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Validation of the YMCA's guide to setting workloads for the submaximal cycle ergometer test

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VALIDATION OF THE YMCA'S GUIDE TO SETTING WORKLOADS FOR THE SUBMAXIMAL CYCLE ERGOMETER TEST

by

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ABSTRACT

The YMCA cycle ergometer test is a nationally used submaximal test that measures heart rate response to an increasing exercise workload. Two exercise heart rates are used to estimate maximal physical working capacity. A workload guide was established to make testing more efficient. The principle underlying the workload guide was that the examiner would assess the heart rate response to the first low intensity workload and from there would set workloads according to the guide. Problems have occurred with the guide, specifically with the highest intensity workload column. The purpose of this study was to validate the YMCA's guide to setting workloads for the submaximal cycle ergometer test. It was found that 20 of the 98 subjects would have needed to be re-tested because the workload guide would have elicited heart rates of greater than 150 bpm. The third and fourth workload columns produced a significant number of invalid tests.

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CHAPTER 1

INTRODUCTION

The YMCA cycle ergometer test is a commonly used submaximal test that measures a the heart rate response to an increasing exercise load. Two exercise heart rates between 110 beats per minute (bpm) and 150 bpm are plotted on the physical working capacity graph, then joined and extrapolated to the age predicted maximum heart rate. Where theses two lines (age predicted max heart rate and the actual workload heart rate line) intersect, a perpendicular line is dropped to the base line in and maximal physical working capacity is predicted, i.e. the workload that would elicit maximum heart rate. This prediction can be used to also predict maximal oxygen consumption (VO2 max).

Cycle ergometry tests are relatively simple, inexpensive tests that can be used to evaluate heart rate response to exercise. For many physical working capacity assessments, cycle ergometers are the preferred equipment when compared to treadmills or other cardiovascular equipment. Cycle ergometers provide standardization of workload and involve large muscle groups, while keeping the upper body relatively stationary and supported (Winter, 1991). Having the upper body stationary and supported provides a non weight bearing activity that allows for easy measurements of physiological responses to exercise. Examples are measuring heart rate and blood pressure.

Most submaximal physical working capacity tests are based on the relationship between heart rate and exercise load. Heart rate increases linearly

with an increase in workload (Astrand and Rodahl, 1986). However, at rest and during low intensity work, heart rate can be affected by external stimuli, such as talking, anxiety, dehydration, ambient temperature and altitude (Brooks and Fahey, 1985). As the workload increases the heart rate responds to the need for oxygen at the tissue level by increasing its rate to meet that demand. As the heart rate responds to the physiological needs it is less affected by external stimuli. Exactly at what heart rate external stimuli can have an affect is unknown, since different individuals with different resting heart rates and fitness levels are affected differently at lower workloads. Empirical knowledge indicates that for the average unfit individual external stimuli have little effect on heart rates greater than 110 bpm, especially since most testing situations attempt to control external stimuli.

The linear increase in heart rate as a response to increasing workload, beginning at a heart rate above 110 bpm, continues until maximum heart rate is reached. Maximum heart rate is defined as that heart rate which is unaffected by further increases in workload (Nieman, 1990). Maximum heart rate decreases with a person's increase in age. The inverse relationship between maximum heart rate and age is mostly due to the decrease in physical activity and fitness as the person ages. However, even individuals who remain active experience a decrease in maximum heart rate, although the decrease is not as rapid (Golding, Myers, and Sinning, 1989). Age-predicted maximum heart rate has been determined to be equal to 220 - age. Age-predicted maximum heart rate is the average maximum heart rate at any particular age plus or minus 10 bpm (Nieman, 1990). Since a 70 year old will usually be the oldest individual tested on a cycle ergometer, and because a 70 year old's age predicted maximum heart rate is 150 bpm, it is most likely that everyone will be linear between 110 bpm and 150 bpm, (Golding, et.al.,

1989). Due to the high probability that heart rate may not be linear below 110 bpm and above 150 bpm, heart rate is said to be linear between 110 bpm and 150 bpm (Golding, et. al., 1989).

Steady state heart rate occurs when the heart at a given workload supplies enough blood and therefore oxygen to equal the demands of the tissues: when the oxygen supply meets the oxygen requirement of the working tissues. At a given workload, steady state heart rate is normally reached by the end of three minutes (Brooks and Fahey, 1985). Steady state is assumed when two heart rates taken a minute apart, at a given workload, are within five beats of each other. Once two steady state heart rates are established at two different workloads (heart rates not under 110 bpm or exceeding 150 bpm) the results can be plotted on the prediction graph (Golding, et. al., 1989) (See Appendix C).

The YMCA prediction of maximal physical working capacity is graphed by drawing a straight line through two submaximal steady state heart rates for two different workloads and extending it to the level of the subjects age-predicted maximum heart rate. A perpendicular line is dropped from the intersection of the two lines to the baseline where the predicted maximal physical working capacity can be read (Golding, et.al., 1989).

In addition to the linear increase in heart rate with the increase in workload, there is similarly a linear relationship between oxygen uptake and workload (Astrand and Rodahl, 1986). Heart rate increases in a linear fashion as a function of increasing oxygen uptake (Astrand and Rodahl, 1986). Cardiac output (heart rate times stroke volume) is highly related to oxygen uptake. The increase in heart rate is an important factor causing the increase in cardiac output during exercise

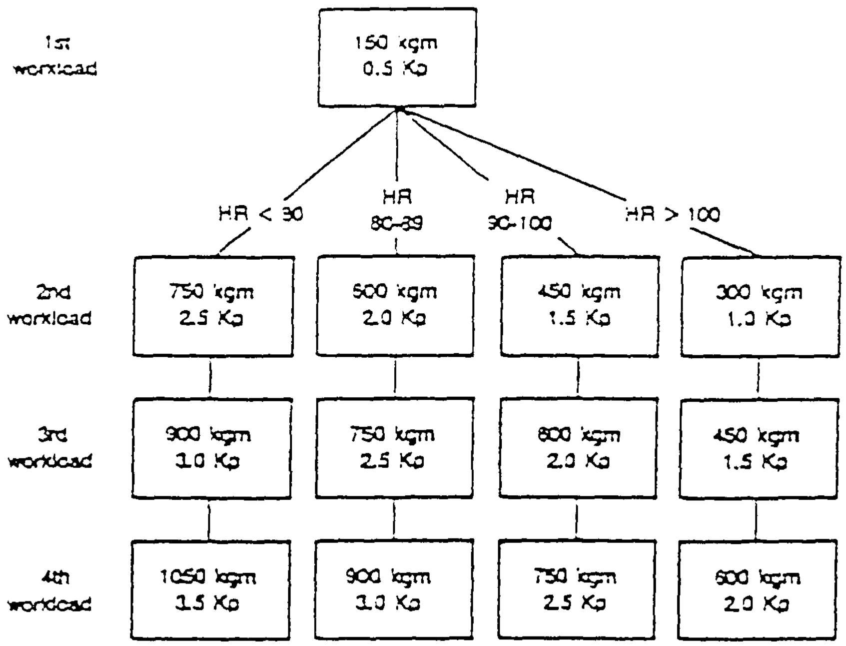
(Brooks and Fahey, 1985). As heart rate increases, oxygen uptake also increases; by using this relationship oxygen uptake can be predicted from heart rate.

The initial YMCA workload guide for the submaximal cycle ergometer test was established from minimal data from cycle ergometer tests performed prior to its introduction nationally. After the test and the workload guide had been used for several years a new workload guide was created to minimize errors which required re-testing. In the revised workload guide chart all subjects start at the same first workload (150 Kgm). Once steady state heart rate has been established at the first workload, the next workload is set according to this heart rate (See Figure1 --YMCA Workload Guide). The second workload establishes what column the subject will remain in until two heart rates are established between 110 bpm and 150 bpm (Golding, et. al., 1989). The principle underlying the workload guide is that the first workload (150 Kgm) allowed the examiner to assess the individual's heart rate response to a low level intensity workload. If the heart rate response was poor (greater than 100 bpm) and increased sharply, then the next workload should be the smallest increase possible. The lowest workload increment increase on the Monark cycle ergometer is 150 Kgm, therefore the next workload would be 300 Kgm. Subsequently, the smallest increase was made between successive workloads (300 Kgm, 450 Kgm, 600 Kgm, etc.) until two heart rates between 110 bpm and 150 bpm were obtained.

Figure 1

Workload Guide

YMCA Guide to Setting Workloads for the Submaximal Cycle Ergometer Test



If the subject's heart rate response to the first workload (150 Kgm) was lower than the first example (90 - 100 bpm) then the next workload was the next highest possible increase from 150 Kgm to 450 Kgm (a two increment increase - 2 X 150 Kgm). Once this second workload was established (placing the subject in a specific workload column) the subsequent workload increased by the smallest increment (150 Kgm); 450 Kgm, 600 Kgm, 750 Kgm, etc...

If the subject's heart rate response was lower than the first and second example (80 bpm - 89 bpm) then the next workload was the next highest possible, 600 Kgm (a three increment increase 3 X 150 Kgm). Then once this second workload was established, the subsequent workload increased by the smallest increment (150 Kgm), therefore; 600 Kgm to 750 Kgm to 900 Kgm, etc...

Finally if the subject's heart rate response to the first workload was the lowest (less than 80 bpm), then the next workload was the next highest possible, 750 Kgm (a 4 increment increase -- 4 X 150 Kgm). Once this second workload was established, the subsequent workloads increased by the smallest increment 750 Kgm to 900 Kgm to 1050 Kgm, etc... This continued until two steady state heart rates at two different workloads (between 110 and 150 bpm) were reached.

Due to the slow progression of workloads based on heart rate theoretically the workload guide should work, however, problems have occurred specifically with the column that is used when a person's heart rate at the end of the first workload (150 Kgm), is less than 80 bpm. Commonly, in a certain percentage of subjects, the second workload (750 Kgm) causes the heart rate to rise too sharply

and the third workload (900 Kgm) produces a heart rate that cannot be used because it is greater than 150 bpm, the test must then be rescheduled.

The purpose of this study was to validate the YMCA's guide to setting workloads for submaximal cycle ergometry testing.

CHAPTER 2

LITERATURE REVIEW

Physical Working Capacity

Maximal oxygen uptake (VO2 max) and maximal physical working capacity are often used synonymously. However, maximal oxygen uptake is not an absolute measure. It may be dependent upon the capacity of the active muscles and is less of a measure of the ability to maintain a high work intensity for a prolonged period of time (Sjostrand, 1966)

Physical working capacity is defined as the ability to perform physical work (Sjostrand, 1966). Physical working capacity is not related to a single function, but is directly or indirectly dependent upon a number of functions such as; muscular strength, functional capacity of the heart and lungs, resistivity to mental fatigue, etc. Due to the complicated nature of physical working capacity it cannot be measured directly. For this reason tests have been developed to measure one or more functions of physical working capacity. The functions chosen to be measured should be the ones most representative under different conditions. Such functions include: the ability to develop muscular strength, maximal oxygen uptake, size of chemical energy reserves and the adaptation of respiration and blood circulation (including heart rate) (Sjostrand, 1966). Between maximal oxygen uptake and heart rate at a given submaximal workload there exists a high correlation in different individuals (Sjostrand, 1966).

Oxygen Uptake

Oxygen uptake is the amount of oxygen that is taken up and used by the working muscles, expressed per minute (liters per minute = L/min, or mililiters per kilogram per minute = ml/kg/min). Measuring oxygen uptake during work also indirectly determines the caloric output required to perform the task (1 liter of oxygen consumed corresponds to about 5 kcals of energy). Because oxygen uptake is closely related to cardiac output, the load on the circulation can be evaluated from an oxygen uptake measurement (Astrand, 1966). Cardiac output is the amount of blood pumped per minute and is a product of heart rate and stroke volume (Brooks and Fahey, 1985). Cardiac output increases linearly as a function of oxygen uptake and is a result of the increase in heart rate and the increase in stroke volume (Astrand, 1966). Maximum oxygen uptake is the maximum rate at which an individual can consume oxygen and is important in determining maximal physical working capacity (Brooks and Fahey, 1985). Maximum oxygen uptake is considered the best test of aerobic fitness (Astrand and Rodahl, 1986). Direct measurement of oxygen consumption requires the proper equipment to collect, measure the volume and analyze the expired respiratory gases. Oxygen consumption is determined by collecting expired air and analyzing the gases. The basic principle is that VO2 is obtained by subtracting the oxygen expired from the oxygen inspired. The process is much more complicated and requires sophisticated equipment and knowledgeable test administrators. For this reason many procedures have been developed for estimating maximal oxygen consumption from submaximal exercise.

Maximal versus Submaximal Physical Working Capacity Tests

Tests of maximal physical working capacity require that an individual exercise at an increasing workload until they can no longer continue. Generally these maximal tests are performed on a treadmill, cycle ergometer or a step bench, activities which require large muscle groups (Astrand and Rodah, 1986). The treadmill (running at an incline) has shown to produce the highest oxygen uptake (Astrand and Rodahl, 1986). Due to the equipment needed, the skill of the researcher or technician involved and the risks involved in maximal testing, not to mention the discomfort of the subject; methods of predicting maximal physical working capacity have been developed.

Several methods of predicting maximal physical working capacity have been developed. Most common procedures involve cycle ergometer tests, bench stepping tests and a few treadmill tests. Many submaximal tests measure heart rate and are dependent upon the linear relationship between heart rate and workload, such as the YMCA cycle ergometer test (Golding, et.al., 1989), the Astrand-Ryhming test (Astrand and Ryhming, 1954), and the PWC-170 test (Sjostrand, 1947).

During submaximal testing, measurements should be taken during steady state work if they are to be used for prediction. Submaximal exercise tests for the prediction of VO2 are valuable for screening the functional capacity of the oxygen transport system, but are not accurate enough to use in research (Astrand and Rodahl, 1986). Measurements from repeated tests on the cycle ergometer are

useful in controlling and evaluating the effectiveness of a physical fitness program and can be a useful tool for motivation.

Use of Heart rate to predict max VO2

One of the most common functions used to predict maximal physical working capacity (or maximal oxygen uptake) is heart rate. Most prediction protocols of maximal physical working capacity are based on the linearity of heart rate with an increase in workload (Astrand, 1966). However, when heart rate is used to predict maximal physical working capacity, the fitness level of an individual must be taken into consideration. Due to the nonlinear increase in heart rate with oxygen uptake at the highest workload (Astrand, 1966), there is a tendency that untrained individuals will have a higher maximal oxygen uptake than predicted. Top trained athletes in endurance sports tend to have a lower maximal oxygen uptake than predicted, due to lower maximal heart rates than is typical for their age (Astrand, 1966).

Although the best way to determine max VO2 is to measure it while doing a maximal test, for reasons such as potential risk, time and cost it is many times desireable to predict max VO2 from submaximal tests. Although the one best method for predicting VO2 max is not universally agreed upon, the most popular are those in which heart rate is extrapolated to the age-predicted maximum heart rate.

Sjostrand Test

Sjostrand, (1947) conducted an investigation at an ore smelting works to determine the cause of respiratory troubles experienced by workers. One of the many tests conducted was a working test (test of physical working capacity). The working test was intended to determine the load at which heart rate starts to rise rapidly or the heart rate reaches or exceeds the critical value. The critical value being the point where the heart minute volume (or stroke volume) decreases with rising pulse frequency. The basis of the critical value is that heart rate generally increases when respiration and circulation can no longer adapt themselves to meet the needs of the working muscles. The critical pulse level for adults was predetermined to be about 180 bpm (Sjostrand, 1947).

The working test was performed on a cycle ergometer with variable workloads. The lowest workload was 300 Kgm and then the load was increased to 600 Kgm and 900 Kgm (in some cases it was increased to 1200 Kgm). The workloads were performed for approximately ten minutes before the workload was increased, the greatest workload was performed for 4 to 6 minutes. Heart rate was measured every second minute. Heart rate was also measured before and after the work and also after ten minutes of rest in a recumbent position. The load in which heart rate achieved 175 bpm (which happened to be the workload in which heart rate increased by more than ten beats between the second minute and the last heart rate measurement of that workload) was the actual working load in which the heart rate achieved the critical value. The critical value was the point where the stroke volume decreased with the increasing heart rate. The next lower workload was then considered to be the highest workload that could be applied without signs of respiratory or circulatory problems occurring.

