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Validity and reliability of the YMCA submaximal cycle test using an electrically braked ergometer

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Validity and Reliability of the YMCA Submaximal Cycle Test Using an Electrically Braked Ergometer

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Abstract

Purpose: To test the effect of using an electrically braked ergometer on the validity and reliability of the YMCA submaximal cycle test. ***Methods:*** 22 male and 13 female subjects ages 19 to 31 completed one maximal treadmill test and four submaximal cycle tests to measure and estimate VO_{2max}, respectively. The maximal tests involved recording heart rate and VO_2 during graded exercise until volitional fatigue; an actual max was verified when two out of the following criteria: respiratory Exchange Ratio > 1.1, VO_2 plateau (< 150 ml/min increase in VO_2 during final stage), and achievement of 90% age-predicted HR max (or completed a validation stage). The submaximal tests were conducted in accordance with ACSM guidelines (10th ed.). Measured and predicted VO_{2max} measurements were compared between tests using repeated measures ANOVA and Pearson correlations. ***Results:*** The treadmill VO_{2max} protocol yielded significantly higher values (50.3 ± 7.7 mL/kg/min) than the YMCA submax protocol using a friction-braked (40.8 ± 5.5 mL/kg/min) and electrically braked ergometer (38.8 ± 4.5 mL/kg/min). Furthermore, estimated VO_{2max} using the friction-braked ergometer was higher than that observed using the electrically braked ergometer. There were similar reliability coefficients between the friction-braked (R = 0.63) and electrically braked (R = 0.52) ergometers. Lastly, a moderately strong (R = 0.74) relationship was observed between actual VO_{2max} and prediction error (VO_{2max} - estimated VO_{2max}). ***Conclusion:*** Both Monark and Viasprint ergometers severely underestimated VO_{2max} in a sample of generally fit, young individuals. Future investigations should explore the possible relationship between higher aerobic fitness and accuracy of predicting VO_{2max} via HR response.

Keywords: YMCA Submaximal Cycle Test, cycle ergometry, electrically braked ergometer, validity, reliability, VO_{2max}, indirect calorimetry

Chapter I

Introduction

When assessing cardiovascular fitness, VO_{2max} (oxygen utilization rate relative to body weight,) testing is widely accepted as the criterion measurement[1]. Endurance training can increase aerobic fitness in both older, sedentary[2] and young, healthy adults, typically following a dose-response curve according to current fitness level.[3] By extent, assessing VO_{2max} can provide information reflecting current fitness status and can also serve to chronicle improvements due to a training regimen.

VO_{2max} is also linked to risk factors for metabolic and cardiopulmonary diseases.[4] Specifically, peak aerobic capacity is associated with biomarkers such as body fat distribution, high density lipoprotein (HDL) cholesterol, low density lipoprotein (LDL) cholesterol, and insulin sensitivity,[5] and also has been proposed to be the best predictor of postoperative cardiopulmonary complications after surgical resection in lung cancer patients.[6,7] Significant correlations exist between VO_{2max} and fat free mass ($r = 0.37$), body mass index ($r = -0.32$), and, most notably, body fat percentage ($r = -0.75$).[7] One study noted significant differences in 10-year CVD risk, HDL, systolic blood pressure, C-reactive protein, insulin resistance, and fibrinogen, among subjects with rheumatoid arthritis who were grouped into aerobic fitness categories based on control-tested VO_{2max} levels.[8] Lastly, a 15% difference in VO_{2max} has been observed between high- and low-risk individuals for insulin-resistance syndrome (IRS) and/or type II diabetes mellitus (T2DM), with an inverse correlation existing between maximal aerobic capacity and a homeostatic model assessment for assessing β-cell function and insulin resistance ($r = -0.30$, $p < 0.0001$).[9] When screening for non-communicative diseases, VO_{2max} could serve as an important biomarker of consideration due to its relationship with associated risk factors for important factors for metabolic as atherosclerosis.[10]

Submaximal Cycle Ergometer Protocols (validity and reliability of both Astrand and YMCA). VO_{2max} is directly assessed using a metabolic cart that analyzes gas exchange as the participant performs graded exercise until volitional fatigue. However, due to the financial expense of this type of equipment, the physical stress associated with a maximal intensity exercise test, and the potential danger to certain populations, a submaximal test is often administered to predict VO_{2max} rather than measure it directly.

