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A comparison of maximal oxygen uptake achieved from a horizontal and inclined treadmill test

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University of Nevada, Las Vegas, 1993
A COMPARISON OF MAXIMAL OXYGEN UPTAKE
ACHIEVED FROM A HORIZONTAL
AND INCLINED TREADMILL TEST

by

Cherri Nowotny Epstein

A thesis submitted in partial fulfillment
of the requirements for the degree of

Master of Science
in
Exercise Physiology

Department of Kinesiology
University of Nevada, Las Vegas
April 1993
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A COMPARISON OF MAXIMAL OXYGEN UPTAKE ACHIEVED FROM A HORIZONTAL AND INCLINED TREADMILL TEST

There are various modalities used to attain an individual's VO2 max. The treadmill, in the United States is widely used. There are several variations in treadmill protocol relating to speed and grade, and there is little conclusive evidence on whether incline running or horizontal running produces a higher max VO2.

The purpose of this study was to compare two protocols and the resulting VO2 max obtained. In one protocol grade only was used to impose greater workloads; in the other protocol speed only was used to impose greater workloads. In addition, maximum heart rate, perceived general fatigue, leg fatigue and cardiorespiratory fatigue between the two protocols was compared. The subjects were also asked which protocol they preferred, and which protocol they thought caused them to perform harder.

Thirty apparently healthy subjects, 15 men and 15 women, between 18 and 35 years of age participated. They exercised maximally once on an inclined treadmill and once on a horizontal treadmill. Oxygen uptake and heart rate were monitored using open circuit spirometry and a MicroCor
ECG Monitor. The subjective questions were posed to each subject after the recovery period.

A 2(gender) x 2(protocol) mixed model ANOVA with repeated measures on protocol was used to determine if there was a significant difference in VO2 max or heart rate between gender and between protocols, and to determine if there was a gender by protocol interaction. A 2(gender) x 3(fatigue) x 2(protocol) mixed model ANOVA with repeated measures on the last two factors was used to determine if there was a difference between subjects' general fatigue, leg fatigue, or cardiorespiratory fatigue on the inclined and horizontal protocols. The percentage of responses were determined for the perception of which protocol was preferred and which protocol seemed harder.

The statistical treatment showed that there was no significant difference in VO2 max between inclined and horizontal running, although there was a significant difference in VO2 max between males and females, this would be expected, (Astrand 1986, Mellerowicz and Smollaka 1981). There was no significant difference in max heart rate, general fatigue, or cardiorespiratory fatigue between the two protocols. Additionally, male subjects perceived that they performed harder on the horizontal protocol and also preferred the horizontal protocol. The females perceived that they performed harder on the inclined protocol and preferred the inclined protocol.
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CHAPTER 1

Introduction

The purpose of exercise is to improve physical fitness. Components of physical fitness are flexibility, muscular strength and endurance, and aerobic or cardiorespiratory fitness. Fitness test batteries assess each of these areas to determine the physical fitness level of an individual.

When assessing cardiorespiratory fitness, exercise heart rate, recovery heart rate or maximum oxygen uptake is measured. The preferred laboratory technique is to measure the maximum oxygen uptake (max VO2).

Maximum oxygen uptake can be measured using a number of different modalities i.e. cycle ergometer, bench step, or treadmill. The most common laboratory technique is the motor driven treadmill. To determine max VO2, the subject needs to be maximally exerted. This maximum workload can be imposed quickly or more slowly by adjusting the speed and grade of the treadmill. Most laboratories develop protocols that increase the workload through 5 or 6 stages.

The max VO2 protocol is similar to the Graded Exercise Test (GXT) protocols used to non-invasively diagnose coronary heart disease (CHD). These protocols may, for unfit or older patients, progress slowly
to maximum work, like the Balke or modified Balke, or they may increase speed and grade quickly as in the Bruce protocol. Many laboratories use GXT's to also determine max VO2. The modifications of these tests are dependent on the population and purpose for which the test is used.

Need For The Study

When selecting a max VO2 protocol, speed, grade, or both can be used to impose greater workloads. Increasing grade to high levels tends to put a great deal of stress on the lower leg muscles. Even in experienced runners, the increased grade is unnatural and tends to be more stressful on legs than on the cardiorespiratory system sometimes causing the subject to terminate the test prior to reaching true max VO2. Increasing speed to high levels may be mechanically uncomfortable and difficult to maintain, which may also result in termination of the test prior to true max VO2.

Purpose Of The Study

The purpose of this study was to compare the maximum VO2 obtained from a treadmill protocol where grade only was used to impose workloads, to a protocol where speed only was used to impose workloads.
Limitations

Certain limitations exist which rule out inferences to the total population. Equipment, time and personnel are also limiting factors in most studies.

1. The number (N=30) of subjects was relatively small, making inference about the total population limited.

2. Subjects were between 18 and 35 years of age, so inferences were primarily limited to this age group.

3. Subjects resided in Las Vegas, Nevada, so inferences were more appropriate to Las Vegas.

4. Subjects were volunteers negating random sampling.

5. Voluntary maximal exertion may not reflect true maximum oxygen uptake values.
With the emphasis on health and fitness in today's society, it is desirable to have methods of assessing an individual's physical fitness level. Physical fitness is broken down into four components: muscular strength and endurance; body composition; flexibility; and cardiorespiratory fitness, (Getchell 1987, Golding et al. 1989). (1) Muscular strength refers to the capacity of the muscles to exert or resist force. Muscular endurance is the capacity of the muscles to sustain repeated contractions, as well as the ability of the muscles to hold a static contraction over an extended period of time, (Getchell 1987). (2) Flexibility is the ability to use a muscle throughout its maximum range of motion; to bend, stretch and twist, (Getchell 1987). (3) Body composition refers to the relative amounts of fatty tissue, as well as lean body tissue (bone, muscle, organs), that constitutes the body, (Getchell 1987). Although muscle strength and endurance, flexibility, and body composition are important, cardiorespiratory fitness is viewed as the most essential physical fitness component. (4) Cardiorespiratory fitness refers to the fitness of the heart, lungs and circulatory system. By improving cardiorespiratory fitness levels through exercise, improvements in the transportation of oxygen through the blood to the working muscle is observed. This is accomplished by the increased efficiency of the heart, which pumps the
blood; the lungs, where oxygen is picked up; and the unloading of oxygen at the tissue level (Golding et al. 1989).

History

Historically, the measurement of cardiorespiratory fitness was determined by measurements of strength, resting heart rate and resting blood pressure. This type of testing, however, was later discarded because it was determined that it did not take into account measurements of endurance or heart and lung development, (Mathews 1973). In 1903, Bowen published the first results of a study of cardiovascular function. He studied the relationship of the pulse rate to exercise and determined that the pulse rate is influenced by the speed and amount of effort exerted during exercise, as well as physiological condition, posture, and mental state of the subject, (Schneider 1920, Meyers 1962). In 1905, Crampton also devised one of the pioneer tests for cardiovascular function, The Crampton Blood Ptosis Test. His test was designed to determine the general condition of an individual on the basis of changes in systolic blood pressure and heart rate when going from supine to standing. The test considered two elements: An increase in systolic pressure, signifying good condition and an increase in heart rate, signifying poor condition. Crampton found that "vigorous" individuals had a rise in systolic blood pressure when going from supine to standing and individual's in poor condition had no rise in systolic pressure or even as much as 10 mmhg decrease. Crampton also found that a "vigorous" individual did not have an increase in heart rate when going from supine to standing, but an individual in poor condition had as much as a 44 beat per minute increase,
(Mathews 1973, Meyers 1962, Schneider 1920). The Crampton Blood Ptosis Test was followed by McCurdy's Test in 1910, which showed that the resting heart rate serves as a fair indication of physical condition; a high resting heart rate suggests poor condition, and a low resting heart rate suggests good condition, (Schneider 1920). Other researchers who reported the correlation between a low resting heart rate and good physical condition were Pombry 1913, and Dawson 1919, (reported by Schneider 1920).

In 1914, as reported by Rebella 1964, Marlin and Greer introduced a test which compared resting pulse pressure and resting heart rate to pulse pressure and heart rate after exercise. This was the first time pulse pressure was used in cardiovascular testing. Also in 1914, Foster developed a cardiovascular efficiency test using heart rate. He demonstrated that an individual’s heart rate will increase in direct proportion to the intensity of the exercise. If the pulse rate increases out of proportion to the intensity, then the individual is considered to be in poor physical condition, (Mathews 1973, Meyers 1962)

In 1920, Schneider devised a test which combined the features of the previously mentioned test done by Crampton 1905, McCurdy 1910 and Foster 1914. The test known as the "Schneider Index" recognized more factors then any other previous tests, and was the first comprehensive cardiovascular test. This test was based on the principle that a physically fit, well conditioned person will have less change in blood pressure and
heart rate when going from supine to standing, less of an increase in heart rate with exercise, and a quicker recovery heart rate after exercise, (Meyers 1962, Schneider 1920, Mathews 1973). Also in the early 1920's, A.V. Hill found that the cardiorespiratory fitness of an individual can be determined by the measurement of an individual's maximum oxygen consumption, (Hill and Lupton 1923, reported by Lindsey 1988). This determination of cardiorespiratory fitness through oxygen consumption is possible because of the inter-individual differences in max VO2, which is crucial in performing prolonged muscular work. Measurement of oxygen consumption as a determinant of cardiorespiratory fitness has subsequently become one of the most accurate methods to date, (Simonson 1942, 1957, Astrand 1956, 1986, Town and Golding 1977, Newton 1963, Rowell 1964, Horvath and Horvath 1973, Howley and Franks 1986, Sinning 1975). As stated by Brooks and Fahey 1984, ... one definition of cardiorespiratory fitness is maximal oxygen consumption.

Maximal Oxygen Consumption

Maximal oxygen consumption is one of the most commonly used physiological indicators of an individual's capacity to sustain hard work. It is also an objective measure by which to determine the fitness of an individual as reflected by their cardiovascular system, (Newton 1963, Gitin 1974, Getchell 1987). Maximum oxygen consumption (VO2 max), is determined by measuring the maximum amount of oxygen that can be taken up by the blood and delivered to the cells per minute, (Sinning
Therefore, VO2 max is not only the ability of the heart to pump the blood to the tissues, but the ability of the lungs to ventilate larger volumes of air and also the ability of the tissues to extract the oxygen from the blood and for the blood to remove carbon dioxide from the tissue (Mitchell et al 1958, Getchell 1987). VO2 max is usually expressed as milliliters of oxygen consumed per kilogram of body weight per minute (ml.kg⁻¹.min⁻¹), (Getchell 1987, Fox and Mathews 1974, AAHPERD Technical Manual 1984), and in most laboratories is measured through open circuit spirometry, (Sinning 1975, Getchell 1987, Howley and Franks 1986).

Like today, early studies of the development of VO2 max consider it to be the moment at which the subject became exhausted, (Robinson, Edwards and Dill, 1937, Cardus 1978). However, for better accuracy, objective criteria should be used to determine when maximum values have been obtained. The most commonly used criteria are:


2. The blood lactate concentration exceeds 130 mg per 100 ml⁻¹, (Astrand and Rodahl 1986).
3. When two determinations of oxygen consumption separated by a grade of 2.5 percent differ by less than 150 ml per minute or 2.1 ml.kg⁻¹.min⁻¹ , (reported by Bernstein 1979, Lindsey 1988).


Of the above criteria, voluntary exhaustion continues to be the most commonly used method of recognizing when an individual has reached VO₂ max, but the "leveling off" of VO₂ max continues to be the most common criteria of objectively evaluating whether or not the subject reached VO₂ max.