Recovery heart rate was measured after 10 minutes of rest in a recumbent position, if the heart rate had returned to 15 beats above where it started then it was considered ordinary. If it had not returned to 15 beats or less from the starting heart rate then it was considered delayed. If the heart rate had returned to five beats above the starting heart rate then it was considered good restitution. Of the 20 men tested six men could perform work at 1200 Kgm, eight could perform work at 900 Kgm, five men could perform at 600 Kgm and one man could only perform work at 300 Kgm without heart rate exceeding 175 bpm. Fifteen of the 20 men had delayed restitution following the work, three had ordinary restitution and two had good restitution

PWC- 170 Test

The PWC-170 test, developed by Sjostrand in 1947, is a submaximal test used for prediction of physical working capacity at a specified heart rate of 170 bpm. Subjects are required to pedal at a rate of 50 rpm. Two steady state heart rates are determined at two different workloads. These heart rates are then plotted on a prediction graph and a line drawn through them is extrapolated to a heart rate of 170 bpm. A perpendicular line is dropped down from the intersection of the extrapolated line and the heart rate of 170 bpm. From this graph a prediction is made indicating the individual's physical working capacity at a heart rate of 170 bpm.

Validation of PWC-170

The PWC-170 submaximal test was validated to see if it was an accurate predictor of physical working capacity at a heart rate of 170 bpm (Dacuma, Golding and Tandy, 1993 b). Forty males and females (21 males and 19 females) between the ages of 18 and 36 years participated in one test session. The subjects were required to pedal at a rate of 50 rpm. Two steady state heart rates (between 110 and 150 bpm), at two different workloads, were obtained. Then the heart rates were plotted on the prediction graph. A line was drawn between the two heart rates and extrapolated to a heart rate of 170 bpm. A perpendicular line was drawn through the intersection of the two lines and extended to get the physical working capacity prediction for a heart rate of 170 bpm. The predicted workload was then set on the cycle ergometer and the subjects were required to pedal at 50 rpm until steady state was reached. The obtained heart rates were then compared to the heart rate of 170 bpm. A significant difference was found between the two heart rates (observed heart rate and 170 bpm) for the combined subjects and the males. No significant difference between the observed heart rate and 170 bpm was found for the females.

Possible sources of error could have been in the prediction graph, and the setting of workloads on the cycle ergometer. Also there is error of +/- five beats for steady state heart rate. The results for all categories fell within the five beat range.

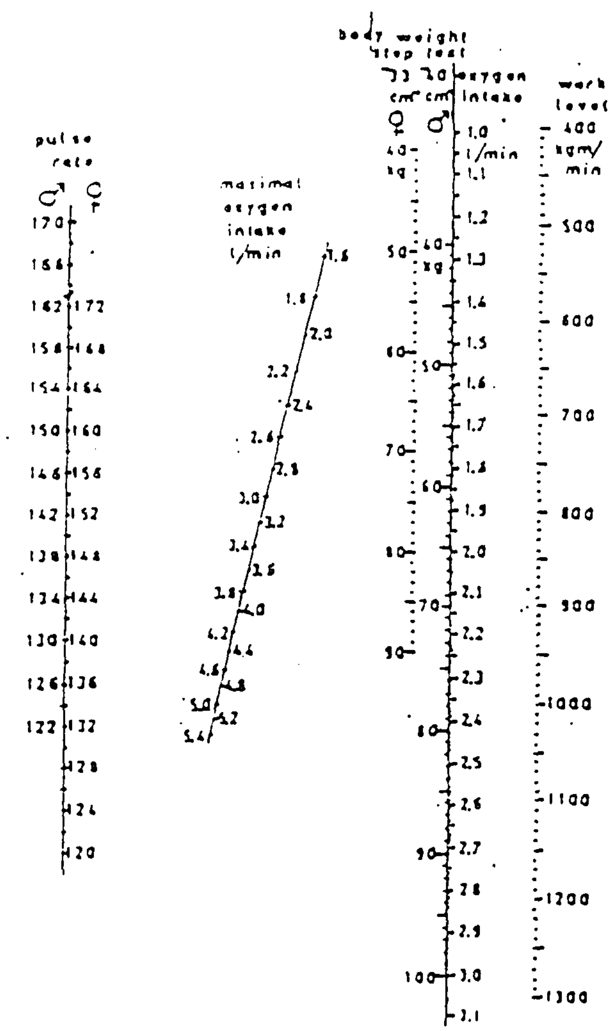
Astrand-Ryhming Test

In 1954 Astrand and Ryhming presented a method of predicting maximal physical working capacity (VO2 max) from submaximal exercise using heart rate and one submaximal workload (Figure 2 -- original Astrand-Ryhming Nomogram).

The test could be performed on a treadmill, cycle ergometer or a step bench. The development of the Astrand-Ryhming nomogram was empiracly based on results from 3 previous studies: Astrand (1952), Wahlund (1948), and Ryhming (1953). The data used to construct the Astrand-Ryhming nomogram consisted of 16 female and 17 male subjects between the ages of 20 and 30 years (Astrand, P. O., 1952). From this study (Astrand, 1952) it was determined that at 50% of max VO2, the average heart rate for males was 128 bpm and oxygen uptake was 2.1 l/min The average heart rate for females at 50% of max VO2 was 138 bpm and oxygen uptake was 1.5 l/min. At 70% of max VO2 the average heart rate for males and females was determined to be 154 bpm and 164 bpm respectively. It was also determined that at 50% of max VO2 the average workload for males and females was 900 kgm and 600 kgm respectively.

Figure 2

Original Astrand-Ryhming Nomogram



The original nomogram (Astrand and Ryhming, 1954) for calculation of aerobic capacity from heart rate and oxygen uptake during submaximal work. VO2 can be estimated by reading horizantally from the body weight scale (step test) or the work level scale (cycle test) to the O2 intake scale.

The development of the nomogram was based on the figures from above (Astrand, 1952).

There are several assumptions that are made when using the Astrand-Ryhming Nomogram. The Astrand-Ryhming nomogram is based on the assumption that heart rate, VO2 and workload are linear and that maximum heart rate and maximum VO2 occur at approximately the same time (Astrand, 1952). The test also assumes that for males resting heart rate is 60 bpm (Astrand, 1960). Another assumption is that maximum heart rate has a small standard deviation of +/- 10 bpm (Astrand, 1960). A heart rate between 125 bpm and 170 bpm should be used for a more accurate estimation of VO2 max (Astrand and Rhyming, 1954).

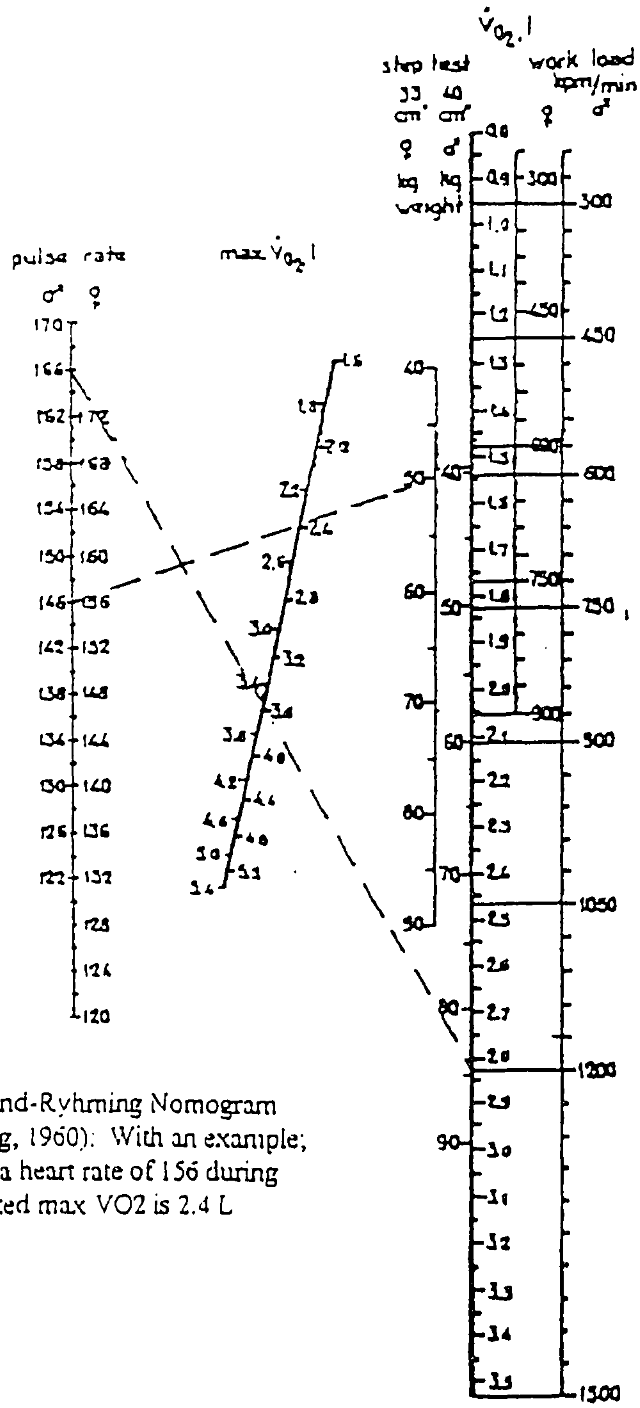
Many of the assumptions made by the Astrand-Ryhming Nomogram are also limitations of the test. Studies have reported that heart rate and workload are linear up to 50% to 70% of max VO2 and at the higher workloads heart tends to be less linear (Astrand, 1960). Maximum heart rate and maximum VO2 do not occur at the same place. A resting heart rate of 60 bpm is not representative of everyone. The test only uses one workload heart rate to make a prediction. The test can only be assumed correct for individuals between the ages of 18 and 30 years. A limitation is that the test also assumes that every subject has a maximum heart rate of 195 bpm (Astrand, 1960).

Revision of the Astrand-Ryhming nomogram was made in 1960 by I. Astrand. The revisions were made in order to be able to use a larger age group of individuals and account for differences between males and females. The mechanical efficiency for the original nomogram was assumed to be 23 percent for

all workloads, which would have been correct for the high workloads used in the 1954 study by Astrand and Ryhming. However, the mechanical efficiency is considerably lower at the lower workloads (300 Kgm and 450 Kgm as compared to 600 Kgm and 900 Kgm). The lower workloads were necessary especially when testing older individuals. Mechanical efficiency was adjusted for the nomogram. Due to the difference in oxygen uptake at particular workloads for males and females, separate scales were set up. Mean values for oxygen uptake for all age groups were used (Figure 3 -- Adjusted Astrand-Ryhming Nomogram).

Figure 3

Adjusted Astrand - Ryhming Nomogram



The adjusted Astrand-Ryhming Nomogram (Astrand and Ryhming, 1960): With an example; 49 Kg female reaches a heart rate of 156 during a step test, her predicted max VO2 is 2.4 L

Fitchett, (1985) conducted a study to determine the predictability of VO2 max from submaximal workloads by extrapolation of the heart rate. Both progressive and steady state protocols were used on the cycle ergometer and step bench. The subjects were 12 males between the ages of 23 and 58 years (x = 32.07). Each subject performed four submaximal tests, two on the cycle ergometer and two on the step bench. They also performed a maximal physical working capacity test on the treadmill. The treadmill test being the internationally accepted reference standard for cardiorespiratory fitness, was used as the standard for comparison (Fitchet, 1985). For all four submaximal tests continuous increasing protocols designed to bring the subjects within 83% of their age predicted max, were used. Workloads were adjusted according to age groups to try to produce a gradual increase from 45% to 75% of max VO2. For the progressive protocols the workloads were increased every minute (through five workloads or until the target heart rate was achieved). Expired air samples were collected the 30 seconds of each workload. During the steady state protocol an initial workload of three minutes was followed by two additional work intervals of 2.5 minutes (two additional minutes were required if target heart rate was not achieved). The differences between the maximal test and all four of the submaximal tests were statistically significant at the 0.5 level. The submaximal protocols underestimated the VO2 max by 0.13 L/min to 0.5 L/min. The coefficient of variation for the cycle tests were 13% and the coefficient of variation for the step test was 16%. The conclusions drawn from this study indicate that submaximal cycle ergometer and bench stepping tests can accurately predict VO2

max for a group of male subjects, however the individual predictions are subject to considerable error. Had the researchers compared the submaximal bike test with the max bike test rather than the max treadmill test the results may have shown submaximal tests to be better predictors. Treadmill tests on average yield a higher max VO2 than cycle ergometer tests, (Astrand and Rodahl, 1986).

Other Tests for Prediction of Max VO2

Burke, (1976) determined the validity of several physical working capacity tests by comparing them to the criterion standard, maximal VO2 test on a treadmill. Forty male college students were administered a series of physical working capacity tests in random order. Usually only one test was given per day. The average time required to administer all tests to one subject was four weeks. The treadmill test (VO2 max) was administered as described by Mitchell, Sproule and Chapman (1957). The Harvard step test and Balke treadmill test were administerd as described by Consolazio, (1973). The Progressive-Pulse Ratio Test, the PWC - 170 test and the Astrand - Ryhming test were administered as described by De Vries and Klafs, (1965). The Margaria test of Anaerobic Power was administerd as described by Margaria, Aghemo and Rovelli, (1955). The All-Out Treadmill Run and the Harvard Fitness Test were administered according to the direction of Hebbelinck, (1969). The 10 yard dash and the 50 yard dash were given as described by Fleishman, (1964). The sums 50 test, 300 yard run and 600 yard run were administerd as described by Falls, Ismael and Macleod, (1966). The 1 mile run and the 12 minute run were administered according to Cooper, (1968).

The data was analyzed using the Pearson Product Moment Correlation in which 23 variables were intercorrelated. Significant correlations were found

between max VO2 and the following tests; 12 min. run (.90), 600 yd. run (.78), 1 mile run (-.74), the Balke Test (.77), the All Out Treadmill Run (.74) the Harvard Fitness Test (.69), the 300 yd. run(-.52), Astrand-Ryhming Test (.62), the Harvard Step Test (.55), the PWC-170 (.58), and the Progressive - Pulse Ratio Test (.47), (Burke, 1976). The conclusions drawn in this study state that maximal or near maximal tests seem to be better measures of aerobic power than submaximal tests. Tests of longer duration seem to be the best measures of aerobic power. Of all the tests, the 12 minute run was the most valid measure of aerobic power. Among submaximal heart rate tests the Balke Test was the most valid measure. Also partial correlations were calculated to determine the effects of body weight and lean body mass on max VO2. The results indicated that body weight and percent of lean body mass affected VO2 max when expressed as liters/minute, but not when expressed as ml/kg/min.

Dwyer and Bybee (1983), determined the relationship between heart rate at anaerobic threshold and maximum heart rate in normal young women. The assumption was that anaerobic threshold would be a better method of determining an optimal training level than the usual percentage of VO2 max, assuming that anaerobic threshold represents a transition in metabolic stress. They suggested that anaerobic threshold may be a more sensitive indicator of circulatory and metabolic changes during progressive exercise. Exercise prescriptions based on a percentage of VO2 max do not take into account anaerobic threshold. Even though heart rate is not an effective means to determine anaerobic threshold it may be effective in regulating intensity above or below the anaerobic threshold.

Twenty females with an average age of 23.8 years participated in four test sessions. During the first two test sessions the subjects performed maximal tests

on the cycle ergometer. The subjects pedaled at a rate of 60 rpm and increased to 80 rpm. The workload began at 10 watts and was increased by 25 watts every minute until the subject could no longer pedal at a rate above 55 rpm. Ten days later they returned to perform two submaximal tests during two different sessions. The submaximal tests were identical to the maximal tests except the pedal rate stayed at 60 rpm and they only went up to 90% of max. Heart rate, VO2, VCO2, R, VE, and VEO2 were measured on all tests. Anaerobic threshold was determined by plotting VE, VCO2, VEO2 and R against VO2 for each subject (Dwyer and Bybee, 1983). Ventilation and gas exchange are closely related to blood lactate levels. The point where VE, VEO2 and VCO2 diverge from linearity relative to VO2 was considered the anaerobic threshold. Heart rate at anaerobic threshold was determined by using regression equations (regressing heart rate on VO2). In simple terms the results indicated that all subjects were below their anaerobic threshold at 70% of maximum heart rate. For most individuals exercise stress (anaerobic work) began to appear between 75% and 80% of maximum heart rate. One of the conclusions of the study is that when assessment of anaerobic threshold is not possible an alternative might be to regulate exercise intensity around 75% of maximum heart rate (or less if completely aerobic exercise is desired).