Submaximal cycle ergometer protocols involve pedaling at prescribed workloads and using heart rate as a surrogate for oxygen uptake (VO_2). Two well-known protocols are the Astrand and YMCA bike tests. Since its development in the late 1980's, the YMCA submaximal cycle test has become one of the most common indirect methods to estimate VO_{2max}. The test involves a participant pedaling on a stationary bike at a constant rate, with multiple stages of increasing power outputs. This protocol has been suggested to be an adequate predictor of VO_{2max} for the general population[11,12] and in physically active individuals.[13] Additionally, submaximal cycle protocol predictions have shown to have high intrasubject test-retest reliability, as well as significant correlations (r = 0.66-0.80) with results attained using a maximal cycle ergometer test administered on stoke patients.[14] However, it has also been observed that the YMCA cycle ergometer test underestimates VO_{2max} across a range of aerobically fit individuals[15] and collegiate athletes[16] while the Astrand protocol accurately estimated VO_{2max} in the latter study.[16] Similarly, the YMCA test has slightly underpredicted VO_{2max} in samples containing both males and females who averaged around 50th percentile,[17] but to a similar degree as the Astrand protocol.[18] Conversely, YMCA bike test protocols have resulted in overestimated VO_{2max} values with low to modest[19] or inconsistent test-retest reliability.[20] Potential reasons for low reliability include daily fluctuations in physiological responses to exercise, as well as biologically and technologically induced variation between direct VO_{2max} tests. One investigation saw significant day-to-day coefficients of mean variation in minute-oxygen consumption (4.42%) and minute-ventilation rate (3.86%) as participants cycled at 100, 150, and 200 W.[21] Furthermore, another study calculated biological plus technological error to result in 5.6% variability across 80 total maximum aerobic power tests across five trained subjects, with biological (individual) variability accounting for at least 90% of this sum.[22] Overall, a consensus for the practical accuracy and precision of the YMCA bike test in predicting maximal VO_2, either across the general population or for any specific demographic, has not yet been established.

Sources of Error-YMCA Test. Potential variability associated with the YMCA test could be due to a number of factors. First, predicting maximal heart rate will not always yield valid estimations, as the respective calculation (HR_{max} = 220 - age) has an accepted margin of error of at least plus/minus 10 bpm.[23] Additionally, this calculation tends to overestimate and underestimate max heart rate for individuals older and younger than ~40 years of age, respectively.[24]

Next, cycling efficiency may not be equivalent across all individuals. However, while some evidence exists for a difference in gross mechanical efficiency at certain workloads based on training status,[25] multiple studies have recorded no relationship between cycle ergometer efficiency and cycling experience,[26] even between world-class and recreational cyclists.[27]

Further, short-term variations in heart rate occur in healthy individuals due to baroreceptive biofeedback that occurs with inhalation and exhalation, which increases and decreases contraction rate, respectively.[28] The within-subject variability of heart rate has averaged 3.2% of the mean steady-state response at submaximal power outputs on a cycle ergometer,[29] which could equate to a modest, but significant variability in heart rate during incremental exercise. However, despite these factors, it has been suggested that the YMCA submaximal cycle ergometer protocol has the potential to accurately assess aerobic fitness so long as pre-screening guidelines are followed.[30]

Although a linear workload-heart rate relationship up to an intensity that elicits 85% maximum predicted HR is assumed for the ACSM protocol, a graphical deflection point prior to this estimated workload would serve as another potential source of error. One of the first studies to assess an intensity-heart rate relationship had runners increase speed progressively, and found that a mean HR-speed delineation occurred near anaerobic threshold.[31] Additionally, heart rate and lactate thresholds, when assessed using computerized breakpoint analysis between HR or lactate concentration and power output during incremental cycle ergometry, were not significantly different.[32] However, the degree of heart rate deflection and its relationship with lactate turnpoint ("second lactate threshold") are highly dependent on the protocol used, and not all studies report 100 percent consistency.[33] Overall, since a potential relationship between HR deflection and lactate threshold exists (with high inter-subject variability), coupled with the fact that many individuals, particularly sedentary or detrained, often reach lactate threshold at intensities below 85% maximal heart rate,[34] a non-linear heart rate vs. workload relationship may induce some error when using the YMCA cycle ergometer protocol.

