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A comparison of predicting VO2Max with two different heart rate endpoints from a sub-maximal bike test

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A Comparison of Predicting VO2Max With Two Different Heart Rate Endpoints from a Sub-maximal Bike Test

(TITLE)

BY

Chad C. Shirar

THESIS

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I HEREBY RECOMMEND THAT THIS THESIS BE ACCEPTED AS FULFILLING THIS PART OF THE GRADUATE DEGREE CITED ABOVE

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ABSTRACT

Obtaining VO_{2max} values can be valuable for both healthy and diseased populations to establish exercise prescriptions, monitor progress, and monitor overall health. Unfortunately, testing procedures to obtain VO_{2max} involve highly skilled technicians, expensive sophisticated equipment, a slight risk to the patient, and more time and more space compared to other fitness tests. The most accurate way to measure maximal oxygen uptake is by analyzing oxygen consumption and carbon dioxide production using closed-circuit gas analysis while the subjects runs or walks on a treadmill or rides a cycle ergometer. The YMCA Submaximal Bicycle Ergometer test was developed to allow the subject to work at a submaximal level to predict VO2max. This is accomplished by measuring two consecutive heart rates between 110 and 150 bpm, and plotting those heart rates against the respective workloads. The purpose of this study was to determine if continuing the YMCA test to 85% of APMHR would elicit a more accurate estimation of VO_{2max}.

Twenty-three apparently healthy subjects, ages 18-25, participated in the study. All subjects were Eastern Illinois University students, recreationally active, and engaged in at least three days per week of aerobic exercise. Testing included two testing sessions. The first test involved performing the YMCA test and continuing the test to slightly before reaching 85% APMHR. The second test was a maximal treadmill test that was performed at least five days after the

submaximal cycle ergometer test, but no longer than two weeks. An ANOVA with repeated measures was conducted to determine differences between the tests ($p > 0.05$).

The results from the test indicated that there was no difference between the YMCA test (YMCA) and continuing to 85% APMHR (85%BIKE), where $p=0.135$. There was a significant difference between YMCA and the maximal treadmill test (Max), where $p = 0.001$. There was also a significant difference between 85%BIKE and Max, where $p = 0.000$.

It was expected that continuing the test to 85% of APMHR would provide a more accurate estimation of VO_{2max}, due to these values being closer to maximal exertion. Continuing the test did not show improvement in estimation values; therefore, extending the test to 85% of APMHR is a waste of time and energy. The reason for no improvement is most likely due to no relevance of what heart rates are used when extrapolating heart rate versus workload. As long as two consecutive heart rates are between 110 bpm and 85% of APMHR, it does not affect the results if the first two heart rates after 110 bpm are used, or the last two heart rates before reaching 85% APMHR are used.

If more subjects or an updated protocol, designed for males and very fit women had been used, the results of this study might have been more significant. Further research needs to be done with a larger population to determine if there is a difference in these two protocols.

DEDICATIONS

First and foremost, I would like to dedicate this paper to my wife, Misty, for her patience and love throughout this whole process, and for following me to Charleston, to let me pursue my dream. I would also like to thank all of the undergraduate and graduate students, faculty, and staff that I have had the privilege of knowing. I am a better person for getting to know all of you better. You will all be in my thoughts and prayers.

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CHAPTER 1

INTRODUCTION

Knowledge of an individual's maximal oxygen uptake (VO_{2max}) can be an invaluable tool for fitness professionals. It allows exercise to be prescribed more accurately, as well as track progress for feedback and motivation. This number can be attained in different ways. The most commonly used methods of obtaining VO_{2max} are either from measurement of gas exchange or estimated through estimation using submaximal exercise tests. Unfortunately, the direct method requires highly trained technicians and very sophisticated and expensive equipment. Furthermore, to obtain maximal values, the subject must exercise to maximal exertion, which does increase the risk of complications during and after the test (Holmes, 1985).

There is also an assumption that the subject is working to maximal exertion, which can be subjective among individuals (Black, 1980). There is a way, however, to estimate VO2max where the subjects only exert themselves submaximally, which is much safer and can be administered with less equipment. This indirect method can utilize different modes of exercise, which allows different facilities with different equipment to take full advantage of this submaximal exercise tests to predict VO_{2max} (Stanforth, et al., 1999). These indirect methods of estimating VO_{2max} involve plotting two variables against each other. The variables most commonly used in estimating VO_{2max} are heart rate and a measurement of work (Swain, Parrott, Bennett, Branch, & Dowling, 2004). For a treadmill stress test, heart rate is plotted against speed and grade. For the bicycle ergometer, heart rate is plotted against either kilograms per minute (kgm) or watts (W). The YMCA Bicycle Ergometer Test allows the subject to exercise at gradually increasing workloads until either two consecutive workloads produce heart rates between 110 and 150 beats per minute (bpm) or a heart rate of 150 bpm is achieved. The test is then terminated. Heart rate is then plotted against the workload in kilograms per minute (kgm), and is then extrapolated to cross a horizontal line that represents the age-predicted maximal heart rate (APMHR). A perpendicular line is then drawn to obtain an estimate of maximal oxygen consumption (Swain, et al., 2004). Another option to plotting heart rates and workloads is to use regression equations, which take into account age, gender, body weight, and other individually specific data to predict VO_{2max}.

While the YMCA test protocol terminates when heart rate reaches 150 bpm, using a stopping point of 85% of APMHR would allow the subject to have a greater increase in heart rate and time of testing, which may result in submaximal values which are closer to measured VO_{2max}. A heart rate of 85% of APMHR is much closer to the subject's maximal heart rate, minimizing the effects of a high initial heart rate when only using two or three stages, as is most often used in theYMCA bicycle ergometer test. The subject will be working at a much higher work rate, but not exceeding 85% of APMHR.

Purpose of the Study

The purpose of this study was to determine if a more accurate estimation of VO_{2max} is obtained using a stopping point of 85% of APMHR on the YMCA Cycle Ergometer Test compared to a stopping point of 150 bpm in college aged subjects.

Hypothesis

Using a stopping point of 85% of APMHR will be more accurate in predicting VO_{2max}, than using 150 beats per minute as the end point of all submaximal exercise tests using the YMCA Cycle Ergometer protocol.

Limitations of the Study

1. Subjects were recruited by convenience from Eastern Illinois University.
2. Assumptions exist that heart rate and VO_2 are linear between 110-150 bpm, the prediction of maximal heart rate using 220-age is within $\pm$ 10 bpm, all subjects have constant mechanical efficiency, and there is no day-to-day variation in heart rate (Grant, Joseph, Campagna, 1999).
3. An assumption was made that each patient complied with all the directions given prior to the test.

Definition of Terms

Maximal Oxygen Consumption (VO_{2max}): The maximal amount of oxygen the body can take in, distribute, and use at a given time. This is usually expressed in either ml/kg/min or L/min (Akalan, Kravitz, & Robergs, 2004).

Maximal Heart Rate (Age-Predicted Maximal Heart Rate): The maximum frequency at which the heart can beat per minute. The most accurate value comes from a true maximal exercise test. The common equation used to estimate maximal heart rate is 220-age (Greiwe, 1993).

Steady-State Heart Rate: Two consecutive readings, taken at the second and third minute of each stage, with a heart rate no more than a 6 bpm difference (Holmes, 1985).