Patton, Vogel and Mello (1982), determined whether a specific, continuous, maximal test performed on a cycle ergometer could be used to predict maximal oxygen consumption as well as the reference standard treadmill test. In addition to comparing their continuous maximal cycle ergometer test with the, interrupted, maximal treadmill test (Taylor, Buskirk and Henschel, 1955) the subjects also performed and interrupted maximal cycle ergometer test and the

submaximal Astrand-Rhyming Test. Although measurement of VO2 max on the treadmill is the reference standard, it is time consuming and you need a well equipped lab and personnel to run the test. It was the purpose of these researchers (Patton, et. al., 1982) to design a test that did not require much equipment or expertise, but is maximal so the researchers do not need to rely on submaximal responses to exercise to predict max.

The maximal predictive cycle ergometer test protocol required that the subjects pedal continuously at a rate of 75 rpm. After a warm-up, the intensity was set at 37.5 watts for the first minute and was increased by this amount every minute until the subject could no longer pedal at a rate of 70 rpm for 10 seconds. Fifteen males and 12 females were selected as subjects. They performed four tests in random order with at least three days between tests; 1) the maximal predictive cycle ergometer test as designed for this study, 2) the maximal treadmill test as described by Taylor, et. al. (1955) and modified by Mitchell, et. al., (1957), 3) the maximal cycle ergometer test, an interrupted test, and 4) the submaximal Astrand-Rhyming test (1954). Results indicated that there were high correlation coefficients of VO2 max from the predictive cycle ergometer test and both the treadmill test and maximal cycle ergometer test for both males and females (0.89 and 0.87 for males, and 0.88 and 0.83 for females, respectively). The submaximal Astrand-Ryhming test correlated significantly with the treadmill test and the maximal predictive cycle ergometer test only in the male group. The data indicates the predictive cycle ergometer test gives a reliable and valid estimate of VO2 max (Patton, et. al., 1982).

Common problems of measuring VO2 max or using submaximal tests to predict max VO2 are the equipment needed, the time involved and increased risk

factors, such as; older age and over weight. Shoenfeld, Keren, Birnfeld and Sohar, (1981) felt the need to find a screening test that was able to be used on a large scale population. The purpose of this study (Shoenfeld et. al., 1981) was to determine if resting heart rate correlates with VO2 max. Six hundred male volunteers, between the ages of 20 and 60 years, who were healthy, did not work physically and had not engaged in physical activity over the last years participated in the study. Resting heart rate was measured twice, one week apart. If the resting heart rate varied more than five beats, the subjects were not used. Then VO2 max was measured twice on a cycle ergometer, one week apart. The average of the two max tests was used in the statistical analysis. The results indicated that there was a gradual decrease in VO2 max with an increase in age. There was also a significant decrease in max VO2 with the increase in resting heart rate. The correlation between resting heart rate and VO2 max was significant ($r = -0.331$, $p < 0.005$). Weight also had a significant negative correlation with VO2 max. From the data a regression line was established which may be used to determine VO2 max in screening surveys for large populations.

Wilmore, Roby, Stanforth, Buono, Constable, Tsao, and Lowden, (1986), performed a study to determine if estimating VO2 max could be improved by using RPE by itself or using RPE in combination with heart rate. Sixty two subjects (27 males and 35 females) between the ages of 15 and 31 years ($\bar{x} = 23$ years) participated in one test session. Subjects performed a submaximal test that consisted of four stages performed for three minutes. The resistance was started at 29, 59, 88, or 118 watts, depending on the physical characteristics of the subject, and progressed by increments of 29 watts. After the initial four submaximal workloads the subject was then taken to max by increasing the workload by 29

watts every minute until volitional fatigue was reached. Heart rate VO2, VE, RER (respiratory exchange ratio) and RPE were monitored. The results indicated the reliability of estimating VO2 max from RPE, power output and heart rate was high. Correlations ranged from r = 0.85 to r = 0.95. The validation coefficients were reasonably high ranging from r = 0.77 to r = 0.95. This new approach may be beneficial for testing, using RPE in combination with power output and heart rate.

History of the YMCA cycle ergometer test

The YMCA submaximal cycle ergometer test was developed to be used as a prediction of maximum physical working capacity or an individual's response to submaximal work (Golding, Myers and Sinning, 1982). This test can also be used to predict maximum oxygen consumption, but this is not the primary purpose for the test. The test is a useful tool for tracking an individuals response to a training program, in which the results reflect the cardiorespiratory endurance.

The YMCA cycle ergometer test is based on the assumption that heart rate and oxygen uptake increase linearly with an increase in workload (Golding, et. al., 1982) The basis for this test is to establish linearity between heart rate and workload for an individual from two points (two workloads). Caution must be taken that the two points are within the linear portion of the relationship between heart rate and workload (110 bpm - 150 bpm).

Validation of the YMCA Cycle Ergometer Test

Lindsay, (1988), performed a study in which one of the purposes was to validate the YMCA's submaximal cycle ergometer test as a method of predicting max VO2. Another purpose was to determine which of the three exercise methods, and which of the three equation modifications (Lindsay, 1988) used with the Astrand-Ryhming Nomogram, predicted max VO2 most accurately. The exercise methods included; (a) cycle ergometer using VO2 and heart rate, (b) cycle ergometer using workload and heart rate, and (c) the treadmill using VO2 and heart rate. Fifteen males and 15 females between the ages of 18 and 35 years performed two maximal tests (one on the treadmill and one on the cycle ergometer). Heart rate and VO2 were measured during the submaximal and maximal workloads during both tests. The results indicated that the YMCA's submaximal cycle ergometer test was a good predictor of max VO2. The results of this study indicated that heart rate and submaximal VO2 gave a better prediction than heart rate and workload using the cycle ergometer with the Astrand-Ryhming Nomogram. Also the Astrand-Ryhming Nomogram and a prediction equation developed using subjecs age predictedmax (EQ/PRED) showed to be good predictiors of VO2 max. The treadmill combined with EQ/PRED was the best combination for predicting VO2 max. Other results from this study showed a significant difference between VO2 max on the treadmill and VO2 max on the cycle ergometer. The treadmill VO2 max was significantly higher than the cycle ergometer VO2 max.

The YMCA Workload Guide

In order to eliminate the need to guess the workload needed to start the test (a workload that will elicit a heart rate of 110 bpm or greater), a guide to setting workloads was developed. Initially two guides were developed, one for males and one for females (See Appendix B). These guides were developed with the idea of presenting a subject with a workload that was not too difficult or that increased the heart rate too much (Golding, et. al., 1982).

The first workload was used to determine the heart rate response to a small workload. Usually this workload heart rate was under 110 bpm and would not be plotted for use in making the prediction. Then two more workloads were given to establish two points within the linear portion of the heart rate, workload relationship. The subject pedaled a minimum of three minutes at each workload to ensure steady state heart rate was established. The second and third minute heart rates could not be more than five bpm apart or the subject had not reached steady state. With the Y's Way revision (1989) a new workload guide was developed that could be used for both males and females (Golding, et. al., 1989).

CHAPTER 3

METHODS AND PROCEDURES

Introduction

The submaximal cycle ergometer test used by the YMCA measures an individual's heart rate response to exercise in order to predict maximal physical working capacity. The YMCA submaximal test is based on the knowledge that heart rate increases linearly with an increase in workload (Astrand and Rodahl, 1986). The increase in heart rate is a response to the physiological needs of the working muscle for oxygen. For almost all subjects, heart rate has been shown to be linear between 110 bpm and 150 bpm (Astrand and Rodahl, 1986). Heart rate may be affected by external stimuli when it is lower than 110 bpm and when an individuals heart rate is over 150 bpm they may be approaching maximum heart rate (in which the heart rate plateaus), therefore heart rate may only be linear between 110 bpm and 150 bpm.

In order to make a prediction of maximal physical working capacity, two steady state heart rates (between 110 bpm and 150 bpm) must be established at two different workloads. The two workload heart rates are then plotted on a prediction graph a straight line is drawn through them and extended to the level of the individual's age-predicted maximum heart rate (220 - age). A perpendicular line is drawn through the intersection of the two lines to predict maximal physical working capacity (Golding, et. al., 1989) (See Appendix C -- Prediction Graph).

The YMCA developed a guide for setting workloads for the submaximal cycle ergometer test in order to make the test more simple. The guide was developed to eliminate the need to guess which two workloads would elicit heart rates between 110 bpm and 150 bpm. All subjects start at the same workload (150 Kgm). This first workload heart rate determines which workload column the individual will follow in order to establish two heart rates between 110 bpm and 150 bpm (See Appendix A).

The workload guide was set up so that the investigator could monitor the individual's heart rate response to a low intensity workload, and depending on the response, set the next workload that should elicit a heart rate above 110 bpm (See workload guide). The workload guide has 4 columns. The first column is the lowest possible workload increase (the workloads increase by increments of 150 Kgm). The first workload column begins with 300 Kgm and increases by 150 Kgm (See Appendix A). The second workload column begins with 450 Kgm and increases by 150 Kgm. The third column begins with a workload of 600 Kgm and increases by 150 Kgm. The fourth workload column begins with 750 Kgm and increases by 150 Kgm.

Subjects

Ninety-eight apparently healthy males and females between the ages of 18 and 45 years, with the mean age of 29.46 +/- 1.15 for males and 31.27 +/- 1.12 for the females, volunteered to participate in this study (48 females and 50 males).

Equipment

An Infrasonde Electronic Blood Pressure Monitor (Model D4000) was used to measure resting blood pressure and heart rate on each subject. Blood pressure and heart rate were measured as a way to pre-screen subjects for hypertension. The subjects pedaled on Monark cycle ergometers (Model G1H Stockholm), while wearing Polar Vantage heart rate monitors and watches (Model 45900). Sigma Electrode Creme was applied to the heart rate electrodes before use, for better conduction. A GRA Lab Universal Timer was used to keep time during the test sessions. A cassette recorder and cassette tape with a metronome beat recorded at 100 bpm were used for the subjects to keep the cadence of 50 rpm. The YMCA Guide for Setting Workload for the Submaximal Cycle Ergometer Test was the guide to be validated during the study.

Prior to testing, the Monark cycle ergometers were calibrated using standardized weights. Although the Monark cycle ergometers retain their calibration, the calibration was checked halfway through the study (after the forty third subject had been tested). The pendulum of the cycle ergometer was calibrated or set at the zero mark on the workload scale prior to each test. The subject would pedal, without resistance and the workload scale would be adjusted until the pendulum weight read zero (See Appendix J -- Cycle Pendulum).

Testing Procedures

Each subject was required to participate in only one test session. Not more than five subjects were tested at the same time. The study was approved by the University's Institutional Review Board.

Pre-test

An activity questionnaire was completed regarding the subject's current exercise habits (See Appendix F). The activity questionnaire was designed to give the researcher some knowledge of the fitness level of the subject as well as additional information on general physical characteristics. Subjects also completed a Par - Q questionnaire (See Appendix E), and read and signed an informed consent form (See Appendix D). The Par - Q was used to assess an individual's risk factors. The informed consent advised the subjects of the possible risks associated with the submaximal exercise they would be performing.

The subject sat relaxed while completing the above forms, after which resting heart rate and blood pressure were measured. In order to describe the subject's physical characteristics, height and weight were measured and age was recorded.

The appropriate cycle ergometer seat height was determined by adjusting the seat so that when the subject's leg was in the down position the knee was very slightly flexed, and while pedaling the subject did not have to rock the hips from side to side in order to reach the pedals.

The Vantage heart rate monitor and watch (Model 45900) was fitted to the subject. Electrode creme was rubbed on the heart rate electrodes for better conduction so that the heart rate reading on the monitor was strong and stable.

The Pilot Study

A pilot study (Dacuma, Golding, and Tandy, 1993 a), was conducted to determine if the protocol used in this study prevented the subjects from being fatigued before starting each new workload The pilot study was done to

compare exercise heart rates at a given workload while exercising on a cycle ergometer in a 'continuous' protocol versus a 'discontinuous' protocol. Ten subjects (six males and four females) between the ages of 23 and 33 years were tested on six different occasions. The subjects of the pilot study performed each workload on a five separate occassions (each workload was preceded by a short warm-up of three to four minutes at 150 Kgm). The five workloads (300 Kgm, 450 Kgm, 600 Kgm, 750 Kgm and 900 Kgm) were given in random orders. The sixth test session was the 'continuous' protocol. It started at a workload of 150 Kgm and progressed continuously by 150 Kgm increments until the subject reached 900 Kgm (the protocol used in the present study - see table 1). The results from the pilot study showed no significant difference between the heart rate means when comparing each 'continuous' workload heart rate with the 'discontinuous' workload heart rate. These results indicate that heart rate is reliable at a given workload whether the exercise is done continuously or intermittently.

It was desired in the present study to be able to test the subjects in one exercise session on all six workloads without concern as to whether fatigue or other factors may have influenced heart rate at a given workload, and at the same time not have to completely warm the subject up before each workload. No rest was needed between the first three workloads because the intensity was not great. A five minute rest period (as described previously) was given after the third workload and each workload thereafter. The preliminary study showed no difference between heart rate means during the continuous protocol (used in this study) and workloads done intermittently on separate days. Heart rate was

recorded at the end of the five minute rest period in order to assure that the subject had somewhat recovered before the next workload was set.

The Cycle Test

The subject began pedaling without resistance to a metronome tape recorded at 100 bpm. At each beat of the metronome, one foot was pressing down resulting in a pedal rate of 50 rpm. While the subject was pedaling without resistance and was becoming familiar with the cadence, the resistance was calibrated to the zero mark on the workload scale as described previously.

Table 1

The Cycle Test

PROTOCOL
Initial Heart Rate
1. 150 Kgm to SSHR*
2. 300 Kgm to SSHR
3. 450 Kgm toSSHR
4. 5 min. Rest Period (pedaling)
5. 600 Kgm to SSHR
6. 5 min. Rest Period (pedaling)
7. 750 Kgm to SSHR
8. 5 min. Rest Period (pedaling)
9. 900 Kgm to SSHR
10. Cool Down (pedaling)

*SSHR = Steady State Heart Rate

Table 1 shows the testing protocol. The first workload was set at 150 Kgm and the subject pedaled at 50 rpm until steady state heart rate was achieved (normally at three minutes). Heart rate was recorded at the end of the second and third minutes of the workload. If the two heart rates were more than five beats apart the subject pedaled for another minute; this continued until steady state heart rate was achieved.

The procedure of achieving steady state heart rate was continued through each workload. After the first three workloads (150 Kgm, 300 Kgm and 450

Kgm) were completed subjects were given a five minute rest period. During the rest period the subject remained on the cycle ergometer and pedaled slowly without resistance. The reason for the rest period (or cool down period) was so the subject would be allowed some recovery before the next, more difficult workload. The protocol did not allow fatigue or thermal stress to influence heart rate at a given workload, as concluded from the pilot study (Dacuma, et.al.,1993 a).

The fourth workload (600 Kgm) was set and steady state heart rate was achieved. Another five minute rest period was given, as before the subject pedaled slow without resistance and heart rate was recorded at the end of the rest period.

The fifth workload (750 Kgm) was then set and the subject pedaled until steady state heart rate was reached. Another five minute rest period was given (subject pedaled slow without resistance) and again heart rate was recorded at the end.

The final workload (900 Kgm) was then set and another steady state heart rate was recorded (See Appendix G -- Score Sheets). At the completion of the last workload the subject was allowed to cool down by pedaling slowly without resistance for approximately five minutes or until their heart rate was 110 bpm or less.