Factors That Contribute To Maximum Oxygen Consumption

Seventy percent of the individual differences in maximal oxygen consumption are probably due to heredity, (Astrand 1986, Shepard 1984). However, various factors that can attribute to an individual's maximum oxygen consumption are:

1. Body Weight - a large individual, with more muscle mass and more cells than a small individual, utilizes more oxygen both at rest and during exercise, (Sinning 1985, Taylor et al 1963, Getchell 1987). It has been determined that there is a linear relationship between body weight and gross energy expenditure, (reported by Buono 1979). Oxygen
consumption between individuals should therefore be compared only if body weight between individuals is considered, (Golding et al 1989, Getchell 1987). Oxygen consumption is usually expressed per kilogram of body weight in order to eliminate the differences due to weight. It has been suggested, (Astrand 1986, Taylor et al 1963), that it may even be more accurate to examine VO2 max per kilogram of lean body mass, since fatty tissue is metabolically fairly inert, but constitutes a large portion of the body weight. When VO2 is expressed per lean body mass, VO2 max becomes very similar between well trained men and women, (Astrand 1986). A useful index for the comparison of work capacity between individuals with different body sizes, is to break it down into milliliters per kilogram of body weight. Buskirk and Taylor 1957 when using total body weight, found only a moderate relationship between VO2, but when fat free weight or "active tissue" was considered, the relationship between the two became quite high.

(2) Age - VO2 max increases from birth to sixteen or seventeen years of age, then there is a gradual decline with age, (Robinson 1938, Mitchell et al 1958, Dill 1963, Naughton 1973, Shepard 1984, Astrand 1961 and 1986). In untrained minimally active individuals, this decline is about ten percent each decade past age twenty or one percent per year, (ACSM Fitness Instructors Handbook, Howley and Franks, 1986, Astrand 1986). At age sixty-five, the mean value is about forty-five percent of what it was at age twenty-five. This decline in VO2 with age may be partly due to:
1. The fact that as most individuals get older, they usually become less physically active. As a result of this inactivity, their VO2 max and performance decreases and they increase their body fatness and decrease their lean body mass, (Saltin and Grumby 1968, ACSM Guidelines for Exercise and Prescription 1986). Getchell 1987 states that studies indicate that as much as 50% of physiological decline is related to disuse.


(3) Gender - Before puberty, there is no difference in VO2 max between gender. Thereafter, the average difference in VO2 max in liters per minute between men and women, amounts to about twenty-five to thirty-five percent, (Astrand 1986, Mellerowicz and Smolak 1981). However, when this percentage is related to body weight in milliliters per kilogram per minute, the difference between men and women after puberty is only fifteen to twenty-five percent, (Astrand 1986, Mellerowicz and Smolak 1981). Some of this difference can be attributed to the fact that in general, women have less muscle mass, (23% compared to 40% in males), lower red blood cell count and about 15% less hemoglobin. Consequently, women cannot carry as much oxygen in their blood, (Getchell 1987).

(4) Muscle Mass Utilized - The amount of muscle mass involved during exercise directly effects the amount of oxygen consumed. The more muscles actively involved, the higher the oxygen consumption,
(Brooks and Fahey 1989). Therefore, for an adequate assessment of VO2 max, the test should utilize large muscle groups, (ACSM Guidelines for Exercise and Prescription 1991). The test should also reflect the specificity of the muscle groups developed in training, (Taylor et al 1955). This is supported by a study involving the measurement of VO2 max in athletes while they engaged in the sport for which they specifically trained, (Strom et al 1977).

(5) Physical Conditioning - physical conditioning has been shown to increase maximum oxygen consumption, (Holloszy 1964, DeVries 1966, Morehouse and Miller 1971, Astrand 1986). Commonly accepted conditioning effects include; improved heart function, improved muscle capillarization, and an increase in cell mitochondria and enzymes, (Leff 1986, Golding et al 1989). Regular training can increase VO2 max by ten to twenty percent, (Brooks and Fahey 1986, Astrand 1970, Golding et al 1989). Pollack et al 1984 states that the VO2 max of a sedentary person can increase, on the average, twenty-five percent after a few months of training. However, the same training program may result in less improvement for some individuals. It appears that the lower the initial level of conditioning, the greater the increase in VO2 max with training.

Top athletes in endurance events have a VO2 max that is about twice as high as that of the average person, (Astrand 1986). Saltin and Astrand 1967, showed that elite endurance athletes have very high maximal oxygen uptakes, while those in events or activities requiring predominantly strength or skill, have lower values. Ekblom, in a
comprehensive series of studies in 1969, showed that athletes, when compared to sedentary people, had a higher maximum oxygen uptake accompanied by both higher cardiac outputs and arteriovenous differences.

(6) Altitude - Because muscle oxygen requirements during exercise are unchanged at high altitudes, it is reasonable that a reduction in oxygen supply at high altitude would limit maximum exercise capacity. VO2 max decreases in proportion to the partial pressure of oxygen, as it decreases with altitude, (Reeves et al, 1992). This decrease is due primarily to the reduction in arterial oxygen content, as the oxygen content decreases with increasing altitude, (Howley and Franks 1986, ACSM Guidelines for Exercise and Prescription 1991). At 7,400 feet, an individual's VO2 max will only be eighty-eight percent of the value that it was at sea level for the unacclimatized individual. This decrease in oxygen consumption will result in a decrease in an individual's physical performance, (Mellerowicz and Smolikla 1981).


1) Oxygen content of the inspired air
2) Pulmonary ventilation
3) Diffusion of O2 from alveolar space to hemoglobin
4) Hemoglobin content
5) Blood volume
6) Ability of the heart to pump blood
7) Distribution of blood flow
8) Ability of the muscle tissue to receive the blood
9) Venous blood return
10) Motivation

Common Laboratory Modalities Used to Determine VO2 Max

Exercise tests for determining VO2 max use a wide variety of exercise modalities. Gartner's ergostat (a wheel turned by the subject by means of a crank), was used for measuring human performance and may be regarded as the forerunner of the present day ergometers. However, work and power could not be measured accurately using this modality, (Mellerowicz and Smoluk 1981).

The three most common laboratory modalities which produce standard work rates for determining VO2 max include the bench step, the cycle ergometer, and the motor driven treadmill, (Cardus 1978, Astrand and Rodahl 1986, Howley and Franks 1986, Fox and Mathews 1974, Naughton et al 1973). These modalities meet the following criteria, (Astrand and Rodahl 1986):

1. They involve large muscle groups,
2. The rate of work is measurable and reproducible,
3. The results are comparable and repeatable,
The test is tolerated by most individuals,
The skill required to perform the test is uniform as possible in the population being tested.

Bench stepping - the simplest of the three modalities is the bench step where the subject steps up and down on a bench at a fixed rate. Advantages include:

1. It is the least expensive modality,
2. Requires little space,
3. Is noiseless,
4. Does not threaten or inhibit the subject, (Naughton et al 1973)
5. It is portable, therefore useful for field location testing, (Shepard 1984)
6. Is popular for rapidly testing large numbers of subjects (Kline et al 1987).

However, the step test has several disadvantages:

1. It is totally dependent on the subject's body weight, resulting in a heavier person lifting more weight with each step.
2. It is difficult to induce the VO2 max in the young healthy subject, except through the combination of tall stepping heights combined with fast stepping rates, (Shepard 1984). Nagle et al, (reported by Naughton et al 1973), developed a platform which could be raised vertically to increase the
external workload during stepping. This was designed to parallel the principle used in treadmill testing, where elevating the percent grade is used to increase the workload. However, increased rates and height of stepping increases the risk that the subject may stumble or fall, (Shepard 1984). One way of overcoming this problem is to supplement the normal body mass by carrying a standard backpack, which was developed by Ladell and Kenney, 1955, (Shepard 1984).

3. When measuring work done on the step test, it is dependent on the subject's ability to step up to the same point during each cycle and to maintain a constant stepping rate set by the metronome. For this reason, the step test is considered to be the least reproducible of the three modalities, (Cardus 1978).

4. The end result of a subject who is unaccustomed to this type of exercise was muscle fatigue (Astrand 1986).

Cycle ergometer - The cycle ergometer was developed in Europe in 1883, (Mellerowicz and Smolilaka, 1981). Historically, it was a cycle which used a friction belt to give the flywheel resistance. Resistance has also been added in other ways, such as the application of electromagnetic force to a brake drum, with the resistance measured in watts, and with capacitors to electrically apply resistance to the flywheel. Today, it is still used and the mechanical resistance is preferred by most researchers because it is easy to calibrate and troubleshoot. The mechanical formula is a measurement of power usually given as distance x resistance x speed. The cycle
ergometer, (either peddled by the legs or arms), allows researchers to evaluate physiological parameters, (i.e. heart rate, blood pressure, cardiac output and blood variables), while a subject performs various levels of physical work. The cycle ergometer has several advantages over the other ergometers or exercise machines, (Mellerowicz and Smodlaka 1981, Golding 1989):

1. The cost is relatively inexpensive,
2. The size is small, requiring little space and making it easy to transport,
3. It is quiet,
4. Heart rates and blood pressures can easily be taken,
5. Tests performed on the cycle ergometer are reproducible,
6. It is a non weight bearing apparatus which allows for longitudinal studies,
7. The subject can use arms, legs or both in a sitting or lying position,
8. It requires little or no training or practice.

Disadvantages to the cycle ergometer include:

1. It is not a natural way of exercising, not every individual knows how to ride a bike. In individuals who have never ridden a bicycle before, a test for VO2 max on the cycle ergometer may be undesirable, (Astrand 1986).
2. It is self limiting, making it possible for the subject being tested to continue to exercise at a lower rate than what they should be for the workload, (Astrand 1986, Shepard 1984).

3. The individual being tested is limited or restricted by local leg fatigue, which may cause them to slow down or stop prior to reaching their max VO2, (Astrand 1986, Naughton et al 1973, Shepard 1984, Howley and Franks 1986, Amsterdam et al 1977). This fatigue is thought to be due to the smaller muscle mass used. It is especially common for the bicycle test done in the recumbent position because the leg muscles push the peddle without using the help of the individual's body weight, (Mellerowicz and Smolilaka 1981).

Treadmill - The treadmill is a motor driven conveyor belt on which a subject can walk or run. The belt can be adjusted for different speeds, the elevation can change and work can be measured. The first treadmill was used in the Harvard Fatigue Laboratory by D.B. Dill in 1928, (Horvath and Horvath 1973). The treadmill has since become the most widely used modality for exercise testing in the United States, (Shepard 1968, 1984, Taylor 1969, Naughton 1973, Fox and Mathew 1974, Amsterdam 1977, Douglas 1981, Freund 1986). However, the treadmill does have its disadvantages, (Naughton et al 1973, Mellerowicz and Smolilaka 1981, Shepard 1984):
1. The individual being tested must be able to walk. This eliminates individuals with various disabilities,
2. It requires considerable floor space,
3. It is heavy, making it difficult to move or transport,
4. It is noisy,
5. It is expensive,
6. It usually requires electrical wiring (220 volts),
7. It is weight dependent, making longitudinal studies difficult due to the fact that as an individual's body weight changes, it changes the workload for the same test,
8. Its slowest speed is the speed of walking, which may be too high for individuals in poor physical condition,
9. There is a danger of falling while running on the treadmill.

The treadmill has many advantages over the step test, cycle ergometer or other exercise machines, (Naughton 1973, Shepard 1984, Ellestad 1975,1986, Getchell 1987):

1. It provides flexibility in setting workloads. Both speed and grade can be adjusted independently or simultaneously.
2. The pace is set by the machine, not by the individual being tested.
3. It appears that the treadmill allows for the highest VO2 max results of the three modalities previously discussed - cycle ergometer, step test and treadmill.
4. Provides an accurate range of exercise intensity with excellent reproducibility.