Mechanical Efficiency: The ability of the body to both make and utilize oxygen during physical work. This can differ between individuals or differ during different testing modes (Greiwe, 1993).

CHAPTER 2

LITERATURE REVIEW

When testing to determine how fit an individual is, having a VO_{2max} value can assist in determining if specific workout routines are effective, as well as assist with developing exercise prescriptions (Alkalan, Kravitz, and Robergs, 2004). This knowledge can also help motivate individuals to initiate an exercise program, as well as obtain documented improvements in cardiovascular fitness (Roitman, 2001). The most accurate way of determining true VO_{2max} is by performing a maximal treadmill test that measures both the consumption of oxygen and the expiration of carbon dioxide. American College of Sports Medicine (Franklin, 2000) defines a maximal effort if:

1) heart rate fails to rise with an increase in exercise intensity
2) VO_2 plateaus with an increase in workload
3) a respiratory exchange ratio ≥ 1.15 is obtained
4) attain a heart rate within $\pm$ 10 beats of APMHR
5) RPE value reaches ≥ 17

Unfortunately, the most accurate way of determining VO_{2max} requires expensive equipment, trained technicians, space, time, and involves much more risk for both the subjects and the observers (Lockwood, Yoder, and Deuster, 1997;Astrand and Rhyming, 1954; Grant, Joseph, and Campagna, 1999; Bassett and Howley, 2000; Greiwe, Kaminsky, Whaley, and Dwyer, 1995, Fitchett, 1985).

Limiting Factors

There are limiting factors, besides heredity, that can lead to good or great outcomes of a maximal VO_{2max} test. The most popular and discussed variables are: the ability of the lungs to transport oxygen to the muscle and get rid of carbon dioxide as a waste product, the oxygen carrying capacity of hemoglobin, cardiac output, which is directly effected by stroke volume, and peripheral factors, which includes extracting oxygen from hemoglobin, diffusion away from red blood cells in the muscle, and transport of oxygen from the muscle to the "powerhouse" or mitochondria. This is the final step of the electron transport chain and the site where oxygen can be utilized in aerobic work. Not one of the single limiting factors above by itself has been shown to limit VO_{2max}. They appear to work in an intricate fashion together to assist in the entire process of aerobic exercise (Warpeha, 2003).

Overview of Leg Ergometry

In addition to using the treadmill to determine VO_{2max}, leg ergometry is another method to determine maximal oxygen uptake. It has been shown to over-predict VO_{2max} by as much as 12% (Grant, et.al., 1999). One would assume that using the YMCA test would be a better predictor of VO_{2max} when compared to a maximal cycle ergometry test, but research shows that the YMCA test is just as accurate when compared to a maximal treadmill test when measuring maximal oxygen uptake (Beekley, Brechue, deHoyos, Garzarella, Werber-Zion, and Pollock, 2004). One study noted that a submaximal cycle ergometry test underestimates males by 25% and 15% in females, compared to a treadmill test, which underestimated VO_{2max} by 7% in males and over-predicted females by 15%. This study also showed that with familiarization, the cycle ergometry test stayed consistent, while the treadmill and step test varied even further from original values (Black, 1980). When calculating predicted VO_{2max}, the YMCA test uses an extrapolation method by using the first two workloads corresponding to heart rates between 110 and 150 bpm. This line is drawn to cross the subject's APMHR, then the line is dropped down to the x-axis, and VO_{2max} is determined. This method seems unnecessary when a regression equation is available that takes into account age, sex, and body weight. One study also showed that there is no difference in a cadence of 50 or 80 rpm during a cycle ergometer test, so 50 rpm was used in addition to YMCA's Y's Way to Physical Fitness recommendation of that particular cadence (George, Vehrs, Babcock, Etchie, Chinevere, and Fellingham, 2000; Golding, Meyers, and Sinning, 1989). The leg ergometer has been shown to underestimate true VO_2 due to the amount of muscle mass being utilized during the test. This test is based on the amount of work performed by the quadriceps, rather than the entire body's total aerobic capacity. ACSM states that an inter-subject variability of 7% exists when directly measuring VO_2, so estimating VO_2 will cause an even greater increase in error (Franklin, 2000). Swain, et al., 2004, evaluated 59 subjects, 24 males and 25 females, performing the YMCA protocol and found that on average, it overestimated VO_{2max} by 28%. A recent study found that a cycle ergometry test that uses a constant workload underestimated VO_{2max}, while a cycle ergometry test with progressive workloads that utilized the age-predicted maximal heart rate reflected the inherent error of age-predicted heart rate, also under-predicting VO_{2max} (Lockwood, 1997). Black states that a cycle ergometry test is not valid if steady-state heart rates are not obtained. A study has shown that if a steady-state heart rate is achieved, heart rate and workload are linear, which is a very critical factor when extrapolating heart rate, as the YMCA Cycle Ergometry Test does (Black, 1980).

The cycle ergometer is not weight bearing, and just using the legs does not give values that would determine a total body VO_2. A previous study has shown that the maximal cycle ergometry test can give maximal values much less than a treadmill (Hermansen, Ekblom, and Saltin, 1970), and using the treadmill as the mode of exercise is much more accurate (Storer, Davis, and Caiozzo, 1990;

Hermansen and Saltin, 1969; Hartung, Blanco, Lally, and Krock, 1994). One study showed a variance of VO_{2max} from the cycle ergometer of 5-25% less than VO_2 measured using the treadmill as the mode of exercise (Lockwood, et.al., 1997). This may be caused by limited use of muscle mass, which will lead to a lower heart rate, arterial pressure, total peripheral resistance, and pulmonary ventilation (Lewis, et.al., 1983).

Estimation of VO_{2max}

If performing a maximal exercise test to determine VO_{2max} is not an option due to risk, there are methods of estimating VO_{2max} (Greiwe, 1993; Margaria, Aghemo, and Rovelli, 1965). These tests include, but not limited to: treadmill tests, step tests, 1.5 mile run, 1 mile walk, cycle ergometry, flume swimming, in-line skating, arm ergometry, and wheelchair exercise (Akalon, 2004). For this study, the YMCA Cycle Ergometry Test was used to estimate VO_2 based on heart rate response to pre-determined workloads. Some advantages of a bicycle ergometer over a treadmill are: amount of space, weight of equipment, easily transportable, and less noise. Most importantly, assuming calibration is performed and accurate, the power can be adjusted and determined in smaller increments for those with lower conditioning levels as well as those with cardiopulmonary disease (Holmes, 1985). Another advantage is that increments of workloads can be more precisely controlled, while repeated measures are more easily obtained