Statistical Analysis

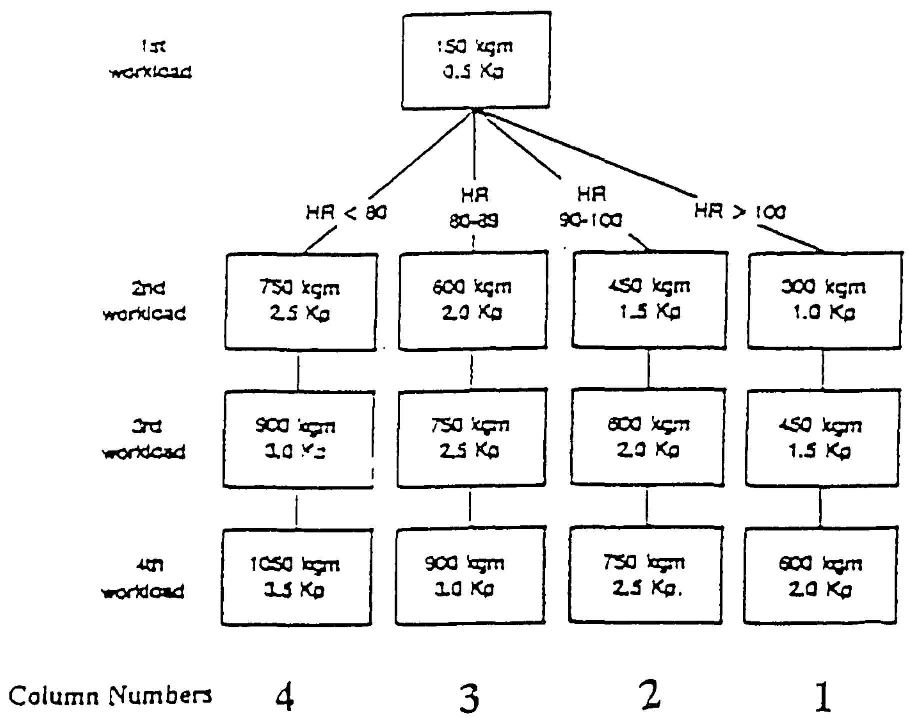
Once the data was collected the results were analyzed by noting the heart rate after the first workload (150 Kgm) to determine the workload column (according to the present YMCA's guide to setting workloads for submaximal cycle ergometer testing), the subject would have used had they been administered

the YMCA submaximal physical working capacity test in the usual manner. The workload guide was assigned column numbers beginning with the column that started with 300 Kgm as column 1 (450 Kgm = column 2, 600 Kgm = column 3 and 750 = column 4) (See Figure 4 -- Numbered Workload Columns). Once the appropriate workload column was determined for each subject, the heart rate at the first workload of that column was checked to determine whether it was greater than 110 bpm. If it was, then the workload column was considered to have worked for that subject. For example, if an individual's heart rate was 84 bpm at the end of the first workload (150 Kgm) then that subject should have been put into workload column 3 (starting with 600 Kgm). The subject's heart rate at 600 Kgm was checked to determine if it was the first workload heart rate of 110 bpm or greater. If it was, then the workload guide worked for that subject.

Figure 4

Workload Guide With Numbered Columns

YMCA Guide to Setting Workloads for the Submaximal Cycle Ergometer Test



However, if the workload heart rate (at 600 Kgm) was not the first heart rate at 110 bpm or greater, then the workload guide was incorrect (it did not work) for that subject. For example, if the heart rate was 84 bpm at the first workload (150 Kgm), the subject would have been put into workload column 3 (starting with 600 Kgm) as before, but in this case we will say the heart rate was 135 bpm and the workload before that (450 Kgm) elicited a heart rate of 113 bpm, then the workload guide would not have worked for this subject. The subject could have been placed in a lower workload column (column 2 -- starting with 450 Kgm) to get their first workload heart rate at 110 bpm or greater. The reason that the workload guide would not have worked for the previously described individual was because the workload that would have been administered following 600 Kgm, which would have been 750 Kgm, may have elicited a heart rate of greater than 150 bpm, resulting in an invalid test.

Once the workload guide was determined correct or incorrect for each subject, a percentage was determined for how many subjects the workload guide was correct and incorrect. The data was analyzed by breaking the subjects down into groups in order to determine for whom the workload guide would not have worked. The following variables were analyzed using chi-square tests: gender, age and gender, workload columns, and fitness levels. The data was also broken down into four catagories: (a) 'worked-3' (ideal 3 workload test, beginning with 150 Kgm), (b) 'worked-2', in which the subject only needed two workloads, (the first workload of 150 Kgm elicited a heart rate of greater than 110 bpm), (c) 'worked > 3', in which the subject required 4 or more workloads, (a fourth or fifth workload was need to get two heart rates above 110 bpm), and (d) 'did not work' (the workload produced too high of a heart rate, resulting in an invalid test).

CHAPTER 4

RESULTS AND DISCUSSION

Subjects

Ninety-eight apparently healthy males and females between the ages of 18 and 45 years volunteered to be subjects (50 males and 48 females). Tables 2, 3 and 4 present the subjects' physical characteristics. The mean and standard error of the mean were reported for the subjects' age (years), weight (Kg) and height (cm). Resting blood pressure was measured as a way to screen for hypertension. A resting heart rate was also recorded. Fitness level was determined by calculating the predicted maximal physical working capacity and comparing the results to the YMCA's national norms (Golding, et. al., 1989). A number (1 = excellent, through 7 = very poor) was assigned to each rating on the YMCA's physical fitness evaluation profile (See Appendix H).

Table 2 represents the data for all subjects (combined) and divided by gender. The mean age for all subjects was 30.45 years, 29.46 years for males, and 31.27 years for females. According to the height and weight table (Patton, Corry, Gettman and Graf, 1986) the men were overweight (79.92 Kg) for their average height of 178.13 cm. At this height a normal weight would be 60 kg to 75.4 kg. The women were within the recommended weight range (64.35 Kg) for their height of 165.95 cm (the range was 55 kg to 69.09 kg). Blood pressure was normal (non-hypertensive) for males and females. A systolic blood pressure of 140

to 160 mmhg and/or a diastolic pressure of 90 to 100 mmgh is considered hypertensive (Brooks and Fahey, 1985). Fitness levels for males and females were between average (rating of 4) and above average (rating of 3) (See Appendix H).

Table 2

Subject Characteristics
(Means and Standard Errors of the Mean)

N = 98

	Age (years)	Weight (kg)	Height (cm)	Blood Pressure (mmhg)	Start Heart Rate (bpm)	Fitness Level *
Combined (total)	30 +/- 0.8	72.31 +/-1.39	172.17 +/- 0.067	120/72 +/-1.2/0.9	74 +/- 1.3	3.31 +/- 0.19
All Males	29 +/- 1.2	79.94 +/- 1.77	178.13 +/- 0.97	126/74 +/- 1.6/1.3	71 +/- 2.2	3.5 +/- 0.28
All Females	31 +/- 1.1	64.35 +/- 1.47	165.95 +/- 0.88	114/70 +/- 1.5/1.3	76 +/- 2.0	3.10 +/- 0.27

* Fitness level was determined by using the YMCA's maximal physical working capacity prediction and assigning a number to each rating on the YMCA's physical fitness evaluation profile (1 = excellent, 7 = very poor) (Golding, et. al., 1989) (See Appendix H).

Table 3

Subject Characteristics
(Means and Standard Errors of the Mean)

Males

N = 50

	Age (years)	Weight (Kg)	Height (Cm)	Blood Pressure (mmhg)	Start Heart Rate (bpm)	Fitness Level *
18 - 25 years	21 +/-1.0	82.50 +/- 3.00	181.12 +/- 1.39	129/75 +/- 2.5/2.6	74 +/- 2.9	2.90 +/- 0.44
26 - 35 years	30 +/- 0.8	76.46 +/- 3.48	175.76 +/-1.90	122/73 +/-2.5/1.8	68 +/- 2.5	3.33 +/- 0.46
36 - 45 years	41 +/-0.7	78.84 +/- 2.4	176.17 +/- 1.46	124/75 +/-2.8/1.8	73 +/- 3.4	4.56 +/- 0.46
Mean (total)	29 +/- 1.2	79.94 +/- 1.77	178.13 +/- 0.97	126/74 +/- 1.6/1.3	71 +/-2.2	3.5 +/-0.28

* Fitness level was determined by using the YMCA's maximal physical working capacity prediction and assigning a number to each rating on the YMCA's physical fitness evaluation profile (1 = excellent, 7 = very poor) (Golding, et. al., 1989) (See Appendix H).

Table 4

Subject Characteristics
(Means and Standard Errors of the Mean)

Females Only

N = 48

	Age (years)	Weight (kg)	Height (cm)	Blood Pressure (mmhg)	Start Heart Rate (bpm)	Fitness Level *
18 - 25 years	22 +/- 0.6	60.82 +/- 2.14	165.43 +/- 1.55	112/68 +/-2.9/2.7	80 +/-3.8	3.66 +/- 0.44
26 - 35 years	31 +/- 0.7	63.24 +/- 3.05	165.22 +/-1.61	116/67 +/-2.2/1.7	70 +/- 3.7	2.18 +/- 0.48
36 - 45 years	40 +/-0.5	68.5 +/-2.08	158.29 +/-8.916	114/73 +/-2.7/2.1	78 +/- 3.0	3.47 +/-0.42
Mean (total)	31 +/- 1.2	64.35 +/- 1.47	165.95 +/- 0.88	114/70 +/- 1.5/1.3	76 +/-2.0	3.10 +/- 2.70

* Fitness level was determined by using the YMCA's maximal physical working capacity prediction and assigning a number to each rating on the YMCA's physical fitness evaluation profile (1 = excellent, 7 = very poor) (Golding, et. al., 1989) (See Appendix H).

Results

Of the 98 subjects tested during this study, the YMCA guide to setting workloads for submaximal cycle ergometer testing was correct for 78 (79.6%) of the subjects (subjects would not be required to be re-tested) (See table 5). Whether or not the workload guide worked for each subject was determined by measuring their heart rate at the end of the first workload (150 Kgm) and determining which workload column the subject would have continued in had it

been the YMCA's submaximal test. Once the workload column was determined the heart rate at the workload that should have been used next (YMCA's test protocol-- Workload Guide) was checked to see if that was the first workload heart rate of 110 bpm or greater. If the heart rate was greater than 110 bpm then the workload guide worked for that subject, as explained in chapter 3.

The workload guide was incorrect for 20 of the 98 subjects (20.4%) (See table 5). These 20 subjects would be in a workload that produced a heart rate that was too high (a lower workload would have worked - i.e. produced a heart rate of 110 bpm or greater). When the workload guide produces a high heart rate in the first workload (after 150 Kgm) the next workload produces a heart rate of greater than 150 bpm, which invalidates the test, (Protocol: heart rates must be between 110 and 150 bpm).

The questions to be answered were did the workload guide work? How often was the workload guide correct? How often was the workload guide incorrect (would have required the subject to be re-tested)? Was the success rate changed by whether the subject was male or female? Older or younger males and females? Fit or unfit? Or was the success rate of the workload guide changed depending on which workload guide the subject was placed in?

Chi-square

Chi-square tests are used to analyze the relationship between two variables using frequency data. The variables may be qualitative, measured on the same subjects and between-subjects in nature (Jaccard and Becker, 1990). The data is illustrated in contingency tables (frequency tables- see tables 5, 6, 7, 8, 9, 10, 11, and 12). The chi-square test focuses on the concept of expected frequencies (E).

The expected frequencies (E) are compared with the observed frequencies (O). The null hypothesis states that there is no relationship between the variables and the alternative hypothesis states that there is a relationship between the two variables. The expected frequency is calculated under the assumption that there is no relationship between the two variables. For each cell the column marginal frequency is divided by the total number of observations and then multiplied by the row marginal frequency. A chi-square statistic (x^2) must be calculated to reflect the overall difference between the observed and the expected frequencies. The difference between the observed and the expected frequency is first determined. Then each of the difference scores is squared. Next, the squared difference is divided by the expected frequency. Finally, the sum of all the values { $(O - E)^2 / E$ } is the chi-square statistic (x^2) (Jaccard and Becker, 1990). A critical value is determined from a set alpha level and dependent upon the degrees of freedom. When the observed chi-square statistic (x^2) is greater than the critical chi-square statistic (x^2 critical) the null hypothesis is rejected and there is a relationship between the two variables (Jaccard and Becker, 1990). For this study, 'no relationship' means that the variable (for example, gender) had no effect on the effectiveness of the workload guide. If there was a relationship this means that the variable (for example, workload guide column) did have an effect on the success of the workload guide.

Chi-square tests were applied to the following relationships: 1) gender versus the success of the YMCA workload guide to put the subject into the correct workload column; 2) workload guide column versus the success of the YMCA workload guide to put the subject into the correct workload column; 3) age and gender combined versus the success of the YMCA workload guide to put the

subject into the correct workload column; and 4) individual fitness levels versus the success of the YMCA workload guide to put the subject into the correct workload column.

There was no relationship between gender and the YMCA tests ability to correctly classify subjects into workload columns ($x^2 = 0.01$, $p > .05$). There was a significant relationship between workload guide columns and the test's ability to correctly classify subjects ($x^2 = 20.67$, $p < .05$). The source of the relationship was the 600 Kgm and 700 Kgm columns where there were an excessive number of misclassifications. There was no relationship between age and gender, and the tests ability to correctly classify subjects into workload columns ($x^2 = 4.32$, $p > .05$). There was no relationship between individual fitness level and the tests ability to correctly classify subjects into workload columns ($x^2 = 2.48$, $p > .05$).

Table 5

All Subjects
(N =98)

Worked	78 (79.6%)
Did not work	20 (20.4%)

Table 5 presents the general success rate of the YMCA's workload guide for submaximal cycle ergometer testing, for all subjects. Twenty of the 98 subjects would have needed to be re-tested to get a valid score.

Table 6

Males and Females
(N = 98)
Chi-square x^2= 0.01, p> .05*

	Males	Females
Worked	40 (40.8%)	38 (38.8%)
Did not work	10 (10.2%)	10 (10.2%)

*There was no relationship between the variables.

Table 6 represents gender versus the success rate of the workload guide to correctly place subjects in a workload column. Being male or female had no effect on the ability of the workload guide to correctly place subjects into a workload column, there was no relationship between the two variables.

Table 7

Workload Columns
(N = 98)
Chi-square $x^2 = 20.67$, $p < .05$*

	1 (300 Kgm)	2 (450 Kgm)	3 (600 Kgm)	4 (750 Kgm)
Worked	35 (35.7%)	21 (21.4%)	18 (18.4%)	4 (4.1%)
Did not work	0 (0%)	4 (4.1%)	12 (12.2%)	4 (4.1%)

*There was a relationship between the variables. There were too many miss classifications at the third and fourth workload columns.

Table 7 presents each workload column of the workload guide versus the success rate of the workload guide to put subjects into the correct workload column. Both workload column 3 and workload column 4 did effect ability of the workload guide to correctly put subjects into a workload column. Subjects who were placed in workload guide columns 3 and 4 had too many invalid tests.

Table 8

Age and Gender
(N = 98)
Chi-square x^2= 4.32, $p > .05$*

	Females 18-25 yr	Females 26-35 yr	Females 36-45 yr	Males 18-25 yr	Males 26-35 yr	Males 36-45 yr
Worked	13 (13.3%)	12 (12.2%)	13 (13.3%)	19 (19.4%)	12 (12.2%)	9 (9.2%)
Did not work	2 (2.0%)	4 (4.1%)	4 (4.1%)	2 (2.0%)	3 (3.1%)	5 (5.1%)

*There was no relationship between the variables.

Table 8 breaks the data into groups of age and gender versus the ability of the workload guide to correctly place subjects into a workload column. There was no relationship between age and gender and the success of the workload guide.

Table 9

Fitness Levels
(N = 98)
Chi-square $x^2 = 2.98$, $p > .05$*

	1 Excellent	2 Good	3 Above Average	4 Average	5 Below Average	6 Poor	7 Very Poor
Worked	16 (16.3%)	20 (20.4%)	10 (10.2%)	8 (8.2%)	10 (10.2%)	11 (11.2%)	3 (3.1%)
Did not work	5 (5.1%)	4 (4.1%)	1 (1.0%)	3 (3.1%)	3 (3.1%)	2 (2.0%)	2 (2.0%)

*There was no relationship between the variables.

Table 9 presents the subjects' fitness levels versus the ability of the YMCA's workload guide to correctly place subjects into a workload column. There was no relationship between fitness level and the success of the workload guide.

Although the workload guide worked for 78 (79.6%) of the subjects, there were instances where subjects only needed two workloads to complete the test. Some subjects needed four or more workloads to complete the test (these were still valid tests, they just did not meet the goal of three workloads to complete the test).

Eleven subjects, 14.1% of the 78 that the workload guide did work for, would have been put at too low of a workload. Their heart rates would not have reached 110 bpm or greater in the first workload following 150 Kgm (these subjects needed a forth or fifth workload to complete the test). Although the workload guide may have under-predicted for these 11 subjects, this under-

prediction would not necessarily be a problem during submaximal testing. The subjects would need to continue increasing workloads until two steady state heart rates (between 110 and 150 bpm) at two different workloads were achieved.

There were also another eleven individuals of the 78 that the workload guide worked for, that completed the test after the second workload of 300 Kgm. The warm-up workload of 150 Kgm produced a heart rate of greater than 110 bpm.

