr>
<td>Disc. First:</td>
<td>5</td>
<td>-3.41</td>
<td>.019</td>
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</table>
### TABLE 4

**Descriptive Statistics for the Seven Subjects Who Completed the Continuous Test First**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Continuous Test</th>
<th></th>
<th></th>
<th>Discontinuous Test</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>x</td>
<td>s</td>
<td>sx</td>
<td>x</td>
<td>s</td>
<td>sx</td>
</tr>
<tr>
<td>Max VO2: (l/min)</td>
<td>3.06</td>
<td>.47</td>
<td>.18</td>
<td>3.09</td>
<td>.61</td>
<td>.23</td>
</tr>
<tr>
<td>Max VO2: (ml/kg/min)</td>
<td>49.88</td>
<td>2.14</td>
<td>.81</td>
<td>50.26</td>
<td>5.08</td>
<td>1.92</td>
</tr>
<tr>
<td>RER:</td>
<td>.86</td>
<td>.04</td>
<td>.02</td>
<td>.86</td>
<td>.04</td>
<td>.01</td>
</tr>
<tr>
<td>RPE:</td>
<td>16.71</td>
<td>1.70</td>
<td>.64</td>
<td>18.14</td>
<td>1.95</td>
<td>.74</td>
</tr>
<tr>
<td>Stages:</td>
<td>3.14</td>
<td>1.22</td>
<td>.46</td>
<td>4.00</td>
<td>.82</td>
<td>.31</td>
</tr>
</tbody>
</table>
**TABLE 5**

Descriptive Statistics for the Six Subjects Who Completed the Discontinuous Test First

<table>
<thead>
<tr>
<th>Variable</th>
<th>Continuous Test</th>
<th>Discontinuous Test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>x</td>
<td>s</td>
</tr>
<tr>
<td>Max VO2: (1/min)</td>
<td>2.96</td>
<td>.42</td>
</tr>
<tr>
<td>Max VO2: (ml/kg/min)</td>
<td>50.81</td>
<td>3.09</td>
</tr>
<tr>
<td>RER:</td>
<td>.89</td>
<td>.03</td>
</tr>
<tr>
<td>RPE:</td>
<td>18.67</td>
<td>1.03</td>
</tr>
<tr>
<td>Stages:</td>
<td>3.67</td>
<td>.52</td>
</tr>
</tbody>
</table>
### TABLE 6

**Summary for Correlated Group t - test for**

**Respiratory Exchange Ratio**

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>t Value</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Subj:</td>
<td>12</td>
<td>1.38</td>
<td>.192</td>
</tr>
<tr>
<td>Cont. First:</td>
<td>6</td>
<td>-.13</td>
<td>.902</td>
</tr>
<tr>
<td>Disc. First:</td>
<td>5</td>
<td>2.61</td>
<td>.048</td>
</tr>
</tbody>
</table>

### TABLE 7

**Summary for Correlated Group t - test for**

**Rated Perceived Exertion**

<table>
<thead>
<tr>
<th>Source</th>
<th>df</th>
<th>t Value</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Subj.:</td>
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<td>-.44</td>
<td>.665</td>
</tr>
<tr>
<td>Cont. First:</td>
<td>6</td>
<td>-1.34</td>
<td>.229</td>
</tr>
<tr>
<td>Disc. First:</td>
<td>5</td>
<td>1.94</td>
<td>.111</td>
</tr>
</tbody>
</table>
### Summary for Correlated Group $t$ - test for number of Exercise Stages Entered

<table>
<thead>
<tr>
<th>Source:</th>
<th>df</th>
<th>$t$ Value</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Subj.:</td>
<td>12</td>
<td>-3.83</td>
<td>.002</td>
</tr>
<tr>
<td>Cont. First:</td>
<td>6</td>
<td>-2.52</td>
<td>.045</td>
</tr>
<tr>
<td>Disc. First:</td>
<td>5</td>
<td>-3.16</td>
<td>.025</td>
</tr>
</tbody>
</table>
The information presented in Table 1, which presents data on all 13 subjects, reveals that the mean maximum oxygen uptake in liters per minute for the continuous test was 3.01 with a standard deviation of .43. The mean for the discontinuous test in liters per minute was 3.10 with a standard deviation of .52. The correlated group t-test (see Table 2) revealed that the difference was not significant at the .05 level. The mean maximum oxygen uptake value expressed in milliliters per kilogram of body weight per minute (ml/kg/min) for the continuous test was 50.31 with a standard deviation of 2.55. The discontinuous test elicited a mean Max VO2 of 51.60 ml/kg/min with a standard deviation of 4.74 (see Table 1). The t-test (see Table 3) revealed that there was no significant difference at the .05 level between the continuous and discontinuous tests.