(Proctor, et.al., 1998). The accuracy of this test varies anywhere from 10- 25% overestimation or underestimation. Beekley, et. al., 2004, did not demonstrate a significant difference of predicting VO_{2max} from the YMCA test when compared to a true maximal treadmill test. In women, there was a positive correlation between the YMCA test and the treadmill test. According the ACSM's Resource Manual using prediction equations, which we used for this study, may overestimate trained subjects and underestimate untrained subjects (Roitman, 2001). Part of the inaccuracy of the estimation of VO_2 involves assumptions that are made before the test has even begun. These include: heart rate and work rate possess a linear relationship, age predicted maximal heart rate is accurate to within $\pm$ 10 bpm, mechanical efficiency is constant, and there is no day-to-day variation in heart rate. (Grant, 1999) Previous research has noted that heart rate and VO_2 do not become linear until 110 bpm, and after the subject reaches 150 bpm, heart rate and work rate are no longer linear. External stimulus, such as talking, laughing, and irritability can affect heart rate (Rowell, Taylor, and Wang, 1964). As the heart pumps harder during exercise, external stimuli no longer have an effect on the rise in heart rate. Almost everyone tested will possess a linearity of heart rate and VO_2 up to 150 bpm (Golding, et.al., 1989). However, an additional study stated that the heart rate range of 125 to 170 is the range at where heart rate and VO_2 are linear (Astrand and Rhyming, 1954; Glassford, Baycroft, Sedgwick, and Macnab, 1964; von Dobeln, Astrand, Bergstrom, 1967). One study states that the most accurate prediction of VO_2 occurs at heart rates between 160-165, which is closer to 85% APMHR for 20 year old college subjects, than the cutoff point of 150 bpm for the YMCA Cycle Ergometry Test. This difference in heart rates is due to intra-subject variability (Greiwe, 1993). Another method of distinguishing the relationship between heart rate and VO_2 is to evaluate the relationship of VO_2R to heart rate reserve. Swain discussed that during cycle ergometry, when plotting VO_2R against heart rate reserve, the data points are not distinguishable from the line of identity when using a scatterplot diagram (Swain, et.al., 2004). This relationship was not used for this study, but could be utilized to determine a better protocol for estimating VO_{2max} from a submaximal test.

Linearity Between Heart Rate and Work Rate (VO_2)

There are problems that can occur when using the estimation method of determining maximal oxygen uptake. If the assumption of linearity between heart rate and VO_2 is inaccurate, the test results will not be valid (Fox, 1973). This may be due to the recruitment of different fiber types during the exercise test. Fast twitch motor units are recruited more at higher intensity exercise, which would affect the amount of oxygen consumed during exercise. At lower intensities, the slow twitch muscle fibers will be working more efficiently. As the intensity increases, the more fast twitch fibers will be recruited, causing a curvilinear relationship between heart rate and VO_2 (Londeree, Moffitt-Gerstenberger, Padfield, Lottmann, 1997).

Estimation of Maximal Heart Rate

The estimation of maximal heart rate of 220-age, is a well-known and much used equation that is used to determine how fast a person's heart can maximally pump. If a maximal heart rate is unknown, the 220-age method is used, which is a constant throughout all of the subjects tested. Maximum heart rate is not dependent on how well a subject is aerobically trained, and during a maximal exercise test, the improvements in maximal performance is the result of an increase in stroke volume (Warpeha, 2003). Swain noted that using the age predicted maximal heart rate is a source of error due to inter-individual variability. This study had an 8 bpm difference from predicted and actual heart rate values (Swain and Wright, 1997). Lockwood, et.al., (1997) states that there is an understood, given error in age-predicted maximal heart rate of $\pm$ 7 bpm. ACSM and the American Heart Association indicate that variation in prediction of maximal heart rate can vary as much as $\pm$ 12-15 bpm (Greiwe, 1993). Over or under-estimating maximal heart rate can affect the test results, as well as affect the safety of the exercise test and cause an inappropriate exercise training intensity when prescribing exercise (Whaley, Kaminsky, Dwyer, Getchell, and Norton, 1992). ACSM notes that although the relationship between age and heart rate for a large sample is reproducible, the variability between subjects is high, which can cause considerable error when estimating for the submaximal test (Franklin, 2000). Warpeha adds to this stating that there is a large variation in subjects' heart rate response to exercise, and that more aerobically trained subjects have a 5-7% lower heart rate response at a given workload than their deconditioned counterparts (Warpeha, 2003).

Calibration

Calibration of the cycle ergometer is a very critical step before every test to assure that the ergometer reading is showing the workload that is being utilized. This was assured before every submaximal test by using a known weight (1 kg), and hanging the weight from the site where the tension rope places tension on the wheel of the ergometer (Londeree, 1997).

Environmental Factors

The environment in which the subject is performing the submaximal test in can have a significant effect on heart rate. Astrand and Rhyming noted that exercising while dehydrated, being hypoxic, and/or in elevated temperature can all attenuate heart rate (Astrand and Rhyming, 1954). This would obviously not be feasible for this study due to heart rate being the single most sensitive measured value that will determine an accurate estimation of VO_{2max}. Rowell, Taylor, and Wang (1964) suggested that performing a submaximal exercise test in an environment with high temperatures would cause a high amount of error, and they noted that an ambient temperature of 62° F would provide the most accurate heart rate for estimating VO_2. They also noted that a relative humidity of 45-60% gave optimal accuracy during exercise. Humidity can also affect heart rate response, most likely due to a more rapid rate of dehydration, which can lead to inaccurate test results (Hermansen and Saltin, 1969). Conversely, ACSM recommends an optimal testing room temperature of 70 to 74° F (21 to 23° C) produces the most comfortable and accurate test results (Franklin, 2000). ACSM also states that heavy exercise before testing, temperature, humidity, ventilation, fever, consumption of alcohol, smoking, or caffeine intake all affect the outcome of the test (Roitman, 2001).

Positioning on the Cycle Ergometer

The position of the subject on the cycle ergometer can affect the amount of work that the muscles perform. Changes in posture can affect heart rate both at rest and during exercise. It is well known that when one changes body position from a supine to standing position, heart rate increases. The same can be said when changing positions from supine to sitting. However, Hellstrom and Holmgren, 1966, found in 48 male subjects that there is not a significant difference in heart rate while exercising in the supine position (154.6 $\pm$ 14.9 bpm) compared to sitting (156.8 $\pm$ 17.0 bpm). This implies that a decrease in stroke volume may not always correspond in an increase in heart rate (Hellstrom and Holmgren, 1966). For one particular study, subjects were evaluated to assure that the angle of knee flexion at the lowest point of the pedal circumference was 5-10°. This will assure maximal use of the legs, which will allow VO_2 to be estimated more accurately. Another study showed that a knee joint angle of 5° produced the maximum use of the quadriceps at a particular seat height (Nordeen-Snyder, 1977). ACSM affirmed that when a subject is properly positioned on the cycle ergometer, there is a 5° bend at the knee joint at maximal extension (Franklin, 2000). Each subject was evaluated to assure that maximal VO_2 would be produced, and this data was recorded to assure consistency.

Variability of Age

Age can obviously have an effect on the reliability and validity of estimating VO_2. Submaximal exercise tests are most accurate when estimating VO_2 on healthy male and females subjects ages 18 to 30. Most research evaluated these populations, and does not predict the reliability using younger and older populations, as well as those with underlying cardiac and pulmonary diseases. Possessing either cardiac or pulmonary disease would not allow the body to sufficiently make and utilize oxygen (Astrand and Rhyming, 1954). Using older subjects for this test (50-70 years old) would not allow the subjects to complete the protocol, due to the formula of 220-age. If a 70 year-old subject performed the YMCA protocol, the 150 bpm termination point of the test would be a maximal exercise test (i.e. 220-70=150 bpm). One study found fairly reliable results of only a 12% overestimation of VO_2, but this was probably due to the ages of the clients being closer to 18-30 year old range that the test most accurately utilized for (Grant, et.al., 1999). Another study with chronically trained older men aged 65 $\pm$ 2 years old versus sedentary young men aged 26 $\pm$ 1 found that even though the older men trained heavily, the ability to attain a VO_{2max} value that of the younger men, could not be reached due to the decrease in heart rate and stroke volume that occurs with age. Even with a significant increase in left ventricle size in the older men, they could not maintain cardiac output to match the younger men (Minson and Kenney, 1997). Peak VO_2 measurements occur at age 18, while women tend to reach their maximum potential at or around age 14. With normal aging, VO_2 decreases 8-10% per decade. This number is variable, and may be attributed to a decline in maximum heart rate, fat-free mass, a-VO_2 difference, and stroke volume (Akalon, 2004).