Many researchers agree that of the three modalities, step test, bicycle ergometer and treadmill, the treadmill yields the highest VO2 max (Ikai 1972, Stamford 1975, Cardus 1978, Miles et al 1980, Mellerowicz and Smolak 1981, Shepard 1984, and Astrand 1986). In some studies, VO2 max values on the treadmill were shown to be as much as twenty percent higher than those reached on the bicycle ergometer, (Harrison et al 1980, Astrand 1986). Astrand summarized (1986):

"If the objective is to determine the individual's maximal aerobic power, running or combined arms plus leg exercises are, in most cases, slightly superior to cycling or performing a step test. It appears that for the untrained individual, the highest VO2 max values are obtained during an inclined treadmill run to exhaustion".

Other modalities besides the three previously mentioned, have also been used to determine VO2 max. These will not be discussed in this chapter, however, these modalities and how they compare to the VO2 values obtained during an inclined treadmill run are listed in Table 1.

Types of Treadmill Testing

There are many variations in administering a treadmill test to determine VO2 max. The principle of treadmill testing for obtaining VO2 max is to steadily increase the workload until the subject can no longer continue. There are a variety of well documented published protocols, (Howley and
Franks 1986, ACSM Guidelines 1991, Ellestad 1975), however, it is common for laboratory's to adapt or change these existing protocols to fit a particular subject or situation.

TABLE I

Mean Values for Maximal Oxygen Uptake Attained in Various Types of Exercise in Ordinary and Specially Trained Subjects

<table>
<thead>
<tr>
<th>Type of Exercise</th>
<th>Ordinary Subjects</th>
<th>Specially Trained Subjects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Running Uphill</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>Arms and Legs</td>
<td>100</td>
<td>100 - 115</td>
</tr>
<tr>
<td>Running Horizontally</td>
<td>95 - 98</td>
<td></td>
</tr>
<tr>
<td>Cycling, Upright</td>
<td>92 - 96</td>
<td>100 - 108</td>
</tr>
<tr>
<td>Cycling Supine</td>
<td>82 - 85</td>
<td></td>
</tr>
<tr>
<td>One Leg, Upright</td>
<td>65 - 70</td>
<td>75 - 80</td>
</tr>
<tr>
<td>Arms</td>
<td>65 - 70</td>
<td>105 - 115</td>
</tr>
<tr>
<td>Step Test</td>
<td>97</td>
<td></td>
</tr>
<tr>
<td>Rowing</td>
<td>100</td>
<td>100 - 115</td>
</tr>
<tr>
<td>Skiing</td>
<td>100</td>
<td>100 - 112</td>
</tr>
<tr>
<td>Swimming</td>
<td>85</td>
<td>100</td>
</tr>
</tbody>
</table>

All values are expressed as percentage of the maximal oxygen uptake attained at uphill treadmill running, which represents the 100% reference value. For literature references, see Table 1 in Astrand, 1976, and Chapter 14.
 Protocols are single stage, multi-stage, continuous or non continuous, and unless the protocol is for predicting purposes, all protocols take the subject to maximum. A single stage workload is held constant, such as four miles per hour on a five percent grade until max is reached. A multi-stage workload is increased at regular intervals, for example a two percent increase in grade every three minutes. The multi-stage workload can be subdivided into continuous or non continuous workload. Non continuous tests allow the subject to rest between workloads, (Kattus 1972), this allows for heart rates, blood pressures and EKGs to be taken easily and allows muscle strength to be restored so that a greater total stress can be applied, (Ellestad 1986). However, non continuous tests are time consuming, therefore most protocol workloads are continuous. Continuous workloads are progressively increased at regular intervals without rest periods, Naughton 1973, Ellestad 1986, McArdle, Katch and Pecher 1973, found no significant difference in max VO2 between continuous and non continuous tests. The above protocols allow the subject to continue until they attain their true VO2 max, (Naughton et al 1973). The subject continues exertion until they cannot continue any longer, (Amsterdam 1977, Kattus 1972), or until one of the criteria of objectively determining maximal effort is reached (see max VO2 criterias page 8). Maximal tests require a high degree of motivation from the subject since they continue to exhaustion. They are time consuming, and may cause apprehension in the older or inactive person who is not accustomed to doing exhausting work, (Wyndham
sub maximal protocols can be used to predict a subject's VO2 max. The end point to the sub maximal test may include: (1) achieving a target heart rate based upon a percentage of the individual's estimated maximal heart rate, for example seventy to eighty-five percent of the predicted maximal heart rate, (2) achieving a particular workload, (3) achieving a particular oxygen requirement, (4) if the subject becomes symptomatic, (Howley and Franks 1983, Astrand 1986, Amsterdam et al 1977).

Early development of sub maximal testing dates back to the early 1920's when the Harvard Fatigue Laboratory attempted to develop a sub maximal test to classify individual fitness levels. Their first attempt, the Stone Boat Test, involved dragging a weighted sled three-hundred yards and then measuring recovery heart rate, (Horvath and Horvath 1973). Cooper, in 1968, developed a sub maximal field test based on the distance covered by walking or running in twelve minutes, this was correlated to an individual's maximum aerobic capacity, (Kline 1987). Astrand and Rhyming 1954, developed a nomogram to predict VO2 max. The Astrand Rhyming nomogram is based on the assumption that heart rate, VO2 max, and workload are linear, making it possible to estimate VO2 max from sub maximal heart rates, (Kline 1987, Golding 1989, Astrand 1952, Taylor 1955, Astrand and Rhyming 1954, DeVries 1968, Sinning 1975, Mellerowicz and Smidlaka 1981). The prediction of max VO2 is determined by the use of a nomogram through extrapolation by fitting a straight line from a sub maximal point to a predicted maximal point, or by using a mathematical
formula based on a regression equation (reported by Lindsey 1988). Most sub maximal tests for predicting maximal VO2 assume three relationships between work, heart rate and oxygen consumption:

1. There is a linear relationship between heart rate and work,
2. There is a linear relationship between VO2 max and work,

When using heart rate to predict VO2 max, it must be assumed that the linearity between heart rate and VO2 max exists only at certain heart rates. Low heart rates, approximately one-hundred ten or below, tend to be effected by several factors: talking, laughter, nervousness, dehydration, temperature, altitude, elapsed time after meals, previous activity or loss of sleep, and therefore cannot be used. Otherwise, linearity also stops with maximal values which are usually related to age, (Taylor et al 1963, Brooks and Fahey 1984, Golding et al 1989). Any prediction of the VO2 max has a standard error of estimate of ten percent to fifteen percent, (Astrand and Rhyming 1954, 1986, Shepard 1984). Therefore, for more accurate results, maximal testing should be used.

Types of Maximal Treadmill Protocols

Many of the stress test protocols now in use have been based on the work done in 1956 by Bruce, (Ellestad 1975). The most commonly
used protocols developed since Bruce's initial works are the Bruce, Balke, Naughton and the Ellestad, (American College of Sports Medicine Guidelines for Exercise and Prescription 1986, Jopke 1981). These protocols meet the American College of Sports Medicine and the American Heart Association recommendations that stress tests should be graded, and also that the initial workload does not exceed three mets, (Jopke 1981). These protocols are described as follows:

Bruce Protocol: The Bruce Protocol is the most commonly used protocol, (Jopke 1981, Cardus 1978, Shepard 1984, ACSM Guidelines 1981). It involves a change in speed and grade every three minutes with a relatively large increase in intensity equaling two to three mets per stage. It has seven stages; Stage one starts at 1.7 mph at a ten percent grade, the grade then increases 2 percent per stage, and the speed increases .8 to .9 mph per stage. The major advantage of the Bruce protocol is its relative brevity. Few nonathletes can go beyond the third stage, (ACSM Guidelines 1991, Jopke 1981). Because of the difficulty of this test, active or younger people are a more appropriate population to be tested using this protocol, (Howley and Franks 1986).

Balke Protocol: The Balke Protocol involves a constant walking speed of 3.3 mph with an increasing grade of one percent every minute, (Newton 1963, Jopke 1981, Howley and Franks 1986). Because of its slow progression, the Balke test takes longer than the Bruce
test and is more appropriate for inactive individuals because it only increases 1 met per stage, (Howley and Franks 1986).

Ellestad Protocol: The Ellestad Protocol utilizes a constant grade of ten percent with variable speeds at each stage, (Ellestad 1969, Cardus 1978, Jopke 1981). However, at minute eleven, if an individual has not reached peak performance, the percent grade goes up to fifteen percent, (ACSM Guidelines, 1986). This protocol is more appropriate for untrained individuals because work levels are low and therefore, well trained athletes may not be able to reach peak performance, (Jopke 1981).

Naughton Protocol: The Naughton Protocol starts at 1 mph and progresses to 2 mph for the remainder of the test. Each stage is two minutes long with grade increments starting at zero percent and progressing to twenty-two percent. This test is recommended for older, less fit individuals or cardiac patients, (Jopke 1981).

Horizontal vs Inclined Treadmill Protocols

Research is not conclusive on whether incline running protocols or horizontal running protocols elicit higher VO2 max values (Ellestad 1975, Katch et al 1976, McKay and Banister 1976, Allen et al 1986, Freund et al 1986). Studies have demonstrated greater values during horizontal running, greater values during inclined running, as well as values that show no significant difference between the two.
In 1972, Michael and Eckardt studied three trained and three untrained males while they exercised for 15 minutes. They were asked to select a workload they considered difficult while running on the treadmill to eighty percent of max at a 0% grade. They were then asked to repeat the exercise by selecting what they considered an equal work load while running on a 10% incline to eighty percent of max. The data showed there was no significant difference in maximal VO2 values or maximal heart rate values when running horizontally compared to running on a 10% incline.

In 1976, Katch et al studied the VO2 max response of 12 well-trained college males using two treadmill protocols: Horizontal and inclined, no significant difference was found. The VO2 max for the inclined run was 4.267 L/min and the VO2 max for the horizontal run was 4.192 L/min. The max H.R. response was 190.4 and 188.9, for the inclined and the horizontal runs respectively. It was concluded that the intensities of both treadmill protocols were sufficient to produce a non-significant difference in maximal VO2 values for the type of subjects tested.

Succe, 1981, tested twelve females and twelve male distance runners and found no significant difference in VO2 max between inclined and horizontal running.

In 1986, Freund, Allen and Wilmore conducted a study to determine if VO2 max values during inclined running and horizontal running were
affected by training on an inclined terrain. Twenty-two men, age seventeen to twenty-seven, participated in the study. Ten men were randomly assigned to a control group and twelve to an experimental group. The experimental group ran on an inclined terrain four times per week for thirty-five minutes each session, at 65% to 85% of their max VO2, for twelve weeks. Prior to training, it was determined that there was no significant difference in VO2 max values between the two protocols. Following training, the VO2 max on the inclined protocol was significantly greater than the horizontal protocol. These results support the concept of specificity of training, as well as the importance of careful selection of the test protocol, and test modality. Also in 1986, Allen, Freund and Wilmore studied VO2 max values during horizontal and inclined running as affected by training on exclusively flat terrain. Twenty-seven untrained college age males volunteered for the study. Seventeen subjects assigned to the experimental group trained by running on flat terrain for twelve weeks, four days per week, for thirty-seven minutes per day at an intensity equal to 65% to 85% of their heart rate reserve. Ten subjects assigned to the control group remained sedentary. Prior to training, the control group showed no significant difference in VO2 max, however, the experimental group yielded significantly higher values on the inclined protocol. After training, there was no pre-to-post training interaction between protocols for VO2 max. It was concluded that the post-training results do not support the concept of protocol specificity when evaluating VO2 max in subjects trained exclusively on a horizontal terrain. It is concluded by the above researchers that an
inclined protocol imposes no greater demand on an untrained subject than does a horizontal protocol.