The comparison of Max VO2 values for the seven subjects who completed the continuous test first and the discontinuous test second revealed a mean maximum oxygen uptake in liters per minute for the continuous test of 3.06 with a standard deviation of .43. This compared to a mean Max VO2 value of 3.09 l/min with a standard deviation of .61 for the discontinuous test (see Table 4). The correlated group t-test (see Table 2) revealed the difference was not significant at the .05 level. The mean Max VO2 value in milliliters per kilogram of body
weight per minute was 49.88 with a standard deviation of 2.14 for the continuous test. This compared to a mean value of 50.26 ml/kg/min with a standard deviation of 5.08 for the discontinuous test (see Table 4). The \( t \) - test (see Table 3) showed that this difference was not significant at the .05 level.

The comparison of Max VO2 values for the six subjects who completed the discontinuous test first and the continuous test second revealed a mean maximum oxygen uptake in liters per minute for the continuous test of 2.96 with a standard deviation of .42. This compared to a mean value of 3.10 l/min for the discontinuous test with a standard deviation of .44 (see Table 5). The correlated group \( t \) - test (see Table 2) revealed that this difference was significant at the .05 level. The mean Max VO2 value in milliliters per kilogram of body weight per minute was 50.81 with a standard deviation of 3.09 for the continuous test. This compared to a mean value of 53.16 ml/kg/min with a standard deviation of 4.17 for the discontinuous test (see Table 5). The \( t \) - test (see Table 3) revealed that this difference was significant at the .05 level.

**Respiratory Exchange Ratio:**

The mean value of the respiratory exchange ratio for the 13 subjects on the continuous test was .88 with a
standard deviation of .04. The mean value for the discontinuous test was .85 with a standard deviation of .05 (see Table 1). The correlated group t-test (see Table 6) revealed that the difference between the two tests was not significant.

The mean respiratory exchange ratios for the seven subjects who completed the continuous test first was .86 for the continuous test with a standard deviation of .04 and a mean ratio of .86 with a standard deviation of .08 for the discontinuous test (see Table 4). The t-test (see Table 6) showed the difference was not significant at the .05 level.

The comparison of the respiratory exchange ratio for the six subjects who completed the discontinuous test first revealed the mean values for the continuous test were .89 with a standard deviation of .03. The mean value for the discontinuous test was .84 with a standard deviation of .05 (see Table 5). The t-test (see Table 6) revealed this difference to be significant at the .05 level.

**Rated Perceived Exertion:**

Rated Perceived Exertion (RPE) is the subjective rating of the intensity of physical activity by the subject on a continuous scale with a value of 6 reflecting the easiest work and 20 reflecting maximal
work. The data analyses completed on how the subjects subjectively rated the highest workload performed revealed the mean value for the 13 subjects on the continuous test was 17.62 with a standard deviation of 1.71. The mean RPE value for the discontinuous test was 17.92 with a standard deviation of 1.75 (see Table 1). The correlated group \( t \) - test (see Table 7) revealed that the difference was not significant at the .05 level.

The mean RPE value for the seven subjects who completed the continuous test first was 16.71 with a standard deviation of 1.70 on the continuous test and a mean score of 18.14 with a standard deviation of 1.95 for the discontinuous test (see Table 4). The \( t \) - test (see Table 7) showed the difference was not significant.

The mean score for RPE for the six subjects who completed the discontinuous test first was 18.67 with a standard deviation of 1.03 for the continuous test. The mean RPE score for the discontinuous test was 17.67 with a standard deviation of 1.63 (see Table 5). The \( t \) - test (see Table 7) revealed the difference was not significant at the .05 level.