Time of Day of Exercise Testing

Performing the exercise tests at separate times of day can cause heart rate to differ. In the ACSM Resource Manual, it is noted that the time of day of testing should be kept consistent to keep the test adequately accurate and reproducible

(Roitman, 2001). Beekley, et. al., adds that exercise testing should be performed at the same time of day to prevent circadian heart rhythms (Beekley, et. al., 2004).

Subject Adherence

There are items and procedures that the subject must avoid prior to exercise testing. One of the many studies that was evaluated states that subjects should abstain from smoking at least two hours before testing and not be allowed to exercise 24 hours prior to testing (Lewis, et.al., 1983). ACSM adds to these criteria by not allowing subjects to consume food or beverages, use tobacco, drink alcohol, or consume caffeine for three hours before testing. Subjects are also not allowed to exercise vigorously the day of the test. It is also recommended and stressed to drink plenty of water for 24 hours prior to testing, and get an adequate amount of sleep prior to the day of the test. All of these factors can affect heart rate by disrupting the body's normal cycle of homeostasis (Franklin, 2000).

Body Mass

Another interesting finding was that body mass can have a direct affect on heart rate during cycle ergometry. There was a positive correlation between body mass and VO_2, which in turn, would affect heart rate. The body mass of an individual will significantly affect the estimation of VO_2, resulting in large errors.

Body mass may account for as much as 70% of the differences between subjects (Akalan, et. al., 2004). Obese subjects are known to have a higher VO_2 and lower efficiency compared to lean subjects (Berry, Storsteen, and Woodard, 1993).

Gender

The difference in gender may affect outcomes of the submaximal cycle ergometry test. End values coming from either a direct or indirect exercise test tend to favor men over women, assuming all variables are kept constant. Physiologically, men and women differ when looking at determinants of outcomes of exercise testing. Women have smaller hearts, smaller left ventricles, smaller blood volumes, and smaller lungs, which would cause an increased heart rate response during submaximal exercise. Conversely, Beekley showed in his study that when comparing genders, women had an overall lower VO_{2max} than men, but there was not a significant difference between predicted values and measured treadmill values (Beekley, et.al., 2004). Men and women do not differ when observing actual maximum heart rate. Even when power output is matched for each gender, women have a higher heart rate response. However, cardiac output does not seem to differ between the two genders. Even though women have a smaller stroke volume, their increased heart rate response allows their cardiac output to keep up with their male counterparts. Women also have a lower hemoglobin level than men, due to possessing lower testosterone levels than men, which could deter the ability of women to carry oxygen as frequently and efficiently as men, resulting in a lower VO_{2max} value. Stroke volumes at submaximal levels are also shown to not differ significantly in the two sexes (Bassett and Howley, 2000). Keep in mind though that because of women having smaller hearts and lower plasma volume, they are working at a higher percentage of their VO_{2max} than men at a given workload (Akalan, et. al., 2004). Differences in respiratory responses for men and women are due to differences in body size. On average, men tend to have a VO_{2max} value 25 –30 % greater than females (Wilmore and Costill, 1999).

Conclusion

In conclusion, the YMCA Submaximal Cycle Erometry Test appears to have mixed variability when determining the accuracy of predicting VO_{2max} when compared to a true treadmill VO_{2max} test. There are many physiological and environmental factors that can affect heart rate, which is a very sensitive parameter when performing the YMCA test. This study will determine whether or not continuing the YMCA test to slightly before reaching 85% of APMHR, will be a better determinant of treadmill VO_{2max} than the traditional YMCA test. For this test, the last two workloads before reaching 85% of APMHR were used, instead of the first two workloads between 110 and 150 bpm.

CHAPTER 3

METHODOLOGY

The purpose of this study was to determine if a stopping point of 85% of age-predicted maximal heart rate on the YMCA Cycle Ergometer Test, would estimate VO_{2max} more accurately than using a stopping point of 150 bpm for college-aged men and women.

VO_{2max} values are very important in determining both starting points for exercise prescription and monitoring progress of a specific exercise program. Maximal exercise testing elicits the most accurate data for use, but the test itself and the risks do not make the test practical for the common exerciser. On the other hand, submaximal exercise testing does not require sophisticated equipment, highly trained technicians, and presents much less risk for both the subject and the technician.

Subjects

For this study, the subjects being tested were college aged males and females, ages 18-25. All subjects were Eastern Illinois University students. Subjects had different fitness levels, but they were all active through their own exercise program or through recreational programs.

Test Procedures

All subjects were required to attend an orientation that described in detail the procedures of the tests including the risks and benefits. Each subject was given the opportunity to ask questions and discuss any concerns before the tests were administered. They were also instructed to abstain from alcohol, tobacco, and caffeine for at least three hours prior to the test. No exercise was allowed 24 hours prior to test. To ensure proper hydration, all subjects were asked to drink plenty of fluids within 24 hours prior to the administration of the test. All subjects were given an informed consent (Appendix A) outlining the procedures, risks, and benefits of both the maximal and submaximal exercise test. A health history questionnaire (Appendix B) was filled out by the subjects to risk stratify the subjects according to primary risk factors and signs and symptoms of cardiac and pulmonary diseases. All subjects were purposely chosen as low risk, so that a physician would not need to be present during the maximal exercise test. The temperature of the room where both tests were administered was maintained at 70-74°F (21-23°C), to ensure that the subject was comfortable.

Both the cycle ergometer and metabolic cart were calibrated the day of the test to ensure proper data collection. All subjects performed the submaximal cycle ergometer test first. The second test, which was the maximal treadmill test, was performed at least five days after the submaximal test, and at the same time of the day. Time of day was classified into three separate time periods: morning from

6am to 11am, mid-day from 11am to 4pm, and evening from 4pm to 9pm. These were established so a general time of day was generated to keep the results consistent.

YMCA Submaximal Test

The submaximal test was administered on the Monark Cycle Ergometer (Ergomedic 828 E). Subjects were instructed to pedal at a frequency of 50 revolutions per minute (rpm) throughout the entire test. Pedal straps were not used for any subjects, and they were instructed to pedal with the balls of the feet on the pedals. Seat height was adjusted so that leg flexion was 5-10° to ensure the subject was able to obtain maximal use of the quadriceps. The subject was instructed to maintain an upright posture throughout the test, with no leaning forward on the handlebars. The subject was able to use the palms of the hands to maintain posture, but only at the top of the handlebars, closest to the subject's body.