Other researchers have found different results. Astrand, 1952 (sited by Allen 1986 and Freund, 1986) found significantly higher values for horizontal running in trained runners. In 1979, Wilson et al found significantly higher values for horizontal running in ten male milers. Gibson et al, 1979, found higher VO2 max values for horizontal running in athletes trained only on horizontal terrain. Other studies disagree with all of the above studies and have concluded that inclined running not only equals VO2 max values for horizontal running, but also exceeds them. As reported by Ellestad 1986, researchers such as Balke and Ware, Fox et al, and Naughton et al, believe that during treadmill testing, the speed should be kept constant and the grade should be gradually increased. Taylor et al 1955, concludes that "...raising the grade with the speed constant (7 mph), is the more satisfactory method of increasing work load to attain a maximal oxygen uptake". It was found that running up an incline yielded higher VO2 max values as compared with level running, (Kamon 1972). Astrand and Saltin, 1961, found a five percent higher oxygen uptake during maximal incline running, than in any other physical activity involving large muscle groups when the grade was set at three percent or higher, (Hermansen and Saltin 1961). Later, in 1965, Hermansen and Saltin tested six subjects during a maximal run uphill, (three percent), and a maximal run with no hill. They found that inclined running at three percent resulted in a 0.20 liter/min higher oxygen uptake then running maximally with no incline. Hermansen and Saltin
concluded that to ensure the highest possible oxygen uptake is obtained, the incline should be elevated to three percent or more. The American College of Sports Medicine Guidelines for exercise testing and prescription state that values for incline treadmill running are higher than horizontal treadmill running.

There are various hypotheses pertaining to the different findings in VO2 max between incline and horizontal running. One possibility for a lower VO2 max during horizontal running, is that running horizontally at high speeds is technically so difficult that some subjects fail before reaching their max, (Astrand 1986). Subjects who are not trained for running, may not have the ability to achieve or maintain leg speed, or recruit an adequate number of muscle fibers to maximally exert the cardiorespiratory system prior to stopping from leg fatigue, (Allen et al 1986, Freund et al 1986). However, in studies that show a higher VO2 value for horizontal running, it is thought it was due to localized pain in the calf muscles induced by mechanical inefficiency during inclined running, (Stamford 1975, Ellestad 1986). As suggested by Astrand 1952, and Wilson 1979, sited by Freund 1986, an individual's VO2 max value may be higher during horizontal running due to local muscular adaptations from their specific training program.

Higher VO2 max values during inclined running have been attributed to the larger muscle mass utilized, (Hermansen and Saltin 1969, Astrand 1986). the involvement of leg muscles is different for horizontal compared
to incline running. During incline running, ancillary muscle groups, such as those involved in trunk support, arm movement, and vertical lift, may be used and therefore contribute to the higher VO2 max values, (Costill et al 1974, Michael 1972). Another finding which was observed by Hermansen and Saltin 1969, is that the inclined protocol yields lower stride frequency allowing for greater foot contact time on the treadmill, therefore increasing the leg muscle contractions during inclined running.

**SUMMARY**

Physical fitness is broken down into four components: muscular strength and endurance; body composition; flexibility; and cardiorespiratory fitness. Of these, cardiorespiratory fitness is considered the most essential. Historically, measurements of cardiorespiratory fitness were determined by measurements of strength, resting heart rate and resting blood pressure, but in the 1920's, it was found that cardiorespiratory fitness could be determined by the measurement of an individual's VO2 max and has since become one of the most commonly used methods to date. VO2 max is determined by measuring the amount of oxygen that is taken up by the blood and delivered to the cells per minute, and is usually expressed as ml.kg⁻¹.min⁻¹. Various factors can contribute to an individual's VO2 max, although seventy percent of this difference can be contributed to heredity, other factors such as body weight, age, gender, physical conditioning, altitude and muscle mass utilized can also contribute.
The amount of muscle mass utilized directly effects the amount of oxygen consumed, thus, the more muscle actively involved, the higher the oxygen consumption. The type of modality chosen for a test determines the amount of muscle mass used. The three most common modalities are the bench step, the cycle ergometer and the motor driven treadmill. Of these, the treadmill is the most widely used modality in the United States.

Today, the most common treadmill protocols which were all based on the work done by Bruce in 1956, include those of Bruce, Balke, Naughton, and Ellestad. Although these are well established treadmill protocols, treadmill tests can be administered in a variety of ways with the main goal to obtain VO2 max by steadily increasing the workload until the subject can no longer continue. However, to date it has still not been established whether bringing an individual to max by increasing the speed or by increasing the grade will produce a higher maximum oxygen uptake.
CHAPTER 3

Methods

I. Subjects:

Thirty (30) apparently healthy subjects (15 men and 15 women) volunteered for the study. The mean values for age, height, weight, and percent fat for men, women and the two combined are presented in Table I. Data for each subject is presented in Appendix A.

### TABLE II

Mean and Standard Deviation Values For Physical Characteristics of Subjects

<table>
<thead>
<tr>
<th></th>
<th>Age (yrs)</th>
<th>% Fat</th>
<th>HT (cm)</th>
<th>WT</th>
<th>H.R.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Women (Kg)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>26.9</td>
<td>20.0</td>
<td>168.8</td>
<td>61.3</td>
<td>59.4</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>2.6</td>
<td>4.2</td>
<td>5.3</td>
<td>5.1</td>
<td>11.0</td>
</tr>
<tr>
<td>Men</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>27.5</td>
<td>15.3</td>
<td>176.1</td>
<td>76.5</td>
<td>65.5</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>3.8</td>
<td>6.8</td>
<td>6.5</td>
<td>13.0</td>
<td>9.0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>27.2</td>
<td>17.7</td>
<td>172.5</td>
<td>68.9</td>
<td>62.43</td>
</tr>
<tr>
<td>Standard deviation</td>
<td>3.3</td>
<td>6.1</td>
<td>7.0</td>
<td>12.5</td>
<td>10.40</td>
</tr>
</tbody>
</table>

Subjects between the age of 18 and 35 were recruited from university classes. When an individual expressed interest in being a subject, an information packet was given to him/her which included an explanation of the study; a Physical Readiness Questionnaire (PAR-Q); a fitness profile questionnaire; and a general information questionnaire (Appendix B). Volunteers were selected if they satisfied the PAR-Q questions.
II. **Design**

Each subject reported to the laboratory for three, one-hour sessions.

A. The first session was to familiarize subjects with test procedures and equipment, answer questions, sign an informed consent and measure weight, height, resting blood pressure, resting heart rate and skin fold measurements (3 for female and 4 for male).

B. The second session was the first of two graded exercise treadmill runs to exhaustion - either the protocol increasing the speed at each workload or the protocol increasing the grade at each workload was selected.

C. The third session was the second of the two graded exercise treadmill runs - the protocol not used during the first run was selected.

The measurements taken during the treadmill runs were:

1. Oxygen consumption.
2. Heart rate.

Subjects performed each test protocol once. At the end of each test, they were asked to complete a questionnaire regarding their perceptions of their maximum performance (Appendix C).

III. **Equipment:**

A. Electrode and skin preparations:

   All necessary equipment was available for preparing the ECG electrode sites ie; alcohol, razors and towels.

B. Resting measurements and/or procedures:

   1. Harpenden skinfold calipers (British Indicators) were used for measuring skinfolds.

   2. A physician's balanced scale was used for body weight which was recorded to the nearest .25 pound.
3. A tape measure attached to a wall was used to determine height in centimeters.

4. Resting blood pressure and heart rate was taken using a Puritan-Bennett Infrasound D4000.

C. Heart rate:

1. Microcore M101 ECG Monitor, a Microcore P400 digital printer, Microcore patient cables and Red Dot pre-gelled disposable electrode were used for heart rate monitoring.

D. Treadmill:

1. A Quinton model 24 - 18 motor driven treadmill with a 1 to 12 mph speed range and a 0% to 40% grade range was used.

E. Supplementary equipment for VO$_2$ determination:

1. Barometric pressure was measured with a wall-mounted barometer.

2. Ambient room temperature was measured with a thermometer.

3. Time was monitored with a gra-lab timer and a stopwatch.

4. O$_2$ and CO$_2$ analyzers were zeroed with certified calibrated 100% nitrogen and a calibrated gas mixture of 16% O$_2$, 4% CO$_2$ and 80%N.

5. Expired gas samples were analyzed with an Anarad CO2 non-directional infrared gas analyzer and a Servomax 570 A Paramagnetic O2 Analyzer.

6. Gas volumes were measured by a Calibrated Ram 1200 gas meter with electric potentiometer and thermometer.

7. One liter sample bags and a sampling pump were used to collect samples of expired air.
8. Flexible 2 plastic housing, headpiece, mouthpiece, nose clip, Warren E. Collins 3-way valves and a mixing chamber were used to collect gases.

IV. Methodology:

A. Resting blood pressure and heart rate: Blood pressure and heart rate were taken after the subject sat quietly for approximately two minutes or until the heart rate stabilized. The subjects sat with their feet flat on the floor and their backs straight. The electronic blood pressure monitor was used to measure heart rate, systolic blood pressure and 5th phase diastolic blood pressure.

B. Weight: Body weight was measured using a physician's scale. Subjects removed their shoes, stood as still as possible, then body weight was measured to the nearest .25 lb.

C. Height: Standing height was measured in centimeters with a tape measure attached to a wall. Subjects removed shoes, stood as tall as possible, placed feet together against the wall and looked straight ahead.

D. Skinfolds: Percent body fat was estimated using the Jackson and Pollock's skinfold equation-sum of four for men (abdomen, illium, pectoral and axilla) or sum of three (illium, abdomen, tricep) for women. (Golding, 1982)

Exact location of skinfold sites and the procedure were done according to the Y's Way to Fitness (Golding et al., 1982). The subjects were instructed to stand relaxed and comfortable with arms to the side. Each measurement was taken on the right side of the body. Two to three trials at each site were taken for better reliability. Using two hands, the fold was firmly grasped between the left thumb and fore-fingers, then lifted up. This was done several times to make sure that no muscle tissue was included. The right hand was removed and the calipers were placed on the fold next to the left hand. When the caliper's pointer stopped, the reading to the nearest millimeter was taken. The sites are explained below.
TRICEPS: A vertical fold on the posterior portion of the upper arm midway between the acromial process of the scapula and the elbow.

ABDOMEN: A vertical fold approximately one inch to the right of the subject's umbilicus.

ILLIUM: A diagonal fold just above the crest of the highest peak along the mid-axillary line.

AXILLA: A vertical fold on the mid axillary line at the nipple level.

PECTORAL: A diagonal fold on the pectoral line halfway between the axillary fold and the nipple.

V. Procedures:

A. Orientation Session:

1. Subjects were informed of the nature, purpose and possible risk of the study; then read and signed the consent form. (Appendix D)

2. Height, skinfold measurements, resting blood pressure, and heart rate were taken.

3. A practice running session on the treadmill, simulating actual test conditions was given to familiarize the subjects with the treadmill and gas collection equipment.

4. The subjects were given a copy of pre-test procedures to be followed. (Appendix E)

B. Second and Third Testing Session:

1. Equipment Preparation

   a. One hour before each testing session, the O₂ and CO₂ analyzers were turned on to allow adequate time to warm up.
b. The analyzers were calibrated according to standard procedures. (Appendix F)

c. The system was checked for leaks and correct valve placement.

d. The 4 memories of the Microcore EKG monitors were cleared and prepared for use. (Appendix G)

2. Subject Preparation

a. The subjects' adherence to pretest instructions was checked (Appendix E). Failure to follow any of these instructions resulted in cancelling and rescheduling the test.

b. Subjects were weighed.

c. Subjects were prepped for electrode placement. Each electrode site was wiped with alcohol. The skin was abraded for better electrical conduction. Electrodes were placed in CM configuration as follows:

1. The manubrium of the sternum (negative)
2. V₄ position (positive)
3. And on the lower right quadrant of the abdomen (ground lead)

The Microcore cables were attached to the appropriate electrodes and secured to the body with tape.