**Exercise Stages Entered:**

Data analysis performed on the number of exercise stages entered by the 13 subjects resulted in a mean score of 3.4 with a standard deviation of 1.0 for the
continuous test. The mean number of stages entered for the discontinuous test was 4.1 with a standard deviation of .8 (see Table 1). The correlated groups $t$ - test (see Table 8) revealed that this difference was not significant at the .05 level.

A review of the data on the seven subjects who completed the continuous test first reveals the mean number of stages entered for the continuous test was 3.1 with a standard deviation of 1.2. The mean number of stages entered for the discontinuous test was 4.0 with a standard deviation of .8 (see Table 4). The $t$ - test (see Table 8) revealed that this difference was significant at the .05 level.

The mean number of stages entered for the six subjects who completed the discontinuous test first was 3.7 with a standard deviation of .5 for the continuous test. The mean number for the discontinuous test was 4.3 with a standard deviation of .8 (see Table 5). The $t$ - test (see Table 8) revealed this was a significant difference at the .05 level.

Discussion

The results of this study comparing maximum oxygen uptake values obtained during continuous and discontinuous treadmill exercise with 13 sedentary female
subjects indicates there is no difference in the elicitation of Max VO2. This tends to support the previous investigations by McArdle et al. (1973) and Maksud and Coutts (1971) which showed no significant differences in maximum oxygen uptake between continuous and discontinuous treadmill tests, although both studies utilized healthy male subjects.

The research team of Fardy and Hellerstein (1978) found that some of their unfit male subjects were unable to complete the continuous test because of its greater cardiorespiratory cost than for the discontinuous method. Their study revealed that four of the 16 subjects could not complete the continuous test, however, three of the four subjects were able to complete the discontinuous test. As a result, the authors have questioned the validity of utilizing the continuous test for sedentary people. In the present study, when the 2.1 ml/kg/min or less increase was used as the criterion for achieving Max VO2, only two subjects met this criterion on the continuous test. All of the subjects met this criterion on the discontinuous test. Also, the subjects in the present study were able to complete almost one full additional work stage on the discontinuous test even though the initial workload was at a grade of 2.5% compared to 0% for the continuous test. Regardless of the increased workload the subjects were able to complete
on the discontinuous test and of the inability for the majority of the subjects to plateau with the continuous test, the statistical analyses showed no significant differences in the Max VO2 levels reached.

When considering the subjective feelings the subjects had toward the two tests, Fardy and Hellerstein (1978) noted that all of their subjects perceived the discontinuous test as less strenuous than the continuous test. The researchers thought the preference for the discontinuous test may have been a positive psychological factor when completing the discontinuous test since motivation is considered to be an important factor in the work accomplished by sedentary individuals. However, in the present study, when comparing how the subjects subjectively rated the highest workload for each of the tests on the Borg Scale, the ratings were almost identical. Verbal communication with the subjects upon completion of both tests revealed the majority preferred the continuous tests because less time was required and they also complained of "stiff" calf muscles when beginning an exercise stage after the five minute rest period on the discontinuous test. This would support the statement by McArdle et al. (1973) who noted that their "subjects seemed to 'tolerate' the continuous test quite well and preferred the shorter time period for testing" (p. 159).
It is interesting to note that the six subjects who completed the discontinuous test first had a significantly greater Max VO2 in liters per minute and milliliters per kilogram of body weight per minute on the discontinuous test than on the continuous test. A possible explanation is that once the subject experienced a maximal effort with the discontinuous test, which incorporated rest periods, the psychological motivation for completing a test to maximal effort without rest periods was somewhat diminished. Additional research needs to be completed to see what findings will emerge.
Chapter Five

SUMMARY AND CONCLUSIONS

Summary:

The purpose of this study was to determine if there was a significant difference in the elicitation of maximum oxygen uptake using a continuous treadmill test versus a discontinuous treadmill test with sedentary college women. A total of 13 sedentary college females volunteered for the study.