Heart rate was measured pre-exercise to establish resting values, using the Polar YMCA20 model. The subjects were seated quietly and relaxed in a seated position for five minutes before obtaining resting values. For the submaximal cycle ergometer test, the YMCA Cycle Ergometer Protocol was used (Golding, et.al., 1989). The beginning and progression of the protocol is demonstrated in Figure 1.

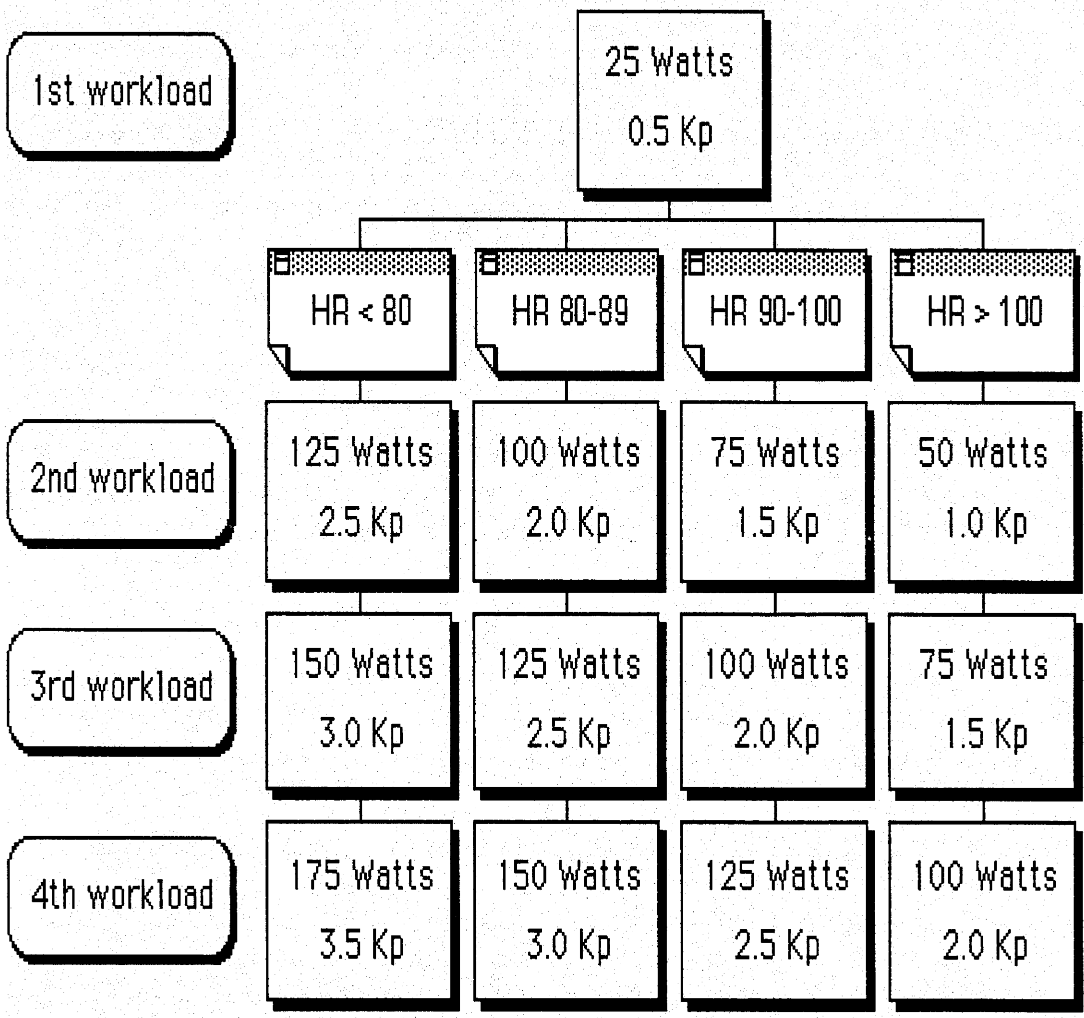

Figure 1: YMCA Protocol

The first workload of 0.5 kp was used as an initial warm-up period, and heart rate values from this workload were used to establish the increment of increase in kp during the second stage. The subject was instructed to pedal at 50 rpm throughout the test. Heart rate was taken after the 2^{nd} and 3^{rd} minute of each stage. Steady state heart rate must have been maintained before proceeding to the next stage. If steady state heart rate was not achieved between the 2^{nd} and 3^{rd} minute, another minute was added to the stage. Then, the difference of heart rate between the 3^{rd} and 4^{th} minute was used to determine steady state heart rate.

Through this progressive increase in workload of 0.5 kp at each stage, two vital points were valuable to the outcome of this study. The first vital point was the value of the workload at 150 bpm, which is where the literature states that heart rate begins to increase at a non-linear rate with an increase in workload (Golding, et.al., 1989). When plotting the heart rates against workloads, the first two heart rates that fell between 110 and 150 bpm were used. The second critical point was recording the last two heart rates and workloads before 85% of age-predicted maximal heart rate (APMHR) was obtained. The predicted VO2max values from these points were compared against a true maximal test to determine which stopping point is more accurate at estimating VO_{2max} from a submaximal exercise test.

After the submaximal test, the heart rates and workloads were entered into a convenient and fast regression formula provide by a website dedicated to exercise prescription: www.exrx.net/Calculators/YMCACycle.html, (Beekley, et.al., 2004). This regression equation makes each test specific for each person, due to taking into account sex, age, and weight. Although METs and percentile rankings were given, these values were not used for analyzing data, but for general knowledge.

Maximal Treadmill Test

The final test that the subjects performed was a maximal graded exercise test on a Marquette Series 2000 treadmill using the Bruce Ramp protocol. As with the YMCA test, resting values of heart rate were obtained using a heart rate monitor (Polar S20). Even though the subjects were informed of the Borg RPE scale during the orientation, procedures were repeated as to how to give feedback on RPE values. Heart rate and RPE were taken every minute throughout the test. The subject was then fitted to an open circuit breathing system that assessed the subjects' VO_2 using a Sensormedics 2900 series metabolic cart. Subjects were instructed to straddle the treadmill before the treadmill belt began to move. Holding on to the rails on the treadmill was not allowed, as it assisted the subject, which would not give accurate values for VO_2. Swinging of the arms was encouraged to help with walking against the grade of the treadmill. The subject was informed of a gradual speed and grade increase during the test. Assurance of subject overall wellness was assessed periodically throughout the test by the technician asking the subject if he/she was feeling normal, considering the physical stress of the treadmill test. After the subjects reached volitional fatigue and the test was stopped, a cool-down period at approximately 2 mph was performed for at least 5 minutes, with the breathing apparatus removed. To determine if the test was truly a "maximal" test, three of the four following criteria had to be met: RPE of ≥ 17, respiratory exchange ratio (RER) of ≥ 1.10, achieving APMHR, and a failure of increased heart rate despite an increase in workload (Franklin, 2000).

Data Analysis

After attaining the values from both workloads during the YMCA test and the values from the maximal test, the submaximal values were compared to the maximal values for VO_{2max} to test the hypothesis that the predicted VO_{2max} value from 85% of maximal heart rate gives a better estimate of the true maximal VO_2 from the treadmill test, than using the predicted VO_{2max} from using a stopping point of 150 bpm. An ANOVA with repeated measures was conducted ($p < 0.05$).