3. Workload Selection

In preparation for the treadmill tests, predicted maximum heart rates were determined by subtracting the subject's age from 220. Exercise heart rates were determined at 40, 55, 70 and 85 percent of the predicted maximum heart rate. The calculation used to arrive at these percentages was as followed:

\[(220 - \text{age} - \text{RHR}) \times (\%) + \text{RHR} = \text{PMHR} \text{ (Karvonen 1957)}\]
Where: PMHR = predicted max heart rate  
RHR = resting heart rate  
% = desired percent of predicted max.  
age = in years

These heart rates were used as guidelines to obtain five different levels of work. Workloads were adjusted so that at each stage subjects worked as close as possible to their target exercise heart rate.

a. Inclined Running Test Protocol:

This protocol was designed to attain max VO\(_2\) by keeping speed constant and only increasing grade. Subjects warmed up by walking 3 mph at a 0% grade for 2 minutes. At the termination of the warm up, speed was increased until the onset of a slow jog, which varied for each individual from 4.5 to 5 mph, (\(x = 5.1\) mph). This speed was kept constant throughout the test.

Each stage was 3 minutes in duration. Stage 1 was at a 0% grade, each subsequent stage was increased by 2.5% or 5% increments depending on the heart rate response. This procedure was used in all but one subject who had an exceptionally elevated heart rate in which case an increased less than 2.5% was used.

Percentages of predicted maximum heart rate (40%, 55%, 70% and 85%) were used as guidelines for stages I through IV. However, if needed, stage V was significantly increased to induce maximal exertion. An effort was made in each test to reach voluntary maximal exertion by stage V. However, in 14 cases, additional stages were added until voluntary maximal exertion was achieved.

b. Speed Running Test Protocol:

The second protocol used to attain maximum VO\(_2\) was by keeping the grade constant at 0% and increasing the speed. As before, subjects warmed up at 3 mph. At the
termination of the warm up, speed was increased to the onset of jogging. Regardless of the speed, this level was specified as stage I. Speeds at consecutive stages were calculated to keep at the target exercise heart rate. The calculation was as follows:

\[ x = (\text{Maximum speed}) - (\text{speed at stage I}) + (5) \]

where:

- \(x\) = amount of increase in mph for each stage
- maximum speed = subject's estimation of his/her maximum speed based on practice run.
- 5 = number of workloads used for the test e.g.

\[ 10 \text{ mph} - 5 \text{ mph} + 5 \text{ stages} = 1; \text{ thus each stage increased by 1 mph workloads. At stage V, workload may have been significantly increased to induce maximal exertion.} \]

C. Testing Procedures

1. Ambient barometric pressure and temperature were recorded prior to the exercise test.

2. Test procedures for that session were reviewed with the subject.

3. The headpiece, mouthpiece, and noseclip were placed on the subject, making the necessary adjustments to fit tightly around the forehead; the mouthpiece was placed securely between the lips and gums; and the noseclip was tight enough to avoid air loss. A hose was connected from the expired air side of the mouthpiece to the gas collection system. (See Gas Collection)

4. The subject sat quietly in a chair for three minutes to clear the system of room air.

5. The ECG cables from the subject were connected to the Microcore ECG monitors and the resting heart rate was taken and recorded on the score sheet (Appendix H).
6. An evacuated sample bag was attached to the appropriate part of the system and the bag number was recorded.

7. The respiratory gas meter readout was set to zero.

8. At the end of three minutes, gas volume and gas samples were collected for one minute. Resting VO$_2$ was then determined. (See Gas Collection)

9. Subjects began their two minute warm up on the treadmill at 3 mph.

10. At the end of the warm up, workload was increased to the level selected for Stage I of the particular protocol being used. (See Workload Selection a and b)

11. The remaining stages were then increased according to the procedure outlined in workload selection for the appropriate test.

12. The test continued until the subject, after much encouragement, indicated that about one minute of exercise remained until exhaustion.

13. At this time, the stopwatch was immediately started, and a one minute gas volume was measured, and a gas sample was collected for analysis. (See Gas Collection) To reconfirm the subject's indication of exhaustion, forty-five seconds into the final minute, the subject was asked if he/she wished to continue. In this case, the process continued until a "quit" signal was given by the subject.

14. Once voluntary maximal exertion was achieved, the heart rate was recorded and then stored into the memory of the Microcore monitor for future retrieval. The test was then terminated and all data collection stopped.

15. The subject actively cooled down, walking until a heart rate of 120 or less was achieved.

16. After the cool down, the subjects completed a post exercise questionnaire. (Appendix C)
17. ECG tracings were retrieved from the memory of the Microcore monitor. The recorded heart rates were confirmed from these tracings.

18. Gas samples were analyzed. (Appendix I)

D. Gas Collection (See schematic)

A one minute collection began by turning the T-valve on the volume meter to the open position. Simultaneously, the air pump attached to the mixing chamber was turned on for ten seconds to clear the sample bag hosing. At the end of ten seconds, the air from the hosing was directed into the sample bag by opening the stopcock. During the collection period, temperature of the expired air passing through the gas meter was recorded.

At the end of one minute, the T-valve on the volume meter was turned on to the closed position so a reading could be taken and the air pump attached to the mixing chamber was turned off.

The volume times the correction factor plus 1 liter was recorded and the volume meters reset to zero. The hosing from the air pump was clamped to avoid contamination by room air. The sample bag was then removed for analysis. (Appendix I) A new evacuated sample bag was attached for the next collection period and the bag number was recorded.

VI Calculation Of Oxygen

Oxygen uptake was calculated by using the Haldane Transformation Equation (Mathews & Fox 1981) and corrected for standard temperature, pressure and saturation.

A. Haldane Transformation Equation:
\[
\text{VO}_2 = \text{VE} \times \left[ \frac{1 - \text{FeO}_2 + \text{FeCO}_2}{0.7903} \right] \times 0.2093 - \text{VE} \cdot \text{FeO}_2
\]

where: \( \text{V}_{\text{STPD}} \) = volume of expired air in liters per minute

\[
\text{FeO}_2 = \% \text{O}_2 \text{ of expired air}
\]

\[
\text{FeCO}_2 = \% \text{CO}_2 \text{ of expired air}
\]

\[
0.2093 = \% \text{O}_2 \text{ of room air}
\]

\[
0.7903 = \% \text{N} \text{ of room air}
\]

B. STPD Correction Equation

\[
\text{V}_{\text{STPD}} = \text{V}_{\text{ATPS}} \times \left( \frac{\text{PB} - \text{pH}_2\text{O}}{760} \right) \times \left( \frac{273}{273 + T} \right)
\]

where: \( \text{V}_{\text{ATPS}} \) = volume of expired air in liters per minute corrected with the gas meter correction factor and 1 liter added for the sample removed for analysis

\[
\text{PB} = \text{Barometric pressure}
\]

\[
\text{PH}_2\text{O} = \text{water vapor pressure (Appendix J)}
\]

\[
T = \text{temperature of expired air}
\]

VII Statistical Treatment of Data

A. Mean and standard deviations were calculated to describe the physical characteristics of the subject.
B. A $2(\text{gender}) \times 2(\text{protocol})$ mixed model ANOVA with repeated measures on protocol was used to determine if there was a significant difference in VO2 max between gender and between protocols; and to determine if there was a gender by protocol interaction.

C. Three subjective responses were elicited. The first determined the type of fatigue that caused the subject to stop. i.e. leg (muscle) fatigue, cardiorespiratory fatigue or a combination of the two. The second determined the subject's preference regarding the protocols, and the third determined which protocol the subjects perceived caused them to work harder.
CHAPTER 4

Results and Discussion

Introduction:
For presentation and discussion of the data, two major sections are reported:

I. Presentation And Discussion Of The Data

1. The data comparing maximum VO2 values obtained on the treadmill during inclined and horizontal running.

II. Presentation Of The Additional Data Collected To Support The Study.

1. Data comparing maximum heart rate values obtained on the treadmill during inclined and horizontal running.

2. Data comparing which protocol induced the most:
   a. leg fatigue,
   b. cardiorespiratory fatigue,
   c. general fatigue.

3. Data comparing which protocol the subjects perceived caused them to work harder.

4. Data comparing which protocol the subjects preferred.
I. Presentation And Discussion Of Data

1. Mean VO2 max values during inclined and horizontal running

This section presents a comparison of the mean VO2 max values obtained during a horizontal running protocol and an inclined running protocol for males, females and males versus females. A 2(gender) x 2(protocol) mixed model ANOVA with repeated measures on protocol was used to determine if there was a significant difference in VO2 max between gender and between protocols; and to determine if there was a gender by protocol interaction. The dependent variable was the measured max VO2 value and the independent variable was the gender and the type of protocol used, (inclined or horizontal).

Mean and standard deviations in max VO2 as a result of performing the two different treadmill protocols are presented numerically in Table III and graphically in Figure 1. Individual data is presented in Appendix K.

Figure 1 shows that for males, the inclined protocol induced a slightly higher, but non significant VO2 max value over the horizontal protocol. The mean max VO2 obtained during the horizontal protocol for males was 49.35 ml.kg\(^{-1}\).min\(^{-1}\) \(\pm\) 7.0 ml.kg\(^{-1}\).min\(^{-1}\), whereas the mean max VO2 using the incline protocol was 50.77 ml.kg\(^{-1}\).min\(^{-1}\) \(\pm\) 6.77 ml.kg\(^{-1}\).min\(^{-1}\), inducing only a difference of 1.42 ml.kg\(^{-1}\).min\(^{-1}\). The results of the
ANOVA indicated no significant main effects or interactions (p > .05), between mean VO2 values for males during inclined and horizontal running.

**TABLE III**

Means and standard deviations for maximal VO2 values obtained during horizontal and inclined running.

<table>
<thead>
<tr>
<th></th>
<th>VO2 Incline</th>
<th>VO2 Horizontal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>50.77</td>
<td>49.35</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>6.77</td>
<td>7.01</td>
</tr>
<tr>
<td>Significance</td>
<td>Non-Significant</td>
<td></td>
</tr>
<tr>
<td>Females</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>42.73</td>
<td>43.26</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>5.33</td>
<td>3.53</td>
</tr>
<tr>
<td>Significance</td>
<td>Non-Significant</td>
<td></td>
</tr>
</tbody>
</table>

When comparing max VO2 values between the two protocols for females (N=15), Figure 1 this time demonstrates a slightly higher, but non-significant max VO2 value induced by the horizontal protocol. The mean
FIGURE 1
COMPARISON OF VO2 MAX
Mean VO2 max values
max VO2 obtained during the inclined protocol was 42.73 ml.kg\(^{-1}\).min\(^{-1}\) ± 5.33 ml.kg\(^{-1}\).min\(^{-1}\), whereas the mean max VO2 using the horizontal protocol was 43.26 ml.kg\(^{-1}\).min\(^{-1}\) ± 3.53 ml.kg\(^{-1}\).min\(^{-1}\) resulting in a difference of .53 ml.kg\(^{-1}\).min\(^{-1}\). The results of the ANOVA indicate no significant main effects or interactions (p > .05), between mean VO2 values for females during inclined and horizontal running.

From the above results it has been concluded that inclined and horizontal running do not produce a significant difference in VO2 max for the type of subjects tested. This is in agreement with the literature. Katch et al (1976), studied twelve well trained males during maximal inclined and horizontal running and found no significant difference in VO2 max between the two protocols. Sucec (1981), tested twelve male and twelve female distance runners and found that inclined and horizontal running will reliably (r = .95), produce VO2 max values comparable to each other. Freund et al (1986), studied twenty-two men and found no significant difference in VO2 max prior to training and Allen et al 1986 also found no difference in VO2 max values between inclined and horizontal running after testing twenty-seven untrained college aged males.