Each subject completed a familiarization session prior to the two actual testing sessions. During this session the continuous protocol was simulated on the motor-driven treadmill. The actual testing involved the completion of a continuous treadmill test and a discontinuous treadmill test, the order of administration being randomly assigned. The continuous test was initiated at a constant speed of 6 mph at a 0% grade. After 3 minutes and every 3 minutes thereafter the grade was increased by 2.5% until the subject became exhausted. The discontinuous test involved the subject running at 6 mph for 3 minutes at 2.5% grade followed by a 5 minute rest period. The grade was then increased by 2.5% and the subject ran for 3 additional minutes followed by a 5 minute rest period. This process was repeated until the subject reached exhaustion or until an increase of 2.1
ml/kg/min or less from one stage to the next was attained.

During the testing session for the last minute of each exercise stage inspired gases passed through a dry gas-meter and expired gases were collected in meterological balloons. Gases were analyzed in oxygen and carbon dioxide analyzers and the accumulated data were reduced. The subject was also asked how she subjectively rated the work level during the last 30 seconds of each exercise stage (RPE).

A correlated group t-test was used to determine if significant differences existed for the following variables: maximum oxygen uptake expressed in liters per minute and milliliters per kilogram of body weight per minute, respiratory exchange ratio, rated perceived exertion, and number of exercise stages entered. The .05 level of significance was used. No significant difference was found in maximum oxygen uptake between the continuous and discontinuous treadmill tests for the 13 subjects. A significantly higher Max VO2 was found for the discontinuous test when comparing the six subjects who completed the discontinuous test first. Subjects perceived the difficulty of the two tests as being equal.
Conclusions:

This study showed that there was no significant difference in the elicitation of maximum oxygen uptake between continuous and discontinuous treadmill tests with sedentary female subjects. The subjects rated the difficulty of the two tests as the same although they preferred the continuous test. The study did reveal that the six subjects who completed the discontinuous test first elicited a significantly greater Max VO2 on the discontinuous test.

RECOMMENDATIONS FOR FURTHER STUDY

The present study revealed no significant difference in Max VO2 values between the continuous and discontinuous tests. It must be noted that significant differences were found for those subjects who completed the discontinuous test first. Therefore, additional research implementing multiple administration of the two test protocols would be justified.
BIBLIOGRAPHY


Appendix A

INFORMED CONSENT FORM

I, ________________, state that I am at least 18 years of age and am voluntarily participating in a program of research being conducted by Miles M. Mettler.

I understand that the purpose of the research is to determine if discontinuous treadmill test values for maximal oxygen uptake are different than values obtained using a continuous protocol in sedentary females.

The project involves four testing sessions to be scheduled at a time mutually agreeable to the investigator and myself. The session will require me to perform a bout of high intensity exercise during which data will be collected. The test will require me to wear testing equipment which includes: head gear, nose clip, and mouth piece. As a participant in this project I can expect to gain information of my current cardiovascular fitness level and knowledge of how fitness is evaluated.

I acknowledge that I have been informed that I will be furnished with information about my test results. I also understand that I may withdraw at any time and will have any questions concerning procedures answered by
the investigator. I freely and voluntarily consent to participate in this research project.

SIGNATURE OF VOLUNTEER ________________________________

DATE ________________________________
# Appendix B

<table>
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<tr>
<th>NAME</th>
<th>DATE</th>
<th>TEST TYPE</th>
<th>AGE</th>
<th>TIME</th>
<th>HEIGHT (IN)</th>
<th>WEIGHT (LB)</th>
<th>BARO. PRESS.</th>
<th>TEMPERATURE (C)</th>
<th>REL. HUMIDITY</th>
<th>VCF</th>
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| SPEED (MPH) | GRADE (%) | SAMPLE TIME | METER RDG #1 | APE | METER RDG #2 | FE02 | FEC02 | HEART RATE | INSP. VOL (VC) | VI (L/MIN) | VE (L/MIN) | #L O2 EXP | VO2 (L/MIN) |
|-------------|-----------|-------------|---------------|-----|--------------|------|-------|------------|----------------|-------------|------------|------------|------------|-------------|
|             |           |             |               |     |              |      |       |            |                |             |            |            |            |             |

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<thead>
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