CHAPTER 4

RESULTS

The purpose of this study was to determine if continuing a YMCA Submaximal Cycle Ergometry Test to 85% percent of age-predicted maximal heart rate would elicit a more accurate estimation of VO_{2max} than using a stopping point of 150 bpm. Instead of using the first two consecutive workloads that correlate with two consecutive steady state heart rates between 110 and 150 bpm and extrapolating those two data points to predict VO_{2max}, this study used the last two workloads that correlated with the last two consecutive steady state heart rates before reaching 85% of APMHR. Estimating VO_{2max} is a widely used tool when prescribing exercise, monitoring progress, and determining fitness levels in both healthy and clinical populations. There are a variety of modes of exercise that are used when performing exercise testing. The most common of these are the treadmill and cycle ergometer. As stated in numerous research findings, usage of a submaximal exercise test is much safer, less time consuming, requires much less expense, takes up less space, and does not require technicians with a strong exercise physiology background. It has been shown to have various amounts of error, depending on when and where the research was conducted. Some studies show that the YMCA test overestimates (Grant, et.al., 1999, Swain, et.al., 2004), while some shown an underestimation (Black, 1980), and some show that the YMCA test is accurate (Beekley, et.al., 2004).

Subject Descriptives

Twenty three subjects (14 male, 9 female) participated in the study. Descriptives for these subjects are shown in Table 1.

Comparing Both Submaximal Cycle Tests

When comparing the two submaximal cycle tests, there was no significant difference, ($t(1,22) = 1.553$, $p=.135$), between the two tests (Table 2). This implies that as long as the steady state heart rates are between 110 bpm and 85% APMHR, the ability to estimate VO2max is not affected. In this study, using 85% APMHR is just as inaccurate as using the traditional YMCA protocol. Therefore, continuing the test beyond a heart rate of 150 bpm is a waste of time and energy when estimating VO_{2max}.

Table 1: Subject Characteristics

	Men and Women (N=23)		Men (N=14)		Women (N=9)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Age	19	1.2	21.2	1.1	21.7	1.5
Weight (lbs.)	162.7	34.5	179.4	34.1	136.9	12.1

Table 2: Submaximal and Maximal Tests by Gender

	Men (N=14)		Women (N=9)	
	M	*SD*	*M*	*SD*
YMCA	42.6	8.0	38.8	5.7
BIKE85%	39.5	8.0	38.8	3.9
Max (ml/kg/min)	47.0	6.7	42.2	2.2

YMCA Cycle Erometry Protocol vs. Maximal Treadmill Test

There was a significant difference (t(1,22) = 3.676, p = .001), between YMCA and Max using all subjects. Overall, the average predicted VO_{2max} for YMCA was 41.1 ml/kg/min while the average VO_{2max} for Max was 45.1 ml/kg/min. According to these measures, YMCA underestimates VO_{2max} by 8.7% for all subjects. This error is rather small when compared to previous literature. While Beekley (2005) showed no significant difference between the YMCA test and the maximal treadmill test, other studies have shown an underestimation of 10-25% (Proctor, et.al., 1998), an overestimation of 12% (Grant, et.al., 1999), and an underestimation of 7% in males and 15% overestimation in females (Black, 1980). Swain, 2004, found an overestimation of as much as 28%. The results of this study showed an 8.9% underestimation, which does not vary as much as some of the previous studies, but did significantly differ from Max.

85% APMHR Stopping Point vs. Maximal Treadmill Test

The difference, (t(1,22) = 5.385, p = .000), between BIKE85% using the last two heart rates and workloads before reaching 85% APMHR and maximal treadmill test, was even greater than using YMCA, but still significant. BIKE85% underestimated all subjects' VO_{2max} by an average of 13%, which is similar to the deviation found in the literature (Black, 1980 and Franklin, 2000). The mean value for BIKE85% was 39.3 ml/kg/min compared to a measured maximal treadmill mean value (Max) of 45.1 ml/kg/min.

Gender Differences

This study did show a few gender specific differences that should be addressed. When comparing YMCA and BIKE85% for men, there is not a significant difference, ($t(1,13) = 1.886$, $p = .082$), as shown in Table 2. There was a significant difference ($p < .05$) between both YMCA, ($t(1,13) = 2.786$, $p = .015$), and BIKE85%, ($t(1,13) = 4.711$, $p = .000$), compared to Max. This difference from Max is similar to the research mentioned earlier. When comparing YMCA and BIKE85% for women, however, there was almost no difference between YMCA and BIKE85% ($t(1,8) = .022$, $p = .983$), but both submaximal tests were significantly different from VO2max, YMCA = $t(1,8) = 2.423$, $p = .042$; and BIKE85% = $t(1,8) = 3.977$, $p = .004$. This also appears to confirm previous studies that women tend to have both lower predicted VO_{2max} from cycle ergometry, as well as lower true maximal VO_2, when compared to age-matched men with estimated similar activity levels, and in absence of cardiopulmonary disease.

Summary

This study did not find a significant difference ($t\,(1,22) = 1.553$, $p = .135$), between YMCA and BIKE85% in estimating VO2max. Therefore, continuing the YMCA test to 85% of APMHR is not necessary to determine a more accurate estimation of VO_{2max}. Neither women nor men showed a significant difference between YMCA and BIKE85% with, $t(1,8) = .022$, $p = .983$, for women and, $t(1,13) = 1.886$, $p = .082$ for men. Utilizing the YMCA protocol for college-aged, recreationally active, males and females appears to estimate VO_{2max} with a similar degree of error as found in previous studies (Black, 1980).

CHAPTER 5

SUMMARY, DISCUSSION, CONCLUSION, AND RECOMMENDATIONS

The purpose of this study was to determine if there is a difference between using a stopping point of 150 bpm or 85% of APMHR to estimate VO_{2max}. The subjects were 23 Eastern Illinois University affiliated healthy persons (14 male, 9 female). The average age for all 23 subjects was 21.4 ± 1.2, and average weight was 162.8 lbs ± 34.5. All of the data was collected during the fall semester, 2004 in the Exercise Physiology Laboratory at Eastern Illinois University in Charleston, Illinois. The order of testing of subjects was random, with the submaximal tests being performed first, followed by the maximal treadmill test. Minimum time between testing for both the submaximal test and maximal test was 5 days, and maximum time between tests was 14 days.

Summary of Major Findings

This study investigated whether or not continuing the YMCA test to just before reaching 85% APMHR would be a better estimation of true maximal VO_2 measured by open-circuit spirometry.

Overall, there was no significant difference ($p= 0.135$) between YMCA and BIKE85%. For the men, YMCA was significantly higher than BIKE85%

(p=0.082) between the two tests, and the women's estimated VO_2 were virtually identical (p=.983). Predicted VO_{2max} (ml/kg/min) values overall were 41.1 ml/kg/min for YMCA, 39.3 ml/kg/min for BIKE85%, and measured VO_2 was 45.1 ml/kg/min. When separating genders, the men's VO_{2max} was 42.6 ml/kg/min, 39.5 ml/kg/min, and 47.0 ml/kg/min for YMCA, BIKE85%, and Max, respectively. Men's mean age (N=14) was 21.2 $\pm$ 1.1 years, and weight was 179.4 $\pm$ 34.1 lbs. However, the women did not show the same relationship as the men. VO_{2max} values for women were 38.8 ml/kg/min, 38.8 ml/kg/min, and 42.2 ml/kg/min for YMCA, BIKE85%, and Max, respectively. The mean age for women (N=9) was 21.7 $\pm$ 1.5 years and mean weight was 136.9 $\pm$ 12.1lbs. Both tests were significantly different from true VO2max for both men (p=0.000 for YMCA and p=0.015 for BIKE85%) and women (p=0.042 for YMCA and p=0.004 for BIKE85%).