A final consideration pertaining to the predictive strength of the YMCA submax test is the dependence on the participant maintaining a consistent power output throughout the durations of multiple trials.[30,35] Although the protocol requires participants to maintain a consistent cadence of 50 rpm, it may be surmised that that pedaling above and below this rate results in under- and overestimated VO_{2max} respectively. Theoretically, this could be corrected by using electrically braked stationary cycles, which are designed to stabilize power output by automatically adjusting pedal resistance with fluctuating pedaling rates in order to maintain a consistent work-rate. However, no studies have established whether or not the use of electrically braked ergometers improves validity and/or reliability of the YMCA submax test. Therefore, the purpose of the current investigation is to determine the validity and reliability of the YMCA protocol using both electrically braked and friction-braked ergometers.

Chapter II

Methods

Participants. Twenty or more people between the ages of 18 and 40 will be recruited from JMU and surrounding communities via social interaction, approved fliers, and electronic mail. Participants will be free from known cardiovascular, metabolic, pulmonary or renal disease as well as signs/symptoms of these conditions.

Protocol. Participants will complete one maximal treadmill test and four submaximal cycle tests to measure and estimate VO_{2max}, respectively, all of which will be completed within a three-week period. Subjects will have been advised to refrain from food, caffeine, or nicotine three hours prior to each trial in concordance with The American College of Sports Medicine guidelines.[30] Furthermore, all trials for each subject will take place at the same time of day.[36]

Treadmill Maximal Test. The participant will begin the test at 2.5 mph. The speed will be increased by 0.5 mph every one-minute interval until 6.0 mph is reached. Every minute thereafter, grade will be increased by 3.0% until the subject reaches exhaustion. Throughout the test, heart rate and expired gases will be monitored using a Polar Electro heart rate monitor and a Parvomedics metabolic measurement cart, respectively. VO_{2max} will be defined as the highest 30-second average for VO_2 achieved during the test. Subjects must achieve two out of the following criteria to ensure achievement of VO_{2max}: Respiratory Exchange Ratio > 1.1, plateau in VO_2 (an increase in VO_2 in the final stage that is less than 150 ml/min), or achievement of 90% of age predicted HR max (determined by subtracting the age of the participant in years from 220). If only one of the criteria is achieved, subjects will rest for five minutes and then resume the test starting at the second-highest stage achieved until volitional fatigue.

Submaximal Tests. Each participant will cycle using mechanically braked (Monark) and electrically braked (Viasprint) ergometers on four separate occasions. Following a brief warm-up, the test will proceed as described previously.[30] For the electrically braked ergometer trials, pedal cadence will be determined by the participant. VO_{2max} will be calculated by extrapolating the linear relationship between power output and HR up to age-predicted maximum heart rate. The resulting estimated maximal power output will be used to estimate the VO_2 associated with that power output (VO_{2max}) using the ACSM metabolic equation for leg ergometry.[30]

Data Analysis.

Validity- VO_{2max} values from the maximal treadmill test, the first friction-braked ergometer test and the first electrically braked cycle ergometer test will be compared using repeated measures analysis of variance (RMANOVA). Post-hoc testing will be performed using Fisher's least significant difference (LSD) to identify differences in sample means. Pearson correlation coefficients will be generated for actual and estimated VO_{2max} for both YMCA protocols. *Reliability*- Repeated VO_{2max} estimates from both ergometers will be compared using paired t-tests. Pearson correlation coefficients for both trails within a given ergometer will be generated. A priori statistical significance will be set a $P < 0.05$.

Chapter III

Manuscript

Introduction

When assessing cardiovascular fitness, VO_{2max}, or oxygen utilization rate relative to body weight (mL O_2/min/kg), is widely accepted as the criterion measurement of aerobic capacity. VO_{2max} testing can provide useful information that can be used by exercise professionals to prescribe physical activity, track improvements, and generate information related to health. However, the usefulness of this information is dependent upon the validity and reliability of the chosen protocol. The Youth Men's Christian Association (YMCA) submaximal test is commonly used to estimate VO_{2max}, as it is easy to administer to most populations and does not require a maximal effort from participants. However, the test is commonly performed on friction-braked cycle ergometers that require maintaining a constant pedaling rate for the duration of the exercise. Electrically braked ergometers, in contrast, regulate power output by automatically adjusting resistance regardless of pedaling cadence, thus eliminating a potential source of error in the YMCA protocol.