Subdividing the subjects into categories of:

1. Workload guide 'worked' - used 3 workloads (Worked -3)
2. Workload guide 'worked' - used only 2 workloads (Worked - 2)
3. Workload guide 'worked' - needed more than 3 workloads (Worked >3)
4. Workload guide 'did not work' (Did not work)

The (worked - 3) category represents all of the subjects that the workload guide would have worked for using the ideal of three workloads. The (worked - 2) category represents all the subjects that only needed two workloads to complete the test (all of these subjects had a heart rate of greater than 110 bpm by the end of the first workload of 150 Kgm). The workload guide worked for these subjects (the test would have been valid) they just didn't get a warm-up workload. The (worked > 3) category represents all the subjects that needed a forth or fifth workload to complete the test. Again the test would have been valid for these individuals, they just would have had to go through extra workloads to complete the test. The (did not work) category represents all the subjects for which the workload guide truly did not work for (produced heart rates above the acceptable range).

Table 10

All Subjects
(N = 98)

Worked -3	56 (57.1%)
Worked - 2	11 (11.2%)
Worked >3	11 (11.2%)
Did not work	20 (20.4%)

Table 10 presents the general success rate of the workload guide to correctly place individuals in a workload column for all subjects. The workload guide worked ideally for 56 subjects (used 3 workloads). Eleven subjects completed the test by the second workload and another 11 subjects would have required a fourth or fifth workload to complete the test.

Table 11

Males and Females
(N = 98)

	Males	Females
Worked - 3	26 (26.5%)	30 (30.6%)
Worked - 2	4 (4.1%)	7 (7.14%)
Worked > 3	10 (10.2%)	1 (1.0%)
Did not work	10 (10.2%)	10 (10.2%)

Table 11 presents the success rate of the workload guide for males and females. The workload guide worked ideally for 26 males and 30 females. Four males and 7 females completed the test with only two workloads, and 10 males and 1 female would have required a fourth or fifth workload to complete the test. Ten males and ten females would have had to be re-tested.

Table 12

Workload Columns
(N = 98)

	1 (300 Kgm)	2 (450 Kgm)	3 (600 Kgm)	4 (750 Kgm)
Worked - 3	22 (22.4%)	19 (19.4%)	13 (13.3%)	2 (2.0%)
Worked - 2	11 (11.2%)	0	0	0
Worked > 3	2 (2.0%)	2 (2.0%)	5 (5.1%)	2 (2.0%)
Did Not Work	0	4 (4.1%)	12 (12.2%)	4 (4.1%)

Table 12 presents the success rate of the workload guide to correctly place the subject into a correct column versus each workload guide column. Of the individuals placed in column 1 the workload guide would have worked ideally for 22 subjects. Eleven subjects placed in column one would have completed the test by the second workload and two subjects would have required a fourth or fifth workload to complete the test.

Of the subjects placed in column 2, the workload guide would have been ideal for 19 of them. Two subjects would have required more than three workloads to complete the test and four would have needed to be re-tested.

Of the 30 subjects placed in column 3, the workload guide would have worked for 13 subjects. Five subjects would have required more than three workloads and 12 subjects would have needed to be re-tested.

In the fourth workload column two of the eight subjects would have used the ideal, three workloads to complete the test. Two subjects would have required more than three workloads and four subjects would have needed to be re-tested

Table 13

Age and Gender
(N =98)

	Females 18 - 25 yr	Females 26 - 35 yr	Females 36 - 45 yr	Males 18 - 25 yr	Males 26 - 35 yr	Males 36 - 45 yr
Worked - 3	10 (10.2%)	10 (10.2%)	10 (10.2%)	9 (9.2%)	10 (10.2%)	7 (7.1%)
Worked - 2	3 (3.1%)	1 (1.0%)	3 (3.1%)	2 (2.0%)	0	2 (2.0%)
Worked >3	0	1 (1.0%)	0	8 (8.2%)	2 (2.0%)	0
Did Not Work	2 (2.0%)	4 (4.1%)	4 (4.1%)	2 (2.0%)	3 (3.1%)	5 (5.1%)

Table 13 presents the success rate of the workload guide to correctly place subjects in a workload column versus the age and gender of the subjects.

Table 14

Fitness Levels
(N = 98)

	1 excellent	2 good	3 above average	4 average	5 below average	6 poor	7 very poor
Worked -3	10 (10.2%)	15 (15.3%)	7 (7.1%)	5 (5.1%)	8 (8.2%)	10 (10.2%)	1 (1.0%)
Worked -2	2 (2.0%)	1 (1.0%)	2 (2.0%)	1 (1.0%)	2 (2.0%)	1 (1.0%)	2 (2.0%)
Worked>3	4 (4.1%)	4 (4.1%)	1 (1.0%)	2 (2.0%)	0	0	0
Did not Work	5 (5.1%)	4 (4.1%)	1 (1.0%)	3 (3.0%)	3 (3.1%)	2 (2.0%)	2 (2.0%)

Table 14 presents the ability of the workload guide to place subjects into correct workload columns versus the fitness level of the subjects.

Summary

Ninety-eight males and females between the ages of 18 and 45 were tested in an attempt to validate the YMCA's guide to setting workloads for submaximal cycle ergometer testing. It was found that 20 of the 98 subjects would have needed to be re-tested because the use of the workload guide would have made an invalid test (produced heart rates of greater than 150 bpm). Through statistical analysis (chi-square tests), it was determined that neither gender, the combination of gender and age, nor cardiorespiratory fitness level had any relationship (did not effect) the success of the workload guide to correctly place individuals into a workload column. However, it was found that the third and fourth workload columns did effect the ability of the workload guide to correctly classify individuals

into a workload column. In other words, the third and fourth columns of the workload guide would have produced too many heart rates greater than 150 bpm, making for invalid tests.

It was also determined that of the subjects who were correctly classified into a workload column (subjects who would not have needed to be re-tested), there were several who did not follow the ideal of three workloads. Of the78 subjects that the workload guide worked for, 11 subjects only needed two workloads, because the initial workload put them at a heart rate of 110 bpm or greater. Another 11 of the 78 subjects that the workload guide worked for, required four or five workloads to achieve two heart rates at two different workloads between 110 bpm and 150 bpm.

CHAPTER 5

SUMMARY, CONCLUSIONS, RECOMMENDATIONS

Summary

The YMCA cycle ergometer test is a frequently and widely used test of cardio respiratory fitness. It is a submaximal test that measures heart rate response to increasing exercise workloads. Two steady state exercise heart rates are plotted on a prediction graph to estimate maximal physical working capacity using age-predicted maximum heart rate as an end point. A workload guide was established to make testing time quicker and more efficient (Golding, et. al., 1989). The workload guide consists of an initial warm-up workload (150 Kgm) and four progressive workload columns. The principle underlying the workload guide was that the examiner would assess the heart rate response to the first low intensity workload and then would set workloads according to the guide. For example if the heart rate response was poor (100 bpm or more) the subject would follow the lowest intensity workload column, which started at 300 Kgm (just 150 Kgm more than the starting workload. If the heart rate response was good (80 bpm or less) the subject would be placed in the highest intensity workload column, beginning with 750 Kgm (See Appendix A). Theoretically, the workload guide should allow subjects to progress slowly through the workloads in order to elicit steady increases in heart rate. However, problems occurred frequently, especially in the higher intensity workload columns. The highest workload column (750 Kgm)

caused the heart rate to rise too sharply and the next workload (900 Kgm) produced a heart rate that could not be used in the prediction (greater than 150 bpm). The purpose of this study was to validate the YMCA's guide to setting workloads for the submaximal cycle ergometer test. Ninety-eight subjects (males and females) between the ages of 18 and 45 years were tested one time. The subjects performed up to six workloads in a protocol designed not to fatigue subjects. Steady state heart rates were obtained at each workload. From the data collected it was determined whether or not the YMCA's guide for setting workloads would have worked for each subject had they been performing the actual YMCA cycle ergometer test. It was found that 20 of the 98 subjects would have needed to perform the test over because the workload guide would have produced an invalid test (elicited heart rates of greater than 150 bpm). Chi-square tests determined that both the third and fourth workload columns (columns beginning with 600 Kgm and 750 Kgm) produced a significant number of invalid tests. However, gender, fitness level and the combination of age and gender did not affect the ability of the workload guide to correctly place individuals into a workload column.

Conclusions

- The workload guide worked for 79.6% of the male and female population between the ages of 18 and 45 years.
- Approximately 20.4% of individuals performing a submaximal test, using the YMCA's workload guide will need to be re-tested, due to heart rates exceeding 150 bpm.
- The two highest workload columns of the YMCA's workload guide frequently produced heart rates above the acceptable range.

Recommendations

This study indicates that a new workload guide should be developed in order to make the YMCA's submaximal cycle ergometer test more efficient, by not requiring the subjects to be re-tested. Although the workloads on the Monark cycle ergometers cannot be changed, the heart rates indicating which workload column to be used can be changed to be more conservative. The initial workload from which the heart rate response is predicted may be too low. It is known that heart rate at low intensities may be affected by external stimuli (Brooks and Fahey, 1985) It may be better to have the initial workload slightly higher. However, if the present YMCA's guide to setting workload is continued to be used, it should be used conservatively, especially the higher intensity workload columns. Since the ability of the workload guide to correctly place individuals into a workload column was unaffected by gender, age or fitness level it is important to use the workload guide conservatively for all individuals, (it is better to use a lower workload than to have to re-test the subject because the workload was too high).

Other than changing the heart rate ranges associated with the workload columns, the only other method of revising the workload guide would be to change the work intensity by changing the pedal rate. The workload increments on the cycle ergometer cannot be changed. A study determining what variables contribute to optimal pedal rate was performed by Coast, Cox and Welch, (1986). Five trained cyclists participated in five exercise tests of cycling at approximately 85% of each subject's predetermined max VO2. Pedal rates of 40, 60, 80, 100 and 120 rpm were used. Subjects exercised for approximately 20 minutes at a constant resistance. Mechanical efficiency (estimated by measuring VO2), heart rate and RPE were measured. Blood lactate, plasma, levels of epinephrine and norepinephrine were measured at rest, during exercise and five minutes into recovery. When comparing across pedal rates, results indicate heart rate and RPE were minimal at 60 and 80 rpm. Subjects were most efficient between 60 and 80 rpm (40 and 120 rpm were the least efficient pedal rates). There was no significant difference in catacholamines between pedal rates, and blood lactate only was significantly different at the 120 rpm pedal rate. For this group of cyclists an optimal pedal rate was determined for a prolonged period of exercise. In previous studies (Hess, 1963 and McKay and Banister, 1976) optimal pedal rates for short term exercise were found to be between 30 rpm and 100 rpm.

Future Studies

Although the reliable mechanical cycle ergometers are easily calibrated and maintain their calibration, more and more electronic exercise equipment is replacing the mechanical. With technology affecting the fitness world, it may be interesting to develop a workload guide to be used on the new computerized cycle

ergometers. However, to develop a workload guide to be used with any model of cycle ergometer may be difficult.

There may also be factors other than gender, age and fitness level that may affect which individuals the workload guide will work for, such as; lower body strength and the trained cyclist's body mechanics. It may be valuable to narrow down what makes the heart rate of certain individuals not conform to the well established linear relationship of heart rate and workload, that the workload guide is based on.

APPENDIX A

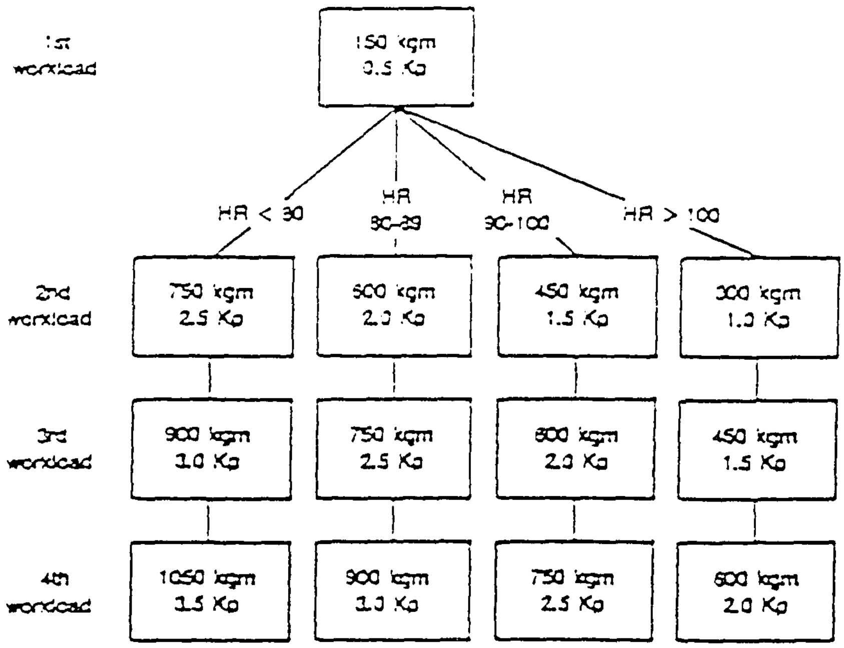
YMCA WORKLOAD GUIDE

FOR SUBMAXIMAL CYCLE ERGOMETER TESTS

Workload Guide
Workload Guide with Numbered Workload Columns

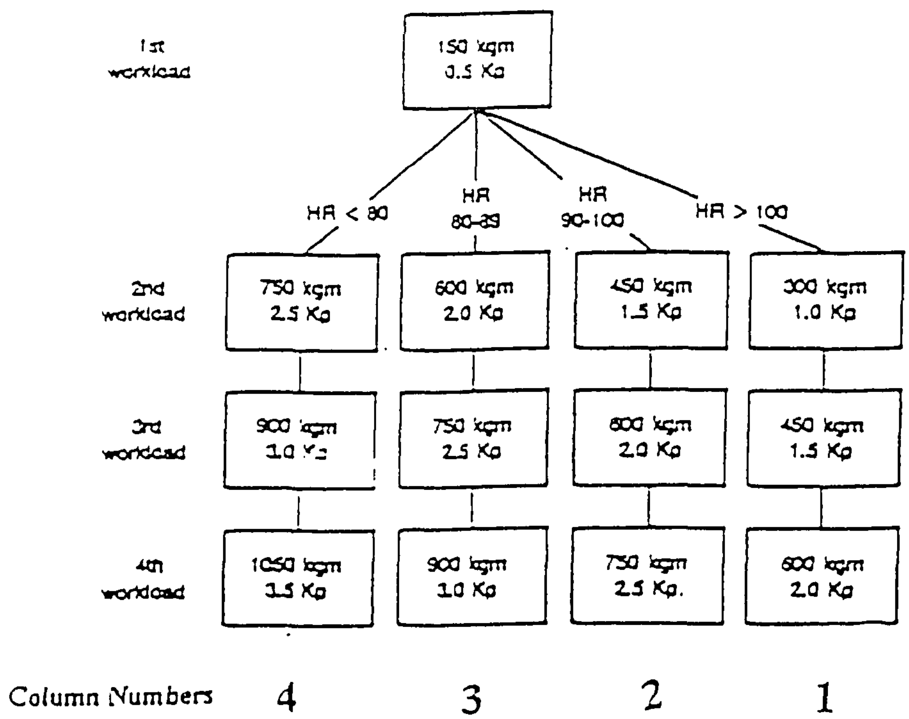
(Golding, Myers and Sinning, 1989)

YMCA Guide to Setting Workloads for the Submaximal
Cycle Ergometer Test



Workload Guide With Numbered Columns

YMCA Guide to Setting Workloads for the Submaximal
Cycle Ergometer Test



APPENDIX B

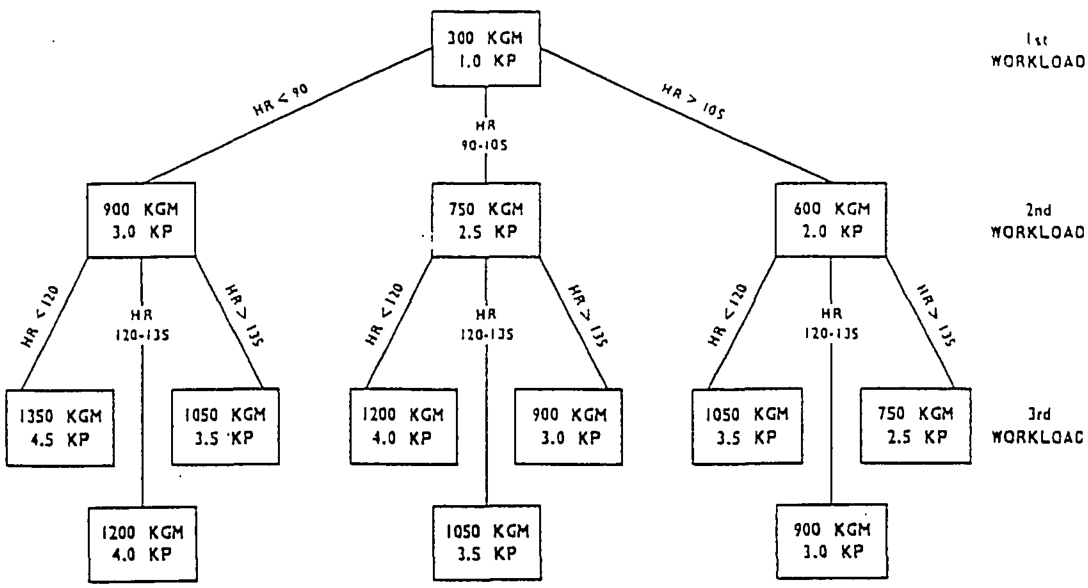
ORIGINAL YMCA WORKLOAD GUIDES FOR CYCLE ERGOMETER TESTING

Male Workload Guide
Female Workload Guide

(Golding, Myers and Sinning, 1982)

Y's Way to Physical Fitness

GUIDE TO SETTING WORKLOADS
FOR MALES ON THE BICYCLE ERGOMETER



DIRECTIONS

1. Set the 1st workload at 300 kgm/min (1.0 KP)
2. If HR in 3rd min is: Less than (<) 90, set 2nd load at 900 kgm (3 KP)
   Between 90 and 105, set 2nd load at 750 kgm (2.5 KP)
   Greater than (>) 105, set 2nd load at 600 kgm (2.0 KP)
3. Follow the same pattern for setting 3rd and final load.
4. NOTE: If the 1st workload elicits a HR of 110 or more, it is used on the graph, and only ONE more workload will be necessary.