Discussion

The purpose of this study was to make an attempt to achieve a more accurate prediction of VO_{2max} from the YMCA Submaximal Cycle Ergometry Test. Attaining accurate VO_2 results is a critical step in deciding proper exercise frequencies and intensities for both healthy and diseased populations. Obviously, the most accurate way of obtaining is through a true maximal exercise test, with measured breath-by-breath analysis. This method possesses much higher risks for both the client and the investigator, compared to a submaximal test. The amount of training of the technician, time of familiarization of subjects, total amount of space, and actual cost of equipment and time is much less with a submaxmial cycle ergometer test, compared to a maximal treadmill test. The number of subjects that an investigator can test in a given time is much more not only due to the factors listed above, but the amount of time needed to complete a single submaximal test is much less also assuming the protocol is followed accurately. There are problems with submaximal exercise testing that can affect the outcomes of prescribing exercise, analyzing aerobic improvements, and simply giving feedback on current fitness levels for baseline purposes. A few errors that can lead to inaccurate initial exercise prescriptions include: inaccurate estimation of maximal heart rate based on the 220-age formula, not following protocol precisely, external stimuli that can cause an increase in resting or submaximal heart rate, or environmental factors, just to name a few. Heart rate is such a sensitive part of the end values of VO_{2max} that the smallest amount of errors from any of those listed above can lead to an over or underestimation of maximal oxygen uptake. This study did account for all of these factors, but continuing on the YMCA test to slightly before 85% age-predicted maximal heart rate appears to be a waste of time and effort. This may have occurred due to the fact that the original test was based on steady state heart rate. Whether the two heart rates that are used for plotting against workload are very close to 110 bpm or 85% of age-predicted maximal heart rate does not appear to affect the outcomes when plugging the data into a nomogram that even takes into consideration age, weight, and sex. The women had almost identical values on the YMCA and BIKE85% tests, while the men did not have a significant difference, (t (1,13) = 1.886, p=.082), between the submaximal tests. They were both significantly different from true maximal value. In men, the original YMCA test appeared to be a better predictor of true maximal values than the BIKE85% test, but still significantly different.

Recommendations

When making recommendations for further research, the first issue that needs to be addressed is the number of subjects that were analyzed for the study. There were only 23 subjects, 14 male and 9 female. This was initially designed to validate that the YMCA test was not accurate when estimating VO_{2max}. Adding to that, allowing a subject to continue the test to just before reaching 85% APMHR, would hypothetically estimate VO_2 more accurately, due to the subject's heart rate and workload approaching maximum. If a much larger number of subjects were used for this study, it is hypothesized that the outcomes would alter the relationship between YMCA, BIKE85%, and Max. If 100 or more subjects were used, it would be a more accurate prediction of how well continuing the YMCA would predict VO_{2max}, being that it is much more representative to the population.

The second issue to be addressed for future research on this topic, is to address different age groups. The original Astrand and Rhyming nomogram was validated with healthy subjects ages 18-30, leaving out a large number of participants that might possibly benefit from a submaximal exercise test. This would include teenagers, middle-aged persons, and the elderly. Analyzing teenagers would provide a large gap between the 150 bpm threshold and 85% APMHR. It would be interesting to distinguish the difference between college-aged males and females and middle-aged people, ages 25-50 roughly. One could look at the differences in how aging affects outcomes of the submaximal test, taking into consideration how VO_{2max} tends to decrease with age, despite aerobic training. One problem that occurs with the elderly is that if the subject is 70 or older, their APMHR would be at the 150 bpm cutoff point for the test, which would be a maximal effort. It would be interesting to observe how accurate the APMHR method is with subjects of that age group.

Next, using updated protocols, provided by www.exrx.net website may give more accurate VO_{2max} predictions due to it giving two separate protocols for the YMCA test. The first protocol, which is designated for women and unfit men, uses the typical YMCA protocol. The second, for men and very fit women, has different set stages depending on heart rate response. It is not stated as to what the cutoff points are for "unfit" men and "very fit" women. This protocol is shown in Figure 2.