The YMCA submax test has been reported to be an adequate predictor of VO_{2max} for the general population[1,2] and in physically active individuals.[3] Additionally, submaximal cycle protocol predictions have shown to have high intrasubject test-retest reliability, as well as significant correlations (r = 0.66-0.80) with criterion results attained using a maximal cycle ergometer test in stroke patients.[4] However, it has also been observed that the YMCA cycle ergometer test underestimates VO_{2max} across a range of aerobically fit individuals[5] and collegiate athletes.[6] Similarly, the YMCA cycle test has slightly underpredicted VO_{2max} in samples containing both males and females who averaged around 50th percentile.[7,8] Conversely, YMCA bike test protocols have resulted in overestimated VO_{2max} values with low to modest[9] or inconsistent test-retest reliability.[10] Potential reasons for low reliability include daily fluctuations in physiological responses to exercise, as well as biologically and technologically induced variation between direct VO_{2max} tests. One investigation observed a day-to-day coefficient of variation (CV) of 4.42% in VO_2 as participants cycled at 100, 150, and 200 Watts.[11] Another study calculated biological plus technological error to result in 5.6% variability across 80 total maximum aerobic power tests across five trained subjects, with biological (individual) variability accounting for at least 90% of this sum.[12]

Overall, a consensus for the practical accuracy and precision of the YMCA bike test in predicting maximal VO_2, either across the general population or for any specific demographic, has not been clearly established, and there is currently insufficient evidence to conclude whether the use of electrically braked ergometers enhances the validity and/or reliability of the YMCA test. Ultimately, this project will assess the effectiveness of a technological innovation designed to increase the accuracy of a well-known protocol. It was hypothesized that the validity and reliability of the YMCA protocol would be improved with the use of an electrically braked ergometer.

Methods

Participants. Twenty-two males (21.7 ± 2.8 years; 176 ± 5.9 cm; 75.8 ± 7.8 kg) and thirteen females (20.8 ± 0.7 years; 164 ± 4.2 cm; 62.1 ± 6.0 kg) were recruited from JMU and surrounding communities via social interaction, approved fliers, and electronic mail. All participants were considered "low risk" based on the American College of Sports Medicine Guidelines for Exercise Testing and Prescription, 10th Edition.[13]

Protocol. Participants completed one maximal treadmill test and four submaximal cycle tests to measure and estimate VO_{2max} respectively, all of which were completed within a three-week period. Subjects were advised to refrain from food, caffeine, or nicotine three hours prior to each trial in concordance with ACSM guidelines.[13] All trials for each subject took place at the same time of day.

Treadmill Maximal Test. The participants began the test at 2.5 mph. The speed was increased by 0.5 mph every one-minute interval until 6.0 mph was reached. Every minute thereafter, grade was increased by 3.0% until the subjects reached either volitional exhaustion or 15% grade If subject achieved 15% grade, speed was further increased by 0.5 mph every minute until termination. Throughout the test, heart rate and expired gases were monitored using a Polar Electro heart rate monitor and a Parvo Medics (Sandy, UT) metabolic measurement cart, respectively. The highest 30-second average for VO_2 was defined as VO_{2max}. To ensure an accurate VO_{2max}, subjects had to achieve two out of the following criteria: Respiratory Exchange Ratio (RER) > 1.1, plateau in VO_2 (< 150 ml/min increase in VO_2 during the last stage), and achievement of 90% of age predicted HR max. Twenty-seven subjects achieved two or more of these criteria, and the remaining eight subjects completed a "validation" stage by resting for five minutes, then continuing the test at the second-highest stage achieved until volitional fatigue. A graded maximal treadmill exercise test using indirect calorimetry was chosen as the criterion measurement because under most circumstances it yields higher, therefore more accurate VO_{2max} values compared to maximal cycler ergometry,[14,15] likely as a result of greater peripheral and overall circulatory rate.[16] Additionally, the ACSM prediction equation is based on VO_{2max} values achieved using a graded treadmill protocol.[13]

Submaximal Tests. Each participant cycled using friction-braked (Monark) and electrically braked (Viasprint) ergometers on four separate occasions (twice on each ergometer). The sequencings of the tests were randomly counterbalanced to minimize any potential order effects. Following a brief warm-up, the subject pedaled at 25 W for the first three minutes (Stage 1). For the Monark tests, cadence was kept constant at 50 rpm, while subjects were allowed to maintain any cadence on the Viasprint. Heart rate (HR) was obtained at the end of each minute; once the participant maintained a steady HR for two minutes, resistance was increased for subsequent stages as described previously.[13] Each trial was terminated if 85% of age predicted HR_{max} was achieved. VO_{2max} was calculated by extrapolating the linear relationship between power output and HR to age-predicted maximum heart rate. The resulting estimated maximal power output was used to estimate the VO_2 associated with that power output (VO_{2max}) using the ACSM metabolic equation for leg ergometer.[13]

Data Analysis.