FOOTNOTES

I. The Y's Way to Physical Fitness bicycle test is for healthy individuals who have been cleared by a physician to exercise. This test measures cardiorespiratory fitness and is *not* a medical screening test.

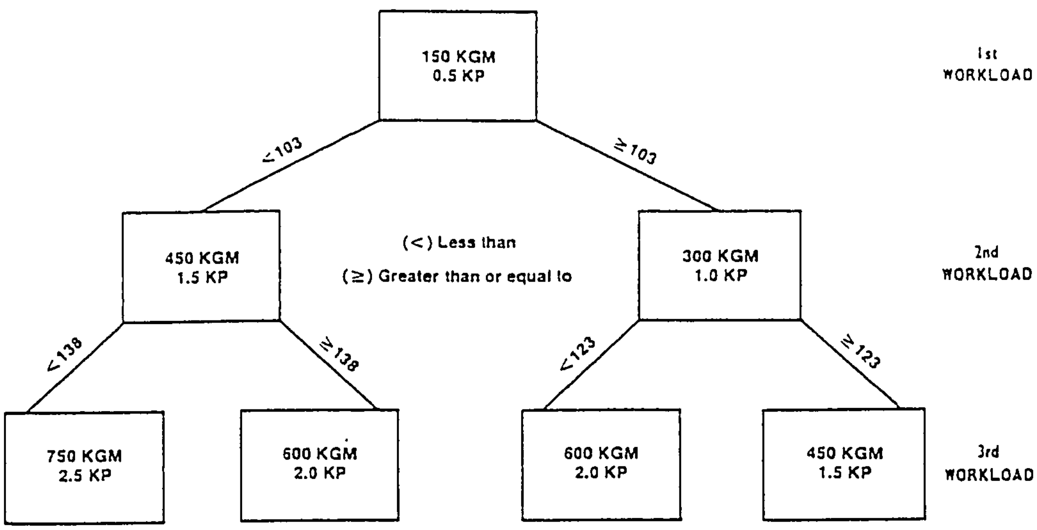
II. This aid to setting workloads is only a guide; common sense should also be used. Always be conservative. Use lower workloads for borderline scores.

III. The two plot points should be in the linear portion of the curve (approximately 110-150 bpm). It is better to have the two points toward the low end of this linearity.

Y's Way to Physical Fitness

GUIDE TO SETTING WORKLOADS

FOR FEMALES ON THE BICYCLE ERGOMETER



DIRECTIONS

1. Set the first workload to 150 kgm/min (.5 KP).
2. If steady-state heart rate is < 103, set 2nd load at 450 kgm/min (1.5 KP).
   If steady-state heart rate is ≥ 103, set 2nd load at 300 kgm/min (1.0 KP).
3. Follow this same pattern for setting the third and final load.
4. NOTE: If the 1st workload elicits a HR of 110 or more, it is used on the graph, and only ONE more workload will be necessary.

FOOTNOTES

I. The Y's Way to Physical Fitness bicycle test is for healthy individuals who have been cleared by a physician to exercise. This test measures cardiorespiratory fitness and is *not* a medical screening test.

II. This aid to setting workloads is only a guide; common sense should also be used. Always be conservative. Use lower workloads for borderline scores.

III. The two plot points should be in the linear portion of the curve (approximately 110 - 150 bpm). It is better to have the two points toward the low end of this linearity.

APPENDIX C

YMCA PHYSICAL WORKING CAPACITY PREDICTION GRAPH

Blank Prediction Graph
Sample Prediction Graph

(Golding, Myers and Sinning, 1989)

YMCA Prediction Graph

MAXIMUM PHYSICAL WORKING CAPACITY PREDICTION

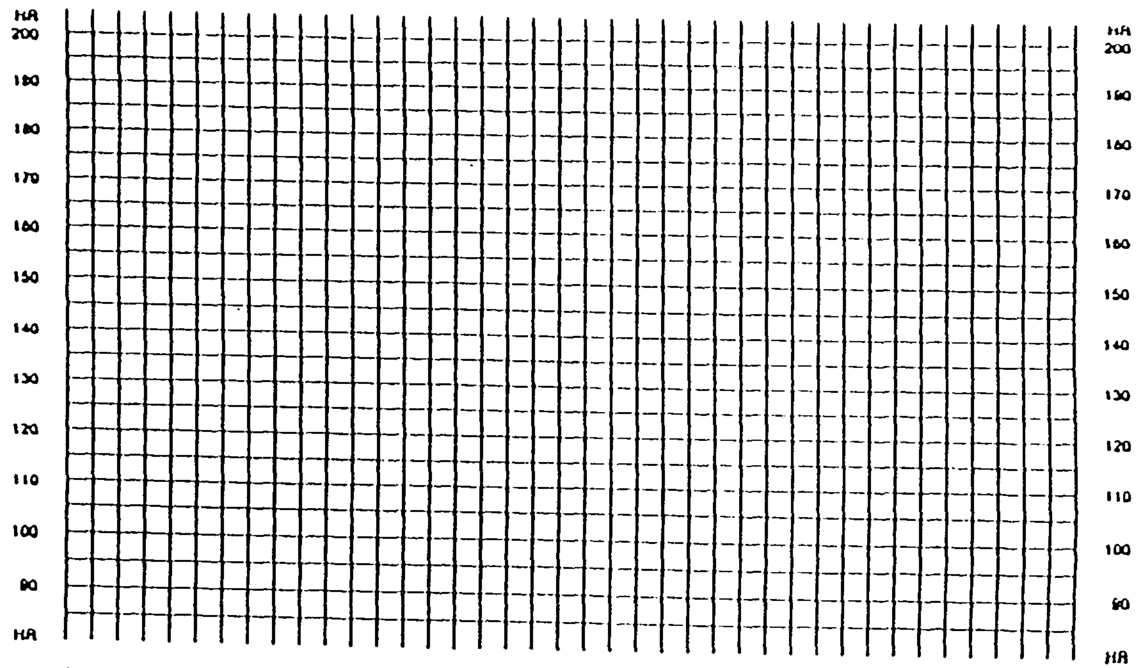
NAME ____________________ AGE ______ WEIGHT ______ LB ______ KG   SEAT HEIGHT ________

PREDICTED MAX HR ______

	DATE	1st WORKLOAD HR USED	2nd WORKLOAD HR USED	MAX WORKLOAD	MAX O_2 (L/min)	MAX O_2 (mL/kg)
TEST 1						
TEST 2						
TEST 3						

DIRECTIONS

1. Plot the HR of the 2 workloads versus the work (kgm/min).
2. Determine the subject's max HR line by subtracting subject's age from 220 and draw a line across the graph at this value.
3. Draw a line through both points and extend to the max HR line for age.
4. Drop a line from this point to the baseline and read the predicted max workload and O_2 uptake.



WORKLOAD (kgm/min)	150	300	450	600	750	900	1050	1200	1350	1500	1650	1800	1950	2100
MAX O_2 UPTAKE (L/m)	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.8	3.2	3.5	3.8	4.2	4.6	5.0
KCAL USED (kcal/m)	3.0	4.5	6.0	7.5	9.0	10.6	12.0	14.0	16.0	17.5	19.0	21.0	23.0	25.0
APPROX MET LEVEL (for 132 lb)	3.3	4.7	6.0	7.3	8.7	10.0	11.3	12.7	14.0	15.3	16.7	18.0	19.3	20.7
APPROX MET LEVEL (for 176 lb)	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0

Sample Prediction Graph

MAXIMUM PHYSICAL WORKING CAPACITY PREDICTION

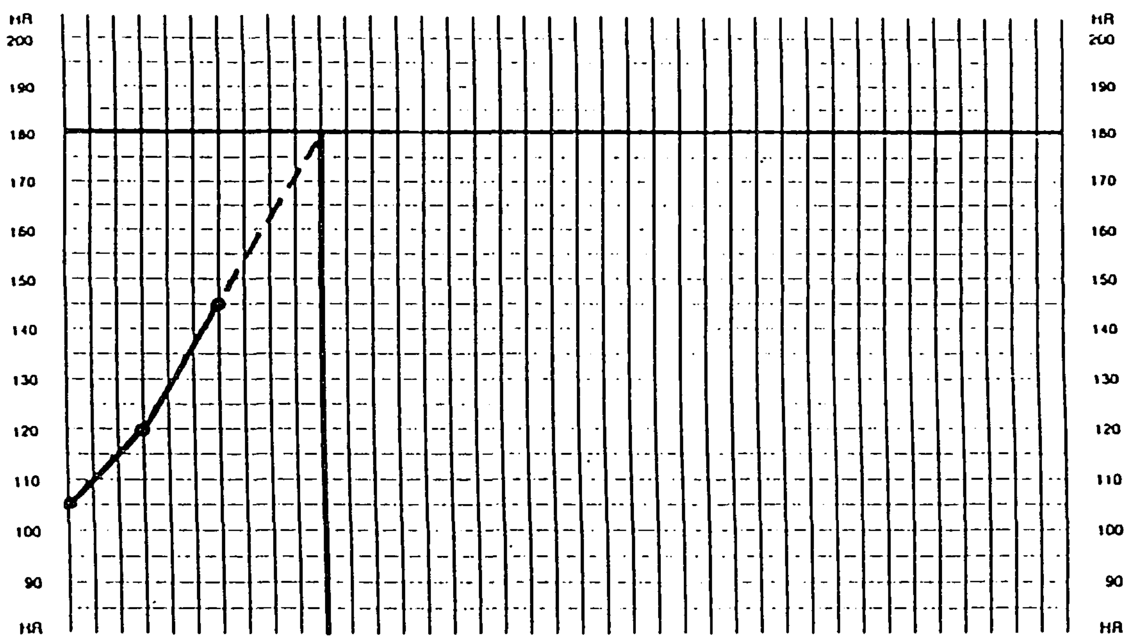
NAME _Example Male_ AGE _40_ WEIGHT _176_ LB _80_ KG SEAT HEIGHT _8_

PREDICTED MAX HR ____

	DATE	1st WORKLOAD HR USED	2nd WORKLOAD HR USED	3rd WORKLOAD HR USED	MAX WORKLOAD	MAX O_2 (L/min)	MAX O_2 (mL/kg)
TEST 1	1-4-88	150/105	300/120	450/145	650	1.6	1600/80 = 20
TEST 2							
TEST 3							

DIRECTIONS

1. Plot the HR of the 2 workloads versus the work (kgm/min)
2. Determine the subject's max HR line by subtracting subject's age from 220 and draw a line across the graph at this value.
3. Draw a line through both points and extend to the max HR line for age
4. Drop a line from this point to the baseline and read the predicted max workload and O_2 uptake.



WORKLOAD (kgm/min)	150	300	450	600	750	900	1050	1200	1350	1500	1650	1800	1950	2100
MAX O_2 UPTAKE (L/m)	0.6	0.9	1.2	1.5	1.8	2.1	2.4	2.8	3.2	3.5	3.8	4.2	4.6	5.0
KCAL USED (kcal/m)	3.0	4.5	6.0	7.5	9.0	10.5	12.0	14.0	16.0	17.5	19.0	21.0	23.0	25.0
APPROX MET LEVEL (for 132 lb)	3.3	4.7	6.0	7.3	8.7	10.0	11.3	12.7	14.0	15.3	16.7	18.0	19.3	20.7
APPROX MET LEVEL (for 176 lb)	3.0	4.0	5.0	6.0	7.0	8.0	9.0	10.0	11.0	12.0	13.0	14.0	15.0	16.0

APPENDIX D

CONSENT FORMS

COLLEGE OF HUMAN PERFORMANCE AND DEVELOPMENT
EXERCISE PHYSIOLOGY LABORATORY

CONSENT FOR RESEARCH PARTICIPATION

The study in which you will participate, involves a submaximal evaluation of cardiorespiratory endurance. You will be asked to participate in only one testing session. The time required of you will be approximately 30 - 45 minutes.

During the testing session you will be asked to exercise on a stationary cycle ergometer for approximately 20 minutes. You will pedal at a rate of 50 revolutions per minute with the workload increasing approximately every 3 minutes. You will also be asked to complete two questionnaires regarding your present physical activities and health. Height, weight and resting blood pressure will be measured.

It is highly unlikely that any physical complications will occur during the test, however if you should feel any discomfort you you can report this to the investigator and the test will be stopped. If you agree to be a subject you can however, withdraw from the study at any time. It is possible that you will begin to feel fatigue during or after the study. Please feel free to ask questions any time if you are unclear about the procedure.

YOUR SIGNATURE BELOW INDICATES THAT YOU HAVE DECIDED TO PARTICIPATE IN THE STUDY AND THAT YOU HAVE READ AND UNDERSTAND THE INFORMATION PROVIDED ABOVE, AND THAT ANY QUESTIONS HAVE BEEN ANSWERED TO YOUR SATISFACTION.

_________________________ ______________________________
Print Name Signature and date

_________________________ ______________________________
Witness Signature and date

UNIVERSITY OF NEVADA, LAS VEGAS/4505 MARYLAND PARKWAY/LAS VEGAS, NEVADA 89154-3016
(702) 739-3766/FAX (702) 597-4191

ASSOCIATE VICE PRESIDENT FOR RESEARCH

UNIVERSITY OF NEVADA LAS VEGAS
4505 MARYLAND PARKWAY • LAS VEGAS, NEVADA 89154-1002 • (702) 597-4240 • FAX (702) 597-4242

DATE:	November 20, 1992
TO:	Nicole M. Dacuma
FROM:	Dr. Lawrence Golding, Chairman, Biomedical Subcommittee of the Institutional Review Board
RE:	Approval of Human Subjects Protocol Project Entitled: "Validation of YMCA Guide to Setting Workloads for Submaximal Cycle Ergometer Test"

This memorandum is official notification that the protocol for the project referenced above was approved by the Bio/Medical Subcommittee of the Institutional Review Board on Friday, November 20, 1992.

If you have any questions or require any assistance, please give us a call.

APPENDIX E

PAR - Q

(Re-constructed from the original PAR-Q)

PAR Q & YOU

(Physical Activity Readiness Questionnaire)

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 the yes or no opposite the question if it applies to you.

YES	NO	
		Has your doctor ever said you have heart trouble?
		Do you frequently have pains in your chest?
		Do you often feel faint or have spells of dizziness?
		Has a doctor ever said you blood pressure was too high?
		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?
		Is there a good physical reason not mentioned here why you should not follow an activity program even if you wanted to?
		Are you over age 65 and not accustomed to vigorous exercise?

If you answered YES to one or more questions: If you have not recently done so , consult with your personal physician by telephone or in person before increasing you physical activity and/or taking a fitness test. Tell him what questions you answered yes on PAR-Q. After medical evaluation, seek advice as to your suitability for unrestricted or restricted physical activity.

If you answered NO to all questions: If you answered PAR-Q accurately, you have reasonable assurance of your present suitability for a graduated exercise program and/or an exercise test. However you should postpone if you have a temporary minor illness such as a common cold.