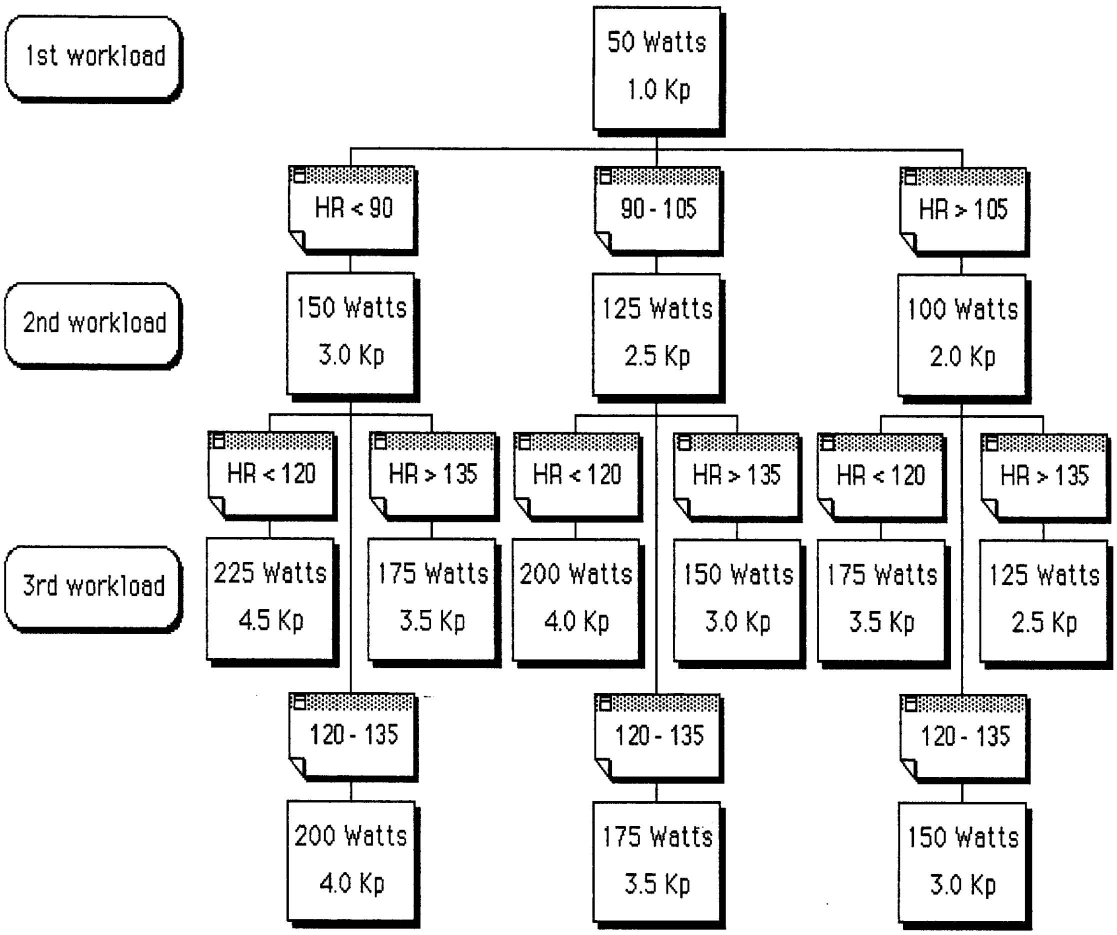

Figure 2: YMCA Protocol for Men and Very Fit Women

Lastly, the issue of heart rate reserve could be utilized in future studies. Swain, et.al., 2004, found that when comparing heart rate and VO_2, heart rate reserve, which takes into consideration resting heart rate, shows no difference at a given workload when compared with VO_2 reserve, rather than straight VO_2. In other words, using 70% heart rate reserve instead of 85% of APMHR, might give more accurate cutoff points for each subject instead of utilizing the 150 bpm cutoff point for the submaximal cycle ergometer test.

Conclusions

When determining what to take away from this study, the first and most important concept to grasp is that regardless of workload and heart rate, as long as the heart rates used in either the extrapolation method or regression equations are between 110 bpm and 85% of APMHR, the results will not differ significantly in college-aged males and females. In other words, whether using heart rates of 112 and 120 versus heart rates of 155 and 166, the difference in predicting VO_2 will not classify a specific individual in different classes (average, below average, etc.). This is an interesting finding due to much data stating that the YMCA test has a high amount of error. Most of the error is caused initially by the estimation of maximal heart rate. The 220-age prediction has been shown to have a variance of anywhere from $\pm$ 8-20 bpm, which is a significant difference when conducting research on college-aged subjects. It would be interesting to observe this same study with both a large number of subjects and using the alternative protocol shown in Figure 2. The VO_2 reserve method versus heart rate reserve might not show much difference, but in addition to the changes stated above, the results might show that there is a difference when using the two intensities as stopping points.

Even though a difference exists between the two sexes, when analyzing the two sexes together, there appears to be no significant difference between the two submaximal tests. However, there is a significant difference between YMCA and Max, and BIKE85% and Max, indicating that the YMCA test does vary when estimating VO_{2max}. YMCA showed a correlation of 0.699 to Max, while BIKE85% showed a correlation of 0.650 when compared to a measured maximal treadmill test.

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APPENDIX A

Informed Consent

I,___________________, have been told that I will perform a series of Health and Physical Fitness Assessment tests designed to aid in my understanding of my own health and physical fitness as well as enhance my understanding of these concepts. I understand that I have the freedom to withdraw from the testing at any time with no penalty. I also understand that I am free to ask any questions that may arise at any time and will have those questions answered to my satisfaction. Should any emergency arise during the testing, I understand that I may contact Mr. Chad Shirar with my concerns.

I have been told that I will perform a series of procedures and test including a Health History Questionnaire, measurement of resting and exercise blood pressure, height weight, sub-maximal cycle ergometer test, and a maximal treadmill test for cardiorespiratory fitness.

There are few risks associated with these procedures and tests. The Health History Questionnaire involves no risk, as it is a pencil and paper test. I understand that after filling out the Health History Questionnaire, I may not be tested due to the results of the questionnaire to ensure my safety. It has been explained to me that there is little risk with having my blood pressure, weight, and height measured. The sub-maximal cycle ergometer test does involve near maximal exertion on my part, and the maximal treadmill test does involve maximal exertion. Therefore, there is some risk associated with these test. The most likely even to occur immediately after or within the first few hours after the tests is local muscle soreness in the lower legs and knees. This should subside with time. I will report any and all signs and symptoms that I may have to Chad Shirar. I understand that all of my personal health and physical fitness data will be kept confidential. I am volunteering for these procedures and test. I have read this form and understand both the form and the explanations given to me.

_____________________________   __________________

Signature   Date

_____________________________   __________________

Witness   Date

APPENDIX B

Eastern Illinois University - HHQ

Name - Date – Birthdate –

Address –

Phone Number – SS# -

Doctor/Address –

Current Medications (Please List Name, Dosage, and Reason for Taking)

Allergies (Please List)

Health History

Have you or any of your family members had the following: (Please describe)

Heart Attack	Yes____	No____	Explain -
High Cholesterol	Yes____	No____	Explain –
High Blood Pressure	Yes____	No____	Explain –
Stroke	Yes____	No____	Explain -
Heart Operation(s)	Yes____	No____	Explain –
Blood Vessel Disease	Yes____	No____	Explain -
Pulmonary/Lung Disorder	Yes____	No____	Explain -
Diabetes(Type 1 or 2)	Yes____	No____	Explain –

Arthritis	Yes____	No____	Explain -

Present Symptoms

Have you recently experienced any of these: (Please explain)

Chest Pain or Tightness	Yes____	No____	Explain -
Indigestion	Yes____	No____	Explain -
Shortness of Breath	Yes____	No____	Explain -
Coughing up Blood	Yes____	No____	Explain -
Blood in Urine or Feces	Yes____	No____	Explain -
Frequent Headaches	Yes____	No____	Explain -
Stiffness or Pain in Joints or Bones	Yes____	No____	Explain –

Health Concerns

Any hospitalizations in the past year?	Yes____ No____ Explain -	
Have you seen your doctor in the past year?	Yes____ No____ Explain –	
Do you currently smoke?	Yes____ No____ How much? -	
Did you ever quit smoking?	Yes____ No____ If yes, when? -	
Do you currently drink alcohol?	Yes____ No____ How much and what kind?	

Do you currently engage in regular exercise? Yes____ No____
What type? -
How many days? -
How many minutes/day? -

Are you short of breath during exercise? Yes____ No____
Does it alleviate with rest?

I have reviewed the above information. It is complete and accurate to the best of my knowledge.

____
Participant Signature

____
Date

____
Witness Signature

____
Date

APPENDIX C

Raw Subject Data

Subject #	YMCA	BIKE85%	M	Age	Weight	Sex
2	37.5	35.11	47.57	22	209.5	M
3	47.92	46.63	42.39	22	133	M
4	35.01	40.19	41.65	21	117	F
5	44.15	42.29	56.49	20	138	M
6	39.95	33.47	45.31	22	169.5	M
7	37.27	37.62	43.71	19	218	M
8	34.19	28.9	33.64	21	254	M
9	50.57	59.78	57.66	21	155	M
10	37.56	37.91	48.32	22	164	M
11	43.74	43.21	47.89	20	157	M
12	35.93	31.9	38.56	22	138	F
13	56.63	44.83	54.6	21	148.5	M
15	41.91	38.12	42.18	21	136.5	F
16	35.7	33.61	45.27	21	201	M
17	38.23	40.59	43.36	25	147.5	F
18	32.54	29.4	41.68	21	195	M
19	50.47	43.49	44.8	23	155	F
20	57.86	41.06	53.31	22	175	M
22	40.6	39.79	40.49	23	194	M
23	40.95	43.09	44.52	21	134	F
24	30.47	34.94	39.5	21	148	F
25	35.57	40.88	41.36	20	123	F
27	40.58	36.24	43.98	21	133	F