Although the above studies support the findings of this thesis, other studies disagree. It is possible that the difference between these studies is due to the relative training level of the subjects tested. Wilson et al 1979, compared ten competitive highly trained runners to ten active controls and found that 9 out of 10 of the highly trained runners attained
significantly higher VO2 max values during the horizontal test. Freund et al 1986 studied twenty-two men to analyze the interaction between a subject's VO2 max on an incline protocol versus a horizontal protocol before and after training on inclined terrain. Freund et al found that prior to training, there was no significant difference in VO2 max between protocols. However, post training, they found a significantly greater VO2 max during the inclined protocol.

These findings suggest that for the highly trained runner, or the runner specifically trained on inclined terrain, the protocol chosen should incorporate what they have been specifically trained for. In addition, from the finding of this thesis, it appears that for the average individual, an inclined or horizontal protocol is sufficient to elicit an individual's true VO2 max.

When comparing max VO2 values between males and females, Figure 1, as expected, demonstrates a significantly higher VO2 value for males during both inclined and horizontal running. The mean max VO2 obtained during the inclined protocol for males was 50.77 ml.kg\(^{-1}\).min\(^{-1}\) ± 6.77 ml.kg\(^{-1}\).min\(^{-1}\), whereas the mean max VO2 for females was 42.73 ml.kg\(^{-1}\).min\(^{-1}\) ± 5.33 ml.kg\(^{-1}\).min\(^{-1}\), inducing a difference of 8.04 ml.kg\(^{-1}\).min\(^{-1}\). The mean max VO2 obtained during the horizontal protocol for males was 49.35 ml.kg\(^{-1}\).min\(^{-1}\) ± 7.01 ml.kg\(^{-1}\).min\(^{-1}\) whereas the mean max VO2 for females was 43.26 ml.kg\(^{-1}\).min\(^{-1}\) ± 3.53 ml.kg\(^{-1}\).min\(^{-1}\) inducing a difference of 6.09 ml.kg\(^{-1}\).min\(^{-1}\). The results of the ANOVA
indicate a significant difference ( p < .0013), between mean VO2 values for males and females during inclined and horizontal running. Because the test for interaction failed significance, the difference between gender can be assumed to exist across both inclined and horizontal treadmill protocols. This higher VO2 max value for males is attributed to the larger muscle mass in males and the lower red blood cell count and hemoglobin content in females (Getchell 1987).

II. Presentation Of The Additional Data Collected To Support The Study.

1. Mean maximum heart rate values during inclined and horizontal running.

This section presents a comparison of the heart rate values obtained during a horizontal running protocol and an inclined running protocol for males, females and males versus females. A 2(gender) x 2(protocol) mixed model ANOVA with repeated measures on protocol was used to determine if there was a significant difference in heart rate between gender and between protocols; and to determine if there was a gender by protocol interaction. The dependent variable was the measured heart rate value and the independent variable was the gender and the type of protocol used, (inclined or horizontal). Individual data is presented in Appendix K. The results of performing the two treadmill protocols are presented in Figure 2. Figure 2 shows that for males, females and males
versus females, there was no significant difference in max heart rate values between the two protocols.

**TABLE IV**

Means and standard deviations for maximal heart rate values obtained during horizontal and inclined running.

<table>
<thead>
<tr>
<th></th>
<th>Heart Rate Inclined</th>
<th>Heart Rate Horizontal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Males</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>189.27</td>
<td>190.73</td>
</tr>
<tr>
<td>SD</td>
<td>9.20</td>
<td>10.64</td>
</tr>
<tr>
<td>Significance</td>
<td>Non-Significant</td>
<td></td>
</tr>
<tr>
<td>Females</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mean</td>
<td>189.67</td>
<td>190.53</td>
</tr>
<tr>
<td>SD</td>
<td>9.67</td>
<td>9.09</td>
</tr>
<tr>
<td>Significance</td>
<td>Non-Significant</td>
<td></td>
</tr>
</tbody>
</table>

2. General fatigue, leg fatigue and cardiorespiratory fatigue induced by inclined and horizontal running.

A comparison was made between general fatigue, leg fatigue and cardiorespiratory fatigue for the inclined versus the horizontal protocol. This comparison was a subjective self-reported opinion.
FIGURE 2
COMPARISON OF MAXIMUM HEART RATE
Mean Heart Rate Values
A 2(gender) x 3(fatigue) x 2(protocol) mixed model ANOVA with repeated measures on the last two factors was used to determine if there was a significant difference between subjects' general fatigue, leg fatigue, or cardiorespiratory fatigue on the inclined protocol or horizontal protocol. The dependent variable was the measure of fatigue and the independent variable was the gender, type of fatigue, (general fatigue, leg fatigue, cardiorespiratory fatigue), and the protocol, (inclined or horizontal).

Mean and standard deviations in general fatigue, leg fatigue and cardiorespiratory fatigue as a result of performing the two different treadmill protocols are presented in Table V and in Figures 3, 4 and 5. Individual data is presented in Appendix K.

Figures 3, 4 and 5 show that no significant difference for any of the groups was found for general fatigue, leg fatigue, or cardiorespiratory fatigue. The results of the ANOVA indicated no significant main effects or interactions (p < .05).

3. Protocol the subjects perceived caused them to work harder

This section presents a comparison of which protocol the subjects perceived caused them to work harder. The percentage of responses was calculated to determine which protocol the subjects felt they performed closest to their max. The subjects responses are presented in Table VI and Figure 6. Individual data is presented in Appendix K.
TABLE V

Perception of general fatigue, leg fatigue and cardiorespiratory fatigue induced by inclined and horizontal running.

<table>
<thead>
<tr>
<th></th>
<th>General Fatigue</th>
<th>Leg Fatigue</th>
<th>C.R. Fatigue</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Incline</td>
<td>Horizo</td>
<td>Incline</td>
</tr>
<tr>
<td>Male Mean</td>
<td>4.87</td>
<td>4.93</td>
<td>4.86</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>.83</td>
<td>.80</td>
<td>.95</td>
</tr>
<tr>
<td>Significance</td>
<td>non-significant</td>
<td>non-significant</td>
<td>non-significant</td>
</tr>
<tr>
<td>Female Mean</td>
<td>4.79</td>
<td>4.71</td>
<td>4.79</td>
</tr>
<tr>
<td>Standard Deviation</td>
<td>.99</td>
<td>1.19</td>
<td>1.18</td>
</tr>
<tr>
<td>Significance</td>
<td>non-significant</td>
<td>non-significant</td>
<td>non-significant</td>
</tr>
</tbody>
</table>

1 = very light  
2 = light  
3 = moderate  
4 = fatigued  
5 = very fatigued  
6 = maximal
FIGURE 3
COMPARISON OF GENERAL FATIGUE
BETWEEN PROTOCOLS

Maximal

Very Fatigued

Fatigued

Moderate

Light

Very Light

Males Males vs Females Males vs Females
Incline Horizontal Incline Horizontal

Incline

Males

Females

NS

NS

NS

NS
FIGURE 4

COMPARISON OF LEG FATIGUE
BETWEEN PROTOCOLS

<table>
<thead>
<tr>
<th></th>
<th>Males</th>
<th>Females</th>
<th>Males vs Females</th>
<th>Females vs Females</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximal</td>
<td>4.86</td>
<td>4.75</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Very Fatigued</td>
<td>4.79</td>
<td>4.0</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Fatigued</td>
<td>4.86</td>
<td>4.79</td>
<td>NS</td>
<td>NS</td>
</tr>
<tr>
<td>Moderate</td>
<td>4.0</td>
<td>4.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light</td>
<td>4.0</td>
<td>4.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very Light</td>
<td>4.0</td>
<td>4.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
FIGURE 5

COMPARISON OF CARDIORESPIRATORY FATIGUE BETWEEN PROTOCOLS

[Bar chart showing the comparison of cardiorespiratory fatigue between protocols for males and females, with categories ranging from Very Light to Maximal.]
Figure 6 shows that males perceived that they performed harder during the horizontal protocol while women perceived they performed harder on the inclined protocol.

4. Protocol the subjects preferred.

A comparison was made of which protocol the subjects preferred. The percentage of responses was used. The subjects responses are presented in Table VI and in Figure 7. Individual data is presented in Appendix K. Figure 7 shows that males preferred the horizontal protocol and females preferred the inclined protocol, which is in agreement with which protocol the subjects thought they performed closest to their max.

|TABLE VI|

Perception of which test the subjects thought caused them to work harder and which test they preferred.

<table>
<thead>
<tr>
<th></th>
<th>Perceived Best</th>
<th>Preferred Test</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Inclined</td>
<td>Horizontal</td>
</tr>
<tr>
<td>Percentage Male</td>
<td>8</td>
<td>92</td>
</tr>
<tr>
<td>Percentage Female</td>
<td>54</td>
<td>46</td>
</tr>
<tr>
<td></td>
<td>Inclined</td>
<td>Horizontal</td>
</tr>
<tr>
<td>Percentage Male</td>
<td>46</td>
<td>54</td>
</tr>
<tr>
<td>Percentage Female</td>
<td>61</td>
<td>39</td>
</tr>
</tbody>
</table>
FIGURE 6

COMPARISON OF WHICH PROTOCOL THE SUBJECTS PERCEIVED CAUSED THEM TO WORK HARDER
FIGURE 7
COMPARISON OF WHICH PROTOCOL
THE SUBJECTS PREFERRED

[Bar chart showing the percentage of subjects preferred for Males and Females in different incline and horizontal conditions.]
Summary and Conclusions

Summary:
The use of exercise to improve an individual's overall physical fitness level is common. As many as eight million adults engage in exercise on a regular basis for cardiorespiratory fitness. Because of this interest in cardiorespiratory fitness, it has become desirable to have a means in which to assess an individual's aerobic capacity. Determining an individual's maximum VO2 is one of the most commonly accepted methods of determining cardiorespiratory fitness to date.

There are various modalities used to attain an individual's VO2 max. The treadmill, in the United States is widely used. There are several variations in treadmill protocol relating to speed and grade, and there is little conclusive evidence on whether incline running or horizontal running produces a higher max VO2.

The purpose of this study was to compare two protocols and the resulting VO2 max obtained. In one protocol grade only was used to impose greater workloads; in the other protocol speed only was used to impose greater workloads. In addition, maximum heart rate, perceived general fatigue, leg fatigue and cardiorespiratory fatigue between the two protocols was compared. The subjects were also asked which protocol
they preferred, and which protocol they thought caused them to perform harder.

Thirty apparently healthy subjects, 15 men and 15 women, between 18 and 35 years of age participated. They exercised maximally once on an inclined treadmill and once on a horizontal treadmill. Oxygen uptake and heart rate were monitored using open circuit spirometry and a MicroCor ECG Monitor. The subjective questions were posed to each subject after the recovery period.

A 2(gender) x 2(protocol) mixed model ANOVA with repeated measures on protocol was used to determine if there was a significant difference in VO2 max or heart rate between gender and between protocols, and to determine if there was a gender by protocol interaction. A 2(gender) x 3(fatigue) x 2(protocol) mixed model ANOVA with repeated measures on the last two factors was used to determine if there was a difference between subjects' general fatigue, leg fatigue, or cardiorespiratory fatigue on the inclined and horizontal protocols. The percentage of responses were determined for the perception of which protocol was preferred and which protocol seemed harder.