APPENDIX F

ACTIVITY QUESTIONNAIRE

COLLEGE OF HUMAN PERFORMANCE AND DEVELOPMENT
EXERCISE PHYSIOLOGY LABORATORY

PHYSICAL FITNESS QUESTIONNAIRE

NAME: ______________________ DATE:____________ SUB.#: _______

RESTING HEART RATE: __________________ AGE: _________

1. Are you currently involved in regular physical activity? ___________

2. What type of exercise do you participate in? _______________________

3. Approximately how many times per week do you exercise?______________

4. Approximately how many minutes do you exercise each session?________

5. When you exercise how hard (intensely) do you work?

(1) Very Hard (2) Hard (3) Moderate (4) Light (5) Very Light

6. How do you rate your current level of cardiorespiratory fitness?

(1) Excellent (2) Good (3) Average (4) Fair (5) Poor

7. How do you rate your current level of muscular endurance?

(1) Excellent (2) Good (3) Average (4) Fair (5) Poor

8. Are you currently taking any medications that effect your heart rate? Yes No

If yes please indicate what the medications are:__________

____

9. Have you recently consumed anything that may effect your heart rate, in the last 24 hours? Yes No

If yes, what? (Caffeine, Alcohol, ect..) And How much?

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APPENDIX G

SCORE SHEETS

COLLEGE OF HUMAN PERFORMANCE AND DEVELOPMENT
EXERCISE PHYSIOLOGY LABORATORY

SCORE SHEET SUB #: __________

NAME: ________________________________ DATE: ______________

SEAT HEIGHT: __________ AGE: ________ HT: _______ WT: ________

RESTING HEART RATE: __________ RESTING BLOOD PRESSURE: _________

COMMENTS: ____

WORKLOAD (KGM)	HEART RATE	
150 KGM	____________	2ND MIN.
	____________	3RD MIN.
	____________	4TH MIN. (IF NEEDED)
300 KGM	____________	2ND MIN.
	____________	3RD MIN.
	____________	4TH MIN. (IF NEEDED)
450 KGM	____________	2ND MIN.
	____________	3RD MIN.
	____________	4TH MIN. (IF NEEDED)
5 MIN. REST	RECOVERY HEART RATE: ______________________	
600 KGM	____________	2ND MIN.
	____________	3RD MIN.
	____________	4TH MIN. (IF NEEDED)
5 MIN. REST	RECOVERY HEART RATE: ______________________	

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COLLEGE OF HUMAN PERFORMANCE AND DEVELOPMENT
EXERCISE PHYSIOLOGY LABORATORY

SCORE SHEET CONTINUED

NAME: ______________________

WORKLOAD	HEART RATE	
750 KGM	__________	2ND MIN.
	__________	3RD MIN.
	__________	4TH MIN. (IF NEEDED)
5 MIN. REST	RECOVERY HEART RATE: __________________	
900 KGM	__________	2ND MIN.
	__________	3RD MIN.
	__________	4TH MIN. (IF NEEDED)
1050 KGM	__________	2ND MIN.
	__________	3RD MIN.
	__________	4TH MIN. (IF NEEDED)

TERMINATION OF THE TEST:

***** See University of Nevada, Las Vegas
Exercise Physiology Laboratory
Termination of Fitness Evaluation

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APPENDIX H

YMCA PHYSICAL FITNESS PROFILES

(Golding, Myers and Sinning, 1989)

Y's Way to Physical Fitness

Physical Fitness Evaluation Profile

Norms—Men 18-25

Name ______________________ Dates: T1 ________ T2 ________ T3 ________

Rating	% ranking	Resting HR	% fat	3-min step test	PWC max (kgm)	$\dot{V}O_2max$ (mL/kg)	Flexibility	Bench press	Sit-ups
Excellent 1	100 95 90	49 52 55	4 6 7	70 72 78	2350 2275 2065	80 71 63	26 22 20	45 42 38	60 54 50
Good 2	85 80 75	57 60 61	8 9 10	82 85 88	1905 1795 1705	59 55 53	20 19 18	34 32 30	48 46 45
Above average 3	70 65 60	63 64 65	11 12 13	91 94 97	1630 1570 1515	51 49 47	18 17 17	28 26 25	42 41 40
Average 4	55 50 45	67 68 69	14 15 16	101 102 104	1455 1400 1350	46 45 43	16 16 15	22 22 21	38 37 36
Below average 5	40 35 30	71 72 73	18 19 20	107 110 114	1305 1250 1195	41 39 38	14 14 13	20 17 16	34 33 32
Poor 6	25 20 15	76 79 81	22 24 26	118 121 126	1135 1090 1050	35 33 31	12 12 10	13 12 9	30 28 26
Very poor 7	10 5 0	84 89 95	28 30 37	131 137 164	975 885 850	29 26 20	9 7 2	8 2 0	24 17 12
Actual Scores T1		____	____	____	____	____	____	____	____
T2		____	____	____	____	____	____	____	____
T3		____	____	____	____	____	____	____	____

	T1	T2	T3
Actual Weight	________	________	________
Target Weight	________	________	________
Blood Pressure	___/___	___/___	___/___

Your actual weight should be within 10% of your target weight. If your blood pressure exceeds 150/90 it is considered high. Your YMCA Medical Advisory Committee should have guidelines for when blood pressure is too high to continue fitness testing.

Y's Way to Physical Fitness

Physical Fitness Evaluation Profile

Norms—Men 26-35

Name ______________________ Dates: T1 ________ T2 ________ T3 ________

Rating	% ranking	Resting HR	% fat	3-min step test	PWC max (kgm)	$\dot{V}O_2max$ (mL/kg)	Flexibility	Bench press	Sit-ups
Excellent 1	100	49	8	73	2300	70	25	43	55
	95	52	10	76	2180	64	22	40	50
	90	54	12	79	1950	58	20	34	46
Good 2	85	57	13	83	1820	54	19	30	45
	80	60	14	85	1740	52	18	29	42
	75	61	15	88	1665	50	18	26	41
Above average 3	70	62	16	91	1600	47	17	25	38
	65	64	17	94	1545	46	17	24	37
	60	65	18	97	1485	44	16	22	36
Average 4	55	66	19	101	1430	42	16	21	34
	50	68	20	103	1375	41	15	20	33
	45	70	21	106	1325	40	15	18	32
Below average 5	40	72	22	109	1270	39	14	17	30
	35	73	23	113	1225	38	13	14	30
	30	74	24	116	1180	35	12	13	29
Poor 6	25	77	25	119	1135	34	12	12	28
	20	78	26	122	1080	33	11	10	25
	15	81	28	126	1020	31	10	9	24
Very poor 7	10	84	30	130	960	28	9	5	21
	5	88	32	140	840	26	7	2	12
	0	94	37	164	780	20	2	0	6
Actual Scores T1		____	____	____	____	____	____	____	____
T2		____	____	____	____	____	____	____	____
T3		____	____	____	____	____	____	____	____

	T1	T2	T3
Actual Weight	________	________	________
Target Weight	________	________	________
Blood Pressure	___/___	___/___	___/___

Your actual weight should be within 10% of your target weight. If your blood pressure exceeds 150/90 it is considered high. Your YMCA Medical Advisory Committee should have guidelines for when blood pressure is too high to continue fitness testing.

Y's Way to Physical Fitness

Physical Fitness Evaluation Profile

Norms—Men 36–45

Name ______________________ Dates: T1 ________ T2 ________ T3 ________

Rating	% ranking	Resting HR	% fat	3-min step test	PWC max (kgm)	$\dot{V}O_2$max (mL/kg)	Flexibility	Bench press	Sit-ups
Excellent 1	100 95 90	50 53 56	10 12 14	72 74 81	2250 2055 1815	77 60 53	24 21 19	40 34 30	50 46 42
Good 2	85 80 75	60 61 62	16 17 18	86 90 94	1725 1640 1565	49 46 44	19 17 17	28 25 24	40 37 36
Above average 3	70 65 60	64 65 66	19 20 21	98 100 102	1500 1440 1375	42 41 40	17 15 15	22 21 20	34 32 30
Average 4	55 50 45	68 69 70	22 23 24	105 108 111	1325 1280 1235	38 37 35	15 14 13	18 17 16	29 29 28
Below average 5	40 35 30	73 74 76	25 26 26	113 116 118	1190 1140 1090	34 33 32	13 11 11	14 13 12	26 25 24
Poor 6	25 20 15	77 80 82	27 28 29	120 124 128	1045 995 945	30 28 27	11 9 9	10 9 8	22 20 18
Very poor 7	10 5 0	86 90 96	30 32 38	132 142 168	[illegible] [illegible] 700	25 21 19	7 3 1	5 2 0	16 9 4

Actual Scores T1 ____ ____ ____ ____ ____ ____ ____ ____

T2 ____ ____ ____ ____ ____ ____ ____ ____

T3 ____ ____ ____ ____ ____ ____ ____ ____

	T1	T2	T3
Actual Weight	________	________	________
Target Weight	________	________	________
Blood Pressure	___/___	___/___	___/___

Your actual weight should be within 10% of your target weight. If your blood pressure exceeds 150/90 it is considered high. Your YMCA Medical Advisory Committee should have guidelines for when blood pressure is too high to continue fitness testing.

Y's Way to Physical Fitness

Physical Fitness Evaluation Profile

Norms—Women 18-25

Name ______________________ Dates: T1 ________ T2 ________ T3 ________

Rating	% ranking	Resting HR	% fat	3-min step test	PWC max (kgm)	$\dot{V}O_2max$ (mL/kg)	Flexibility	Bench press	Sit-ups
Excellent 1	100	54	13	72	1830	71	27	50	55
	95	56	15	79	1640	67	25	42	48
	90	60	17	83	1440	58	24	36	44
Good 2	85	61	18	88	1320	54	23	32	41
	80	64	19	93	1235	50	22	29	38
	75	65	20	97	1175	48	21	28	37
Above average 3	70	66	21	100	1120	46	21	25	36
	65	68	22	103	1075	43	20	24	34
	60	69	23	106	1030	42	20	22	33
Average 4	55	70	24	110	990	41	19	21	32
	50	72	25	112	950	40	19	20	30
	45	73	25	116	915	39	18	18	29
Below average 5	40	74	26	118	880	37	18	16	28
	35	76	27	122	845	35	17	14	26
	30	78	28	124	810	34	17	13	25
Poor 6	25	80	29	128	775	32	16	12	24
	20	82	30	133	740	31	15	9	22
	15	84	31	137	705	29	14	8	20
Very poor 7	10	86	33	142	640	26	13	5	17
	5	90	37	149	555	22	12	2	10
	0	100	43	155	500	18	8	1	4

Actual Scores
T1 ____ ____ ____ ____ ____ ____ ____ ____
T2 ____ ____ ____ ____ ____ ____ ____ ____
T3 ____ ____ ____ ____ ____ ____ ____ ____

	T1	T2	T3
Actual Weight	______	______	______
Target Weight	______	______	______
Blood Pressure	/	/	/

Your actual weight should be within 10% of your target weight. If your blood pressure exceeds 150/90 it is considered high. Your YMCA Medical Advisory Committee should have guidelines for when blood pressure is too high to continue fitness testing.

Y's Way to Physical Fitness

Physical Fitness Evaluation Profile

Norms—Women 36-45

Name ______________________ Dates: T1 ________ T2 ________ T3 ________

Rating	% ranking	Resting HR	% fat	3-min step test	PWC max (kgm)	$\dot{V}O_2max$ (mL/kg)	Flexibility	Bench press	Sit-ups
Excellent 1	100 95 90	54 56 59	15 17 19	74 80 87	1780 1360 1215	66 53 46	25 23 22	46 32 28	50 38 34
Good 2	85 80 75	62 63 64	20 21 23	93 97 101	1135 1085 1035	44 41 39	21 20 19	25 22 21	30 29 27
Above average 3	70 65 60	66 68 69	24 25 26	104 106 109	980 925 880	37 36 34	19 18 17	20 18 17	26 25 24
Average 4	55 50 45	70 71 72	27 28 29	111 114 117	835 800 765	33 32 31	17 16 16	14 13 12	22 21 20
Below average 5	40 35 30	74 76 78	30 31 32	120 122 127	745 720 695	30 29 28	15 15 14	11 10 9	18 17 16
Poor 6	25 20 15	79 80 82	33 35 36	130 135 138	670 625 575	26 25 23	13 12 11	8 6 4	14 12 10
Very poor 7	10 5 0	[illegible] 88 92	39 41 48	143 146 152	530 490 470	21 19 18	10 9 6	2 1 0	6 2 1

Actual Scores T1 ____ ____ ____ ____ ____ ____ ____ ____

T2 ____ ____ ____ ____ ____ ____ ____ ____

T3 ____ ____ ____ ____ ____ ____ ____ ____

	T1	T2	T3
Actual Weight	________	________	________
Target Weight	________	________	________
Blood Pressure	____/____	____/____	____/____

Your actual weight should be within 10% of your target weight. If your blood pressure exceeds 150/90 it is considered high. Your YMCA Medical Advisory Committee should have guidelines for when blood pressure is too high to continue fitness testing.

Y's Way to Physical Fitness

Physical Fitness Evaluation Profile

Norms—Women 26-35

Name ______________________ Dates: T1 ________ T2 ________ T3 ________

Rating	% ranking	Resting HR	% fat	3-min step test	PWC max (kgm)	$\dot{V}O_2$max (mL/kg)	Flexibility	Bench press	Sit-ups
Excellent 1	100 95 90	54 55 59	13 15 18	72 80 86	1800 1440 1330	69 59 54	26 24 23	48 40 33	54 42 40
Good 2	85 80 75	60 63 64	19 20 21	91 93 97	1245 1180 1115	51 48 46	22 21 20	29 26 25	37 34 33
Above average 3	70 65 60	66 67 68	22 23 23	103 106 110	1065 1020 985	43 42 40	20 19 19	22 21 20	32 30 29
Average 4	55 50 45	69 70 71	24 25 26	112 116 118	955 925 885	38 37 35	18 18 18	18 17 16	28 26 25
Below average 5	40 35 30	72 74 76	27 29 30	121 124 127	840 805 765	34 33 31	17 16 16	14 13 12	24 23 21
Poor 6	25 20 15	78 80 82	31 33 35	129 131 135	730 695 655	30 28 26	15 14 14	9 8 5	20 18 16
Very poor 7	10 5 0	84 88 94	36 39 49	141 148 154	600 530 490	25 22 20	13 11 8	2 1 0	12 2 1

Actual Scores T1 ____ ____ ____ ____ ____ ____ ____ ____

T2 ____ ____ ____ ____ ____ ____ ____ ____

T3 ____ ____ ____ ____ ____ ____ ____ ____

	T1	T2	T3
Actual Weight	______	______	______
Target Weight	______	______	______
Blood Pressure	___/___	___/___	___/___

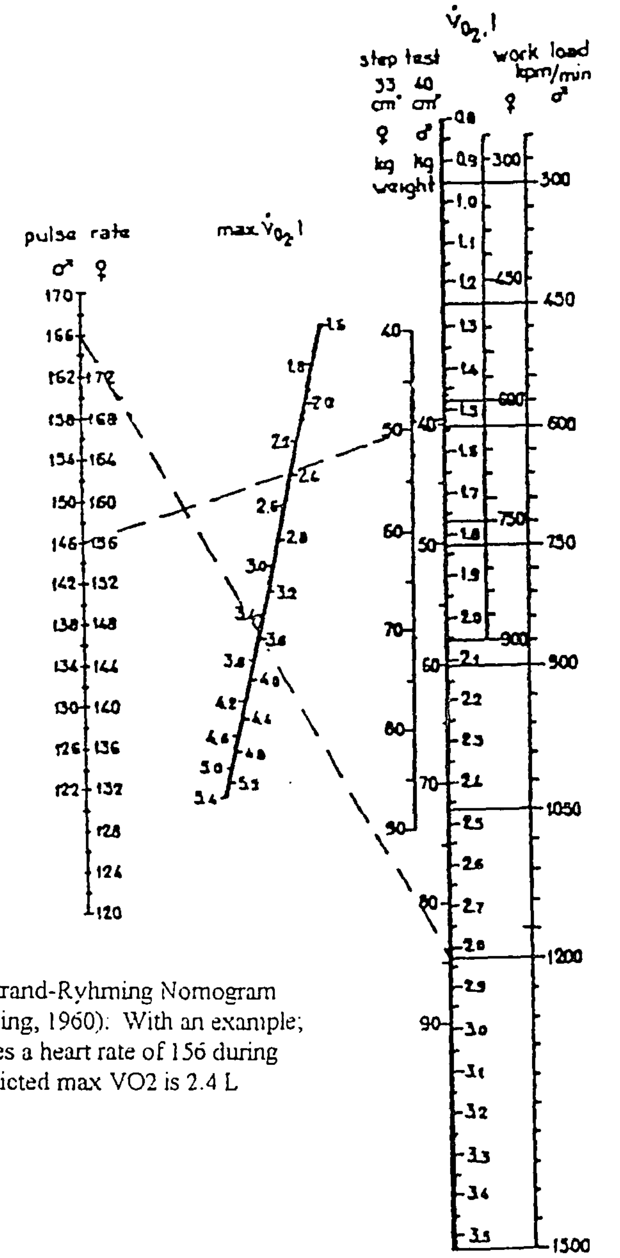
Your actual weight should be within 10% of your target weight. If your blood pressure exceeds 150/90 it is considered high. Your YMCA Medical Advisory Committee should have guidelines for when blood pressure is too high to continue fitness testing.