The statistical treatment showed that there was no significant difference in VO2 max between inclined and horizontal running, although there was a significant difference in VO2 max between males and females, this would be expected, (Astrand 1977, 1986, Mellerowicz and Smolilka 1981). There was no significant difference in max heart rate, general fatigue, or
cardiorespiratory fatigue between the two protocols. Male subjects perceived that they performed harder on the horizontal protocol and also preferred the horizontal protocol. The females perceived that they performed harder on the inclined protocol and preferred the inclined protocol.

Results/Conclusions:
The following conclusions can be drawn from this study:

1. No significant difference in the two protocols exists for VO2 max, heart rate, general fatigue, leg fatigue, or cardiorespiratory fatigue.

2. Male subjects perceived that they worked harder on the horizontal protocol.

3. Female subjects perceived that they worked harder on the inclined protocol.

4. Male subjects preferred the horizontal protocol.

5. Female subjects preferred the incline protocol.

6. Males have a significantly higher VO2 max than females.

Recommendations:
Recommendations arising from this study are:

1. Either treadmill protocol, inclined running or horizontal running, can be selected to elicit an individual's VO2 max for running.
2. To avoid excessive leg fatigue, cardiorespiratory fatigue or apprehension from inclined running or horizontal running, a treadmill protocol that incorporates both speed and grade would seem appropriate.

3. Prior to selecting a protocol, the subject's training habits should be surveyed since it appears that subjects trained on hill running performed significantly better on inclined protocols, and highly trained distance runners performed better on horizontal protocol.

The following recommendations are suggested for further studies:

1. Investigate the results of maximal inclined running and maximal horizontal running in different age groups.

2. Investigate the effect of body composition on inclined running and horizontal running.

3. Study inclined and horizontal running in sedentary individuals, sprinters and distance runners.

4. Compare horizontal and inclined protocols to a protocol that incorporates both speed and grade.
APPENDIX A - K
APPENDIX A

Physical Characteristics of Subjects
### PHYSICAL CHARACTERISTICS OF SUBJECTS

#### MALES

<table>
<thead>
<tr>
<th>Subject</th>
<th>Male</th>
<th>Age</th>
<th>% Fat</th>
<th>WT (kg)</th>
<th>HT</th>
<th>B/P</th>
<th>RHR</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>M</td>
<td>24</td>
<td>8.0</td>
<td>70.01</td>
<td>183</td>
<td>123/67</td>
<td>63</td>
</tr>
<tr>
<td>6</td>
<td>M</td>
<td>29</td>
<td>23.3</td>
<td>84.75</td>
<td>181</td>
<td>143/80</td>
<td>57</td>
</tr>
<tr>
<td>7</td>
<td>M</td>
<td>32</td>
<td>22.1</td>
<td>75.58</td>
<td>172</td>
<td>142/95</td>
<td>75</td>
</tr>
<tr>
<td>11</td>
<td>M</td>
<td>27</td>
<td>12.9</td>
<td>63.74</td>
<td>175</td>
<td>141/76</td>
<td>69</td>
</tr>
<tr>
<td>12</td>
<td>M</td>
<td>30</td>
<td>18.9</td>
<td>68.60</td>
<td>172</td>
<td>111/63</td>
<td>68</td>
</tr>
<tr>
<td>13</td>
<td>M</td>
<td>25</td>
<td>9.6</td>
<td>71.65</td>
<td>181</td>
<td>143/79</td>
<td>78</td>
</tr>
<tr>
<td>14</td>
<td>M</td>
<td>30</td>
<td>7.8</td>
<td>70.28</td>
<td>182</td>
<td>148/88</td>
<td>69</td>
</tr>
<tr>
<td>16</td>
<td>M</td>
<td>25</td>
<td>13.9</td>
<td>71.03</td>
<td>161</td>
<td>134/67</td>
<td>81</td>
</tr>
<tr>
<td>17</td>
<td>M</td>
<td>28</td>
<td>19.4</td>
<td>77.75</td>
<td>169</td>
<td>134/87</td>
<td>58</td>
</tr>
<tr>
<td>18</td>
<td>M</td>
<td>22</td>
<td>22.4</td>
<td>82.65</td>
<td>169</td>
<td>123/79</td>
<td>54</td>
</tr>
<tr>
<td>20</td>
<td>M</td>
<td>32</td>
<td>11.3</td>
<td>77.48</td>
<td>181</td>
<td>126/89</td>
<td>72</td>
</tr>
<tr>
<td>22</td>
<td>M</td>
<td>32</td>
<td>30.3</td>
<td>119.47</td>
<td>185</td>
<td>121/74</td>
<td>59</td>
</tr>
<tr>
<td>24</td>
<td>M</td>
<td>22</td>
<td>6.7</td>
<td>64.02</td>
<td>182</td>
<td>124/69</td>
<td>52</td>
</tr>
<tr>
<td>29</td>
<td>M</td>
<td>33</td>
<td>15.9</td>
<td>58.95</td>
<td>169</td>
<td>104/63</td>
<td>56</td>
</tr>
<tr>
<td>27</td>
<td>M</td>
<td>22</td>
<td>12.0</td>
<td>84.09</td>
<td>175</td>
<td>128/79</td>
<td>57</td>
</tr>
</tbody>
</table>

**Mean** | **M** | **27.5** | **15.3** | **76.70** | **176.1** | **65.5**

**SD** | **M** | **4.0** | **7.0** | **13.6** | **6.8** | **9.0**
### PHYSICAL CHARACTERISTICS OF SUBJECTS

#### FEMALES

<table>
<thead>
<tr>
<th>Subject</th>
<th>Female</th>
<th>Age</th>
<th>% Fat</th>
<th>WT(kg)</th>
<th>HT</th>
<th>B/P</th>
<th>RHR</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F</td>
<td>27</td>
<td>24.5</td>
<td>61.03</td>
<td>188</td>
<td>122/70</td>
<td>65</td>
</tr>
<tr>
<td>3</td>
<td>F</td>
<td>27</td>
<td>15.4</td>
<td>60.90</td>
<td>162</td>
<td>127/79</td>
<td>61</td>
</tr>
<tr>
<td>4</td>
<td>F</td>
<td>25</td>
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Mean F 26.9 20.0 61.20 168.8 59.4
SD F 2.7 4.4 5.2 5.5 11.0
APPENDIX B

Information and Questionnaires:

Explanation of the Test

Fitness Profile and General Information Questionnaire

Physical Activity Readiness Questionnaire
A COMPARISON OF TWO RUNNING PROTOCOLS TO DETERMINE MAX VO2

There is a great interest in knowing your fitness level, how fat you are and what your weight should be. You can find this out by volunteering to be a subject in a study. The exercise physiology laboratory is doing a study which will give you this information. We need volunteer subjects (men and women) between the ages of 18-35 years. The testing will require you to come to the laboratory 4 different days for approximately one hour each time (this will be scheduled at your convenience). The first visit will be for orientation and practice, the second will be for a bike test and the third and fourth for a treadmill test. If you are interested, please fill out the following documents and return to the exercise physiology laboratory. Thank you.

Lawrence A. Golding, PhD. Director

Cherri Nowotny Epstein: Research Associate

Anne Lindsay: Research Associate
A COMPARISON OF TWO RUNNING PROTOCOLS TO DETERMINE MAX VO2

Fitness Profile (Circle the appropriate response 1-5)

1. How would you rate the amount of physical activity you perform while at work or school?
   - Very little 1
   - Little 2
   - Moderate 3
   - Active 4
   - Very Active 5

2. How would you rate the amount of physical activity you perform during your leisure time?
   - Very little 1
   - Little 2
   - Moderate 3
   - Active 4
   - Very Active 5

3. How physically fit do you feel at the present?
   - Unfit 1
   - Below Average 2
   - Average 3
   - Above Average 4
   - Very Fit 5

4. Are you currently performing any physical fitness program? If yes, please describe
   (activity, how often, how long, how hard, etc...)______________________________

General Information

5. Have you ever performed a maximal treadmill or bicycle test?
   - YES__________
   - NO__________
   If yes, please explain when, where and why: ________________________________

6. Please list below the days and hours you are available?

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<tr>
<td>SUN</td>
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</tbody>
</table>

7. Name__________________________________________Age_________M/F__________

   Local Address_____________________________________________________________________

   City, State, Zip___________________________________________________________________

   Home Phone__________________________Work Phone_______________________________

We will contact you in two weeks. If you do not hear from us, please call the lab, 739-3767
and leave a message, particularly as to what time is best to call.

8. Please read and complete the attached PAR-Q form.
PAR-Q & YOU

PAR-Q is designed to help you help yourself. Many health benefits are associated with regular exercise, and the completion of PAR-Q is a sensible first step to take if you are planning to increase the amount of physical activity in your life.

For most people physical activity should not pose any problem or hazard. PAR-Q has been designed to identify the small number of adults for whom physical activity might be inappropriate or those who should have medical advice concerning the type of activity most suitable for them.

Common sense is your best guide in answering these few questions. Please read them carefully and check □ YES or □ NO opposite the question if it applies to you.

YES NO

□ □ 1 Has your doctor ever said you have heart trouble?

□ □ 2 Do you frequently have pains in your heart and chest?

□ □ 3 Do you often feel faint or have spells of severe dizziness?

□ □ 4 Has a doctor ever said your blood pressure was too high?

□ □ 5 Has your doctor ever told you that you have a bone or joint problem such as arthritis that has been aggravated by exercise, or might be made worse with exercise?

□ □ 6 Is there a good physical reason not mentioned here why you should not follow an activity program even if you wanted to?

□ □ 7 Are you over age 65 and not accustomed to vigorous exercise?

If you have not recently done so, consult with your personal physician by telephone or in person BEFORE increasing your physical activity and/or taking a fitness test. Tell him what questions you answered YES on PAR-Q, or show him your copy.

After medical evaluation seek advice from your physician as to your suitability for:

• unrestricted physical activity probably on a gradually increasing basis
• restricted or supervised activity to meet your specific needs at least on an initial basis

Check in your community for special programs or services

If you answered PAR-Q accurately, you have reasonable assurance of your present suitability for:

• A GRADUATED EXERCISE PROGRAM - A gradual increase in proper exercise promotes good fitness development while minimizing or eliminating discomfort
• AN EXERCISE TEST - Simple tests of fitness (such as the Canadian Home Fitness Test) or more complex types may be undertaken if you so desire.

If you have a temporary minor illness such as a common cold....
APPENDIX C

Post Exercise Questionnaire
POST EXERCISE QUESTIONNAIRE

Name ________________________________

Date ________________________________

Test _________________________________

Please circle the number which best describes your level of fatigue (at max) in the following categories:

Example: General Fatigue

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<tr>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very Light</td>
<td>Light</td>
<td>Moderate</td>
<td>Fatigued</td>
<td>Very Fatigued</td>
<td>Maximal</td>
<td></td>
</tr>
</tbody>
</table>

1. General Fatigue: 0 1 2 3 4 5 6
2. Leg Fatigue: 0 1 2 3 4 5 6
   a. leg cramps: 0 1 2 3 4 5 6
   b. heavy legs: 0 1 2 3 4 5 6
   c. shaky legs: 0 1 2 3 4 5 6
   d. hip pains: 0 1 2 3 4 5 6
   e. knee pain: 0 1 2 3 4 5 6
3. Cardiopulmonary Fatigue: 0 1 2 3 4 5 6
   a. shortness of breath: 0 1 2 3 4 5 6
   b. heart pounding: 0 1 2 3 4 5 6
   c. difficult breathing: 0 1 2 3 4 5 6
   d. dizziness: 0 1 2 3 4 5 6
4. Back Pain: 0 1 2 3 4 5 6
5. Arthritic Pain: 0 1 2 3 4 5 6
6. Fear: 0 1 2 3 4 5 6
7. Lack of Motivation: 0 1 2 3 4 5 6
8. State major reason for stopping test
APPENDIX D

Informed Consent
A COMPARISON OF TWO RUNNING PROTOCOLS TO DETERMINE MAX VO2

Informed Consent

Explanation of the test: Each subject will perform three tests. One on a bicycle and two on a motor driven treadmill. The work will begin at a level you can easily accomplish and will be advanced in stages up to your maximum ability. Depending on your level of fitness, the tests will last between 15 and 25 minutes. During the tests, measurements of oxygen consumption and heart rate will be taken. Therefore, you will be asked to breathe through a mouthpiece with your nose clipped in order to collect expired air for analysis and you will have electrodes placed on your chest in order to monitor heart rate. These tests require you to work at your maximum ability and therefore are demanding, vigorous and stressful. We may stop the test at any time if we observe signs of fatigue or you may stop at any time if you feel any discomfort or fatigue.