APPENDIX I

ASTRAND-RYHMING NOMOGRAM

(Astrand and Ryhming, 1960)

Adjusted Astrand - Ryhming Nomogram



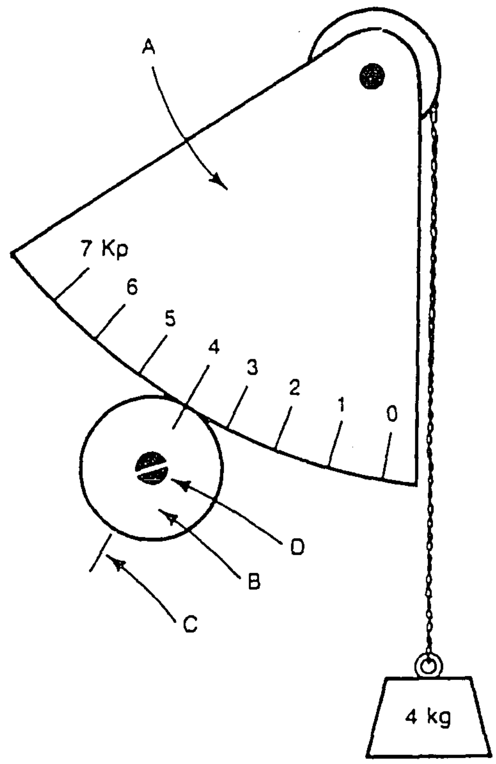
The adjusted Astrand-Ryhming Nomogram (Astrand and Ryhming, 1960): With an example; 49 Kg female reaches a heart rate of 156 during a step test, her predicted max VO2 is 2.4 L

APPENDIX J

CYCLE ERGOMETER PENDULUM DIAGRAM

(Golding, Myers and Sinning, 1989)

Calibration of the Cycle Ergometer



The calibration of the bike is done precisely at the factory and unless the adjusting screw (C) has been tampered with, seldom is there a need for recalibration. However, if you suspect incorrect calibration it can be checked as follows.

Set the mark on the pendulum weight (B) at 0. Attach a weight known to be very accurate as shown above. A 1 kg weight should correspond to a reading of 1 on the scale (A); a 2 kg weight should correspond to a reading of 2 on the scale (A); and so on. The example above shows 4 kg corresponding to 4 on the scale.

If the numbers do not agree it can be corrected by changing the adjusting screw (C). This screw moves the center of gravity of the pendulum (this screw is locked with the screw D).

Bicycle ergometer calibration. *Note.* From *Work Tests With the Bicycle Ergometer* (p. 14) by P.-O. Åstrand, n.d., Varberg, Sweden: Monark. Copyright by Monark-Crescent AB. Adapted by permission.

APPENDIX K

INDIVIDUAL DATA

Subject Characteristics
Test Scores

Subject Characteristics

Column Terminology

Sub # : The number assigned to each subject.

Sex : The gender of each subject.

Age : The age of each subject in years.

Fitnes : The fitness rating assigned to each subject, according to the results of the test (a score of 1 - 7 was assigned see Appendix H).

Wt. : The weight in kilograms (Kg) of each subject.

Height: The height of each subject in centimeters.

BP : The blood pressure of each subject at rest (mmHg).

Start HR: The heart rate of each subject at rest (bpm).

WL col : The workload column that each subject would have been put into based on their heart rate during the first workload (See Appendix A).

sub #	sex	age	fitnes	wt	height	BP	start HR	WL col
1	M	27	6	82.3	182.88	130/82	70	2
2	F	24	1	68.2	165.1	102/58	60	3
3	F	24	2	70.5	170.18	112/75	58	3
4	F	25	2	58.6	172.72	110/68	72	3
5	M	24	3	65.9	175.26	126/66	97	2
6	M	23	1	80.9	175.26	125/57	68	3
7	M	25	5	78.2	177.8	114/57	64	4
8	F	33	1	56.4	154.94	110/67	48	4
9	M	24	5	63.6	162.56	114/50	49	3
10	M	27	1	59.1	171.45	121/67	68	3
11	F	45	1	81.8	177.8	138/82	68	2
12	F	36	2	72.7	160.02	106/64	78	1
13	M	32	2	84.5	182.8	105/57	60	3
14	M	21	1	79.5	182.8	113/65	54	4
15	M	22	2	100	182.8	138/79	71	2
16	M	26	2	75	175.26	138/72	73	3
17	F	38	1	79.5	172.72	121/69	60	4
18	M	20	1	72.7	181.61	136/76	68	3
19	M	20	2	70.9	190.5	145/69	72	2
20	M	39	2	70	180.34	137/70	50	3
21	M	33	6	84.1	180.34	124/64	51	4
22	F	34	2	56.8	168.91	114/61	64	2
23	M	31	2	59	165.1	129/72	59	3
24	M	32	4	63.6	171.45	124/72	60	4
25	M	26	3	79.5	165.1	125/80	90	2
26	M	32	2	68.2	170.18	111/72	68	3
27	M	29	4	81.8	190.5	120/80	77	3
28	F	41	2	61.3	167.64	112/78	76	3
29	F	41	6	56.8	154.94	116/68	74	1
30	F	40	3	74.5	170.18	122/80	91	1
31	F	28	1	64.5	162.56	118/72	73	2
32	F	42	5	62.3	160.02	106/74	84	1
33	M	43	6	66.4	171.45	124/88	94	1
34	F	43	4	67.3	170.18	117/66	82	1
35	F	18	6	49.1	154.94	130/78	94	1
36	M	23	2	84.1	182.88	116/82	63	3
37	M	39	5	76.4	180.34	130/74	78	3
38	F	20	5	61.4	170.18	112/78	90	1
39	F	36	3	72.7	162.56	138/98	91	1
40	M	20	6	78.2	177.8	132/82	83	1
41	F	20	2	72.7	170.18	112/78	95	1
42	M	19	1	102	185.42	138/100	59	3

sub #	sex	age	fitnes	wt	height	BP	start HR	WL col
43	F	20	6	58.2	170.18	108/62	90	1
44	F	26	2	56.4	162.56	108/62	77	2
45	M	20	2	86.4	177.8	138/80	86	1
46	F	25	3	56.8	160.02	136/82	86	1
47	M	22	5	68.2	180.34	138/72	92	2
48	F	20	3	59.1	162.56	118/78	93	1
49	M	21	1	81.8	182.88	130/78	57	4
50	M	21	5	113	180.34	148/88	65	1
51	F	31	1	64.1	165.1	106/68	74	1
52	F	23	5	59.1	165.1	110/60	77	1
53	F	23	3	70.5	165.1	106/78	96	2
54	M	23	1	75	182.88	134/90	86	1
55	F	32	3	54.5	167.64	138/62	48	1
56	M	22	4	72.7	182.88	128/78	78	2
57	M	27	4	75	177.8	118/78	68	3
58	F	34	4	65.9	167.64	108/64	72	1
59	F	22	5	66.8	163.83	98/64	74	2
60	M	23	1	103	190.5	106/68	85	2
61	M	21	5	72.7	177.8	136/78	85	2
62	F	44	3	70.5	167.64	98/70	80	1
63	M	30	3	75	177.8	109/68	61	2
64	M	33	2	81.8	167.64	110/82	83	1
65	M	41	4	93.2	185.42	122/76	85	2
66	M	21	7	81.8	180.34	138/82	85	1
67	M	28	2	113	182.88	138/76	69	3
68	F	20	2	65.9	175.26	102/60	76	1
69	F	25	4	46.8	160.02	124/58	76	2
70	M	35	7	65	175.26	122/74	70	3
71	F	32	7	55.9	163.83	132/78	72	2
72	F	27	1	52.3	162.56	110/62	105	1
73	F	28	6	54.5	162.56	112/70	90	1
74	F	39	5	62.7	172.72	112/72	80	2
75	M	22	1	102	193.04	134/78	78	4
76	F	33	1	70.7	172.72	122/78	69	2
77	M	37	6	76.8	175.26	122/78	78	1
78	M	44	7	75	165.1	130/84	78	1
79	F	34	2	99.5	174.62	120/78	78	2
80	F	41	7	54.5	162.56	108/80	93	1
81	F	31	1	63.6	170.18	112/62	78	3
82	M	40	4	75	170.18	112/74	71	3
83	F	40	2	64.5	171.45	110/68	56	3
84	M	44	6	82.7	175.26	138/78	92	1

sub #	sex	age	fitnes	wt	height	BP	start HR	WL col
85	F	38	5	56.8	160.02	110/76	97	1
86	M	40	3	80.9	175.26	106/60	62	3
87	M	43	6	81.8	176.53	129/76	68	2
88	M	40	5	98.6	180.34	114/76	66	3
89	M	44	6	70	171.45	120/72	60	3
90	M	38	2	85	176.53	117/71	79	2
91	M	36	2	85.9	182.88	143/72	60	3
92	F	38	2	80.9	166.37	100/64	56	3
93	F	40	4	74.1	172.72	113/65	88	1
94	F	29	1	71.8	165.1	111/72	48	3
95	F	27	1	75	172.72	111/56	65	3
96	F	31	1	50	149.86	118/63	67	1
97	F	36	4	71.6	171.45	109/71	82	1
98	F	24	6	48.6	156.21	96/48	63	1

Test Scores

Column Terminology

Sub # : The number assigned to each subject.

Subj : The initials of each subject.

Sex : The gender of each subject.

Age : The age of each subject in years.

150 : The heart rate of each subject at the initial workload of 150 Kgm.

300 : The heart rate of each subject at the second workload of 300 Kgm.

450 : The heart rate of each subject at the third workload of 450 Kgm.

600 : The heart rate of each subject at the forth workload of 600 Kgm.

750 : The heart rate of each subject at the fifth workload of 750 Kgm.

900 : The heart rate of each subject at the sixth workload of 900 Kgm.

**** : The stars indicate individuals whom the workload guide did not work for (both producing too high of heart rates and too low).

Fitnes : The fitness rating for each subject (scores of 1 - 7, See Appendix H).

sub #	Subj	sex	age	150	300	450	600	750	900		fitnes
1	CL	M	27	90	104	118	133	149	164		6
2	LL	F	24	85	92	102	111	125	138		1
3	AP	F	24	88	107	119	133	152	169	*****	2
4	TL	F	25	81	95	105	118	137	155		2
5	SM	M	24	95	99	107	116	129	141	*****	3
6	DS	M	23	85	98	101	107	115	121	*****	1
7	SK	M	25	77	90	96	105	119	135		5
8	MD	F	33	73	85	101	119	132	153	*****	1
9	MT	M	24	80	92	104	115	131	147		5
10	DD	M	27	81	84	94	110	127	132		1
11	RM	F	45	91	104	113	124	138	148		1
12	D	F	36	113	129	138	158				2
13	SF	M	32	86	99	99	105	112	123	*****	2
14	DS	M	21	63	71	87	94	103	114	*****	1
15	RB	M	22	90	98	110	117	126	138		2
16	CB	M	26	85	90	100	111	116	129		2
17	SS	F	38	75	86	99	111	124	135	*****	1
18	PB	M	20	86	104	120	129	140	147	*****	1
19	BS	M	20	96	104	113	123	134	144		2
20	BS	M	39	84	88	107	117	128	135		2
21	LK	M	33	75	82	97	112	137	164	*****	6
22	LF	F	34	91	104	121	139	150	161		2
23	DS	M	31	80	96	103	110	125	135	*****	2
24	MB	M	32	75	85	95	104	118	133		4
25	TE	M	26	93	108	115	116	134	145		3
26	TO	M	32	87	90	105	113	129	138		2
27	JS	M	29	87	92	104	115	125	142		4
28	DC	F	41	84	95	116	132	147	153	*****	2
29	ES	F	41	103	116	146	159	163			6
30	AT	F	40	107	110	126	140	155			3
31	PK	F	28	92	102	124	142	150	157		1
32	NC	F	42	101	123	141	157	173			5
33	ML	M	43	112	124	136	157	173	190		6
34	PM	F	43	105	117	128	150	163	176		4
35	CH	F	18	105	115	146	174	183			6
36	PK	M	23	81	86	96	100	106	120	*****	2
37	DB	M	39	85	96	116	131	155	166	*****	5
38	CC	F	20	114	119	141	154				5
39	GC	F	36	106	118	133	146				3
40	DM	M	20	106	112	131	137	149	158		6
41	NM	F	20	103	115	129	144	157	164		2
42	AS	M	19	81	86	99	109	114	119	*****	1

sub #	Subj	sex	age	150	300	450	600	750	900		fitnes
43	NC	F	20	101	122	152	167	177	185		6
44	SS	F	26	96	114	137	150	162	174	*****	2
45	PJ	M	20	100	105	107	116	129	139	*****	2
46	KH	F	25	110	126	140	155	178			3
47	MA	M	22	92	106	118	134	153	164		5
48	SS	F	20	111	126	143	153	169	176		3
49	BE	M	21	77	94	113	113	131	138	*****	1
50	MH	M	21	127	138	151	156	159	171		5
51	MM	F	31	101	119	129	142				1
52	AS	F	23	105	118	139	151	176			5
53	SR	F	23	95	104	121	138	157	160		3
54	BG	M	23	115	120	126	140	155	165		1
55	DA	F	32	100	110	127	145	158	170	*****	3
56	MB	M	22	91	93	106	116	131	148	******	4
57	DM	M	27	89	104	112	121	131	148	*****	4
58	ML	F	34	102	107	128	148	165	183	*****	4
59	HS	F	22	91	102	119	149	168			5
60	MR	M	23	99	104	114	118	131	138		1
61	CH	M	21	94	108	125	137	157	176		5
62	LS	F	44	107	119	132	141	156	168		3
63	MM	M	30	92	102	111	121	133	146		3
64	BE	M	33	105	111	119	127	141	149		2
65	MM	M	41	96	100	116	126	140	152		4
66	WG	M	21	109	121	139	148	159	170		7
67	RA	M	28	86	90	95	101	107	118	*****	2
68	BM	F	20	100	108	123	130	146	151		2
69	JC	F	25	91	110	131	153	161	171	*****	4
70	RH	M	35	89	106	128	147	160	167	*****	7
71	CM	F	32	92	132	166	184	187		*****	7
72	TZ	F	27	125	132	147	165	179			1
73	SL	F	28	109	130	153	158	160	164		6
74	CC	F	39	93	115	138	159	174		*****	5
75	CL	M	22	77	85	89	101	108	117	*****	1
76	DJ	F	33	93	102	116	137	148	161		1
77	MF	M	37	101	110	124	135	155	165		6
78	CV	M	44	116	135	150	164				7
79	VK	F	34	97	109	127	138	147	160		2
80	LC	F	41	122	149	171	181				7
81	DL	F	31	82	100	112	122	133	147	*****	1
82	JK	M	40	87	103	112	123	132	149	*****	4
83	JK	F	40	83	101	111	118	140	154	*****	2
84	RZ	M	44	104	112	128	142	152	161		6

sub #	Subj	sex	age	150	300	450	600	750	900		fitnes
85	DM	F	38	103	122	142	150	161			5
86	AH	M	40	84	99	112	126	138	148	*****	3
87	NT	M	43	90	99	116	127	145	158		6
88	MA	M	40	82	97	113	128	142	161	*****	5
89	JY	M	44	84	104	123	139	155	165	*****	6
90	JC	M	38	98	105	115	127	136	145		2
91	Dt	M	36	83	90	107	115	125	140		2
92	ER	F	38	82	89	106	111	134	140		2
93	CH	F	40	112	127	141	163	177			4
94	MW	F	29	80	95	109	120	126	140		1
95	GG	F	27	82	90	101	112	128	140		1
96	VL	F	31	101	111	121	137	154	170		1
97	MM	F	36	105	116	138	161				4
98	ND	F	24	101	120	147	164	177	185		6

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