Risks: There is potential risk involved in exercise testing. Although medical clearance is advised, it is not required since you are under 35 and apparently healthy. While exercising, there is always a risk of tripping or falling, as well as muscle soreness, stiffness, lightheadedness or fainting. You will be monitored by staff during the study and every effort will be made to ensure your safety.

Confidentiality: Subject's confidentiality will be maintained with only staff personnel having access to the files. Names, phone numbers and addresses will not be released without the subject's permission; nor will they be used for reports and/or publication.

Right to Refuse or Withdraw: You may at any time change your mind about being in the study and may withdraw after the study has begun. You may refuse to participate in any part of the study, however, you may be dropped from the study at that time.

Questions: Any questions you have about the study, its purpose, design, methodology, procedures and significance will be addressed to your satisfaction. If you have additional questions, please feel free to contact Anne Lindsay, Cherri Nowotny Epstein or Dr. Golding (room 209 MPE or call 739-3767).

Your signature below will indicate that you have decided to volunteer as a research subject, that you have read the information provided above and understand the test procedures, possible dangers and certify that there is no medical reason why you should not participate in this study.

-----------------------------------/__________/__________________________
Signature                      Date                  Print Name

-----------------------------------/__________/__________________________
Witness Signature              Date                  Print Name
APPENDIX E

Pretest Procedures
PRETEST PROCEDURES

Rest -- Try to get a good nights sleep prior to the day of testing.

Caffeine -- Abstain from caffeine (coke/coffee) 12 hours prior to test.

Eating -- Do not eat 3 hours prior to testing; Abstain from eating heavy meals on day of testing.

Smoking -- If you smoke, abstain from smoking 4 hours prior to test.

Menstrual cycle -- Do not schedule your testing days during or 4 days prior to your menstrual period.

Exercise -- Do not exercise on test day; and only light exercise on day before test.

Attire -- Men: Shorts/Running shoes
          Women: Shorts/Bikini Top or Loose Top/Running shoes

NO LEOTARDS OR DANSKINS!
NO NYLON FABRIC!

(These make EKG electrode placement difficult as well as creating static electricity)
APPENDIX F

Calibration of O2 and CO2 Analyzers
CALIBRATION OF THE SERVOMAX 570A O2 ANALYZER

1. The analyzer was turned on and allowed to warm up for 45 minutes prior to calibration.

2. The analyzer was checked for adequate dri-rite.

3. A one liter sample of nitrogen, and a one liter sample of a mixed calibrated gas was obtained from the appropriate cylinders.

4. A sample of the nitrogen was introduced into the analyzer by applying light pressure to the sample bag until a reading of zero was obtained. This was done by adjusting the zero control.

5. A sample of the mixed calibrated gas was introduced in the same manner until a reading was obtained equal to that of the calibrated gas. This was done by adjusting the span.

6. The nitrogen and the mixed calibrated gas were reintroduced until readings equal to that of the gases were reached.

7. Room air was also used as a calibrated gas.

CALIBRATION OF THE ANARD 411 CO2 ANALYZER

1. The analyzer was turned on and allowed to warm up for 45 minutes prior to calibration.

2. The analyzer was checked for adequate dri-rite.

3. A one liter sample of nitrogen, and a one liter sample of a mixed calibrated gas was obtained from the appropriate cylinders.

4. A sample of the nitrogen was introduced into the analyzer allowing the pump to draw the gas into the system until a reading of zero was obtained. This was done by adjusting the zero control.

5. A sample of the mixed calibrated gas was introduced in the same manner until a reading was obtained equal to that of the calibrated gas. This was done by adjusting the span.

6. The nitrogen and the mixed calibrated gas were reintroduced until readings equal to that of the gases were reached.
APPENDIX G

Use of the Microcor Heart Rate Monitor
MICROCOR M101 ECG MONITOR

Heart rates were monitored in this study with the Microcor M101 Portable ECG Monitor. One of the features of this particular monitor is its ability to store EKG strips for later retrieval. Although no specific reference to EKG tracings were made, heart rates were easily monitored and saved as back up data.

This particular model has a feature known as "snap" which memorizes and stores a 2.3 second interval (or "snapshot") of the electrical activity of the heart. Each monitor can record up to 6 different snaps.

1. RESET/CLEAR THE MONITOR

   a. Turn off the monitor by using knob A (OFF/MAX)

   b. Press and hold button B while turning on the monitor. ("reset") will appear in the lower, left hand corner of the screen.

   c. Release button B and the monitor is now cleared. To verify the memory bank is empty, check to see that no words appear on the screen adjacent to button C. (When there is data being stored, the word "recall" appears.)

2. TURNING OFF THE ALARM

   a. Because the alarm is automatically programmed to go off when a heart rate of 150 is achieved, it must be manually shut off. To do this, press button D ("alarm").

   b. Next, press button B ("on/off"). At this time a slash will appear through the alarm symbol located in the lower, left hand corner of the screen signifying that the alarm is off.

   c. Press button E ("run") to return to the original screen.

3. SETTING DESIRED DISPLAY FEATURES

   a. To be sure the EKG standard is set to the appropriate mm/sec (for this study 25 mm/sec was used). Press button G ("sweep") until the number twenty-five appears on the screen.
b. Choose the appropriate lead. "In this study, each lead was evaluated before each test while the monitor was on and the lead that produced the best EKG with the least amount of artifact was used. This helped prevent a lot of excess noise creating false heart rates.) To do this, press button F ("lead") until the desired lead appears at the bottom of the screen.

4. STORING HEART RATES IN THE MEMORY

   a. During the actual test, digital heart rates can be seen displayed on the screen directly above ("rate/time").

   b. The clarity of the picture can be adjusted using knob A ("on/off") which also serves as a contrast (picture control).

   c. When a "snap" is ready to be taken, press button B ("snap") and the word "recall" will appear on the screen adjacent to button C.

   d. When the sixth and final snap is taken, the word "snap" which now appears on the screen adjacent to button B, will disappear. This notifies the operator that there is not more room in the memory. If the test is unfinished, a new monitor must quickly replace the current one and be cleared for further storage.

5. RETRIEVING THE DATA

   a. Upon completion of the test, remove the subject leads from the microcor.

   b. Attach the specialized plug from the printer to the outlet on the microcor labeled "data".

   c. Be sure there is paper in the printer.

   d. Turn both the printer and the microcor to the on position.

   e. Switch lever A and B (on the printer) to the desired size (mm/mv) and speed (mm/sec), respectively. (For this study, 10 mm/mv and 25 mm/sec were used.)

   f. Press lever C ("print") and the data will print out EKG snaps recorded at each stage.
APPENDIX H

Data Collection Forms
## DATA COLLECTION FORM

### General Information:

- **Name**: 
- **Address**: 
- **Telephone ( )**: 
- **Subject # ___**: 
  - Abdomem
  - Ilium
  - Tricep
  - PEC
  - RHR
  - RBP
  - HL (cm)
  - Max Met
  - Body Fat

### Pretest Questionnaire:

- **#1 - BIKE**
- **#2 ELEVATION**
- **#3 SPEED**
  - Hours of sleep
  - Medication
  - Cigarettes (4 hours)
  - Caffeine (12 hours)
  - Last Meal (3 hours)
  - Exercise (today)
  - Menstrual Cycle (4 days)

### Gas Analysis

- **DATE**: 
- **TEST #**: 
- **SUBS #**: 
  - Gas Analysis
  - Air T

### Stages

- **Stage Bag #**: 
  - Rest
  - I
  - II
  - III
  - IV
  - V

- **FE O2**: 
- **FE CO2**: 
- **VOLUME**: 
- **TEMP**: 

---

**UNIVERSITY OF NEVADA, LAS VEGAS/4505 MARYLAND PARKWAY/LAS VEGAS, NEVADA 89154-3016**

(702) 739-3766/FAX (702) 597-4191
DATA COLLECTION FORM

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STAGE

REST

I 1

2

3

40%_____

II 4

5

6

55%_____

III 7

8

9

70%_____

IV 10

11

12

85%_____

V 13

14

15

Max_____

_____

_____

_____

_____

_____

_____

_____
APPENDIX I

Gas Analysis Procedure
GAS ANALYSIS PROCEDURE

1. Oxygen Analysis
   a. The analyzer was inspected for correct calibration (Appendix F).
   b. Expired air in the sample bag was mixed by gently squeezing the bag.
   c. The bag was attached to the tubing of the oxygen analyzer.
   d. The stopcock was opened and light pressure was applied to assist in introducing the gas through the system for analysis.
   e. The gas was continually pushed through the system until there was no change in the oxygen reading.
   f. The stopcock was then closed, the bag was removed and the oxygen reading was recorded in the appropriate space (Appendix F).

2. Carbon Dioxide Analysis
   a. The analyzer was inspected for correct calibration (Appendix F).
   b. Expired air in the sample bag was mixed by gently squeezing the bag.
   c. The bag was attached to the tubing of the CO$_2$ analyzer.
   d. The stopcock was opened which permitted the pump to pull the gas through the system for analysis.
   e. The gas as permitted to flow through the system until there was no change in the CO$_2$ reading.
   f. The stopcock was then closed, the bag was removed and the CO$_2$ reading was recorded in the appropriate space (Appendix H).
   g. Any remaining gas was then vacuumed from the sample bag.
APPENDIX I

Water Vapor Pressure Chart
VAPOR PRESSURE OF WATER AT VARIOUS TEMPERATURES

(The values are for water in contact with its own vapor)

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APPENDIX K

Individual Data
MAXIMAL VO2 AND H.R. VALUES
INCLINED AND HORIZONTAL RUNNING

MALES

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MAXIMAL VO2 AND H.R. VALUES

INCLINED AND HORIZONTAL RUNNING

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PERCEPTION OF GENERAL FATIGUE, LEG FATIGUE, AND CARDIORESPIRATORY FATIGUE INDUCED BY INCLINED AND HORIZONTAL RUNNING

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Mean | 4.87 | 4.93 | 4.86 | 4.75 | 4.83 | 4.83 |
S.D. | .83  | .80  | .95  | 1.35 | .58  | .72  |

1 Very Light | 3 Moderate | 5 Very Fatigued |
2 Light | 4 Fatigued | 6 Maximal |
PERCEPTION OF GENERAL FATIGUE, LEG FATIGUE, AND CARDIORESPIRATORY FATIGUE INDUCED BY INCLINED AND HORIZONTAL RUNNING

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1 Very Light
2 Light
3 Moderate
4 Fatigued
5 Very Fatigued
6 Maximal
PERCEPTION OF WHICH TEST THE SUBJECTS THOUGHT CAUSED THEM TO WORK HARDER AND WHICH TEST THEY PREFERRED

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PERCEPTION OF WHICH TEST THE SUBJECTS THOUGHT CAUSED THEM TO WORK HARDER AND WHICH TEST THEY PREFERRED

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Simonsen, Ernst, "Changes of Physical Fitness and Cardiovascular Functions with Age," *Geriatrics* XII, p. 28 - 39, 1965.