Validity: VO_{2max} values (Treadmill, YMCA test using Monark, and YMCA test using Viasprint) were compared using repeated measures analysis of variance (RMANOVA). Post-hoc testing was performed using Fisher's least significant difference (LSD). Linear regression values (Pearson's R) were generated for actual and estimated VO_{2max} for both YMCA protocols. *Reliability:* Repeated VO_{2max} estimates from both ergometers were compared using paired t-tests. Pearson correlation coefficients for both trails within a given ergometer were generated. A priori statistical significance was set at $P < 0.05$.

Results

Descriptive characteristics of our sample are summarized in Table 1. The VO_{2max} values for twenty-two males and thirteen females were 54.3 ± 6.2 mL/kg/min and 43.4 ± 4.4 mL/kg/min, respectively.

Validity: Average VO_{2max} data for all three protocols are illustrated in Figure 1. The treadmill VO_{2max} protocol yielded significantly higher values (50.3 ± 7.7 mL/kg/min) than the YMCA submax protocol using a friction-braked (40.8 ± 5.5 mL/kg/min) and electrically braked ergometer (38.8 ± 4.5 mL/kg/min). Furthermore, estimated VO_{2max} using the friction-braked ergometer was higher ($P < 0.05$) than that observed using the electrically braked ergometer.

Estimated VO_{2max} using a Monark (friction-braked) cycle ergometer is plotted against actual VO_{2max} in Figure 2. A Pearson's product-moment correlation coefficient of $R = 0.66$ was observed. Similarly, estimated VO_{2max} using a Viasprint (electrically braked) cycle ergometer is plotted against actual VO_{2max} in Figure 3. The validity coefficient was $R = 0.54$.

Reliability: There was no significant difference between estimated VO_{2max} for the two friction-braked ergometer test between Trial 1 (40.58 ± 5.22 mL/kg/min) and Trial 2 (41.04 ± 6.87 mL/kg/min). Similarly, there was no significant difference between Trial 1 (38.32 ± 5.04 mL/kg/min) and Trial 2 (39.30 ± 5.24 mL/kg/min) for the electrically braked ergometer. Trial 1 and Trial 2 using a friction-braked ergometer are plotted against one another in Figure 4, along with the reliability coefficient $R = 0.62$. Likewise, Trial 1 and Trial 2 predicted VO_{2max} values using a Viasprint (electrically braked) cycle ergometer are plotted in Figure 5 along with the reliability coefficient $R = 0.53$.

Discussion

The major finding of the present study is that the YMCA bike test has poor validity and reliability in the studied population, regardless of whether a friction-braked or electrically braked ergometer was used. It appears that any improvements in keeping a constant and accurate workload engendered by the electrically braked ergometer did not substantially affect either the validity or reliability of the YMCA protocol. This may suggest that maintenance of workload is not an important source of error in this test.

In general, the YMCA protocol underpredicted VO_{2max} values compared to the actual value obtained from a maximal treadmill protocol. These findings are consistent with Dabney & Butler,[5] Van Duser et al.,[6] Jamnick et al.,[7] and Akalan et al.,[8] who reported underestimations of ~14%, 22.3%, 8.8%, and 12.3%, respectively. In contrast, Beekley et al.,[1] George et al.,[2] Kovaleski et al.,[3] and Eng et al.[4] reported no significant differences between maximal and submax testing protocols with validity coefficients of 0.77, 0.88, 0.73, and 0.66-0.80, respectively. Furthermore, Grossmann et al.[9] and Griewe et al.,[10] reported overestimations of 12.1 % and 39%, respectively. Thus, there appears to be discrepancies in the literature as to the validity of this protocol.

It should be addressed that the aforementioned prior studies generally used larger sample sizes with greater ranges of both age and measured cardiovascular fitness. While the present investigation tested 22 males (19-31 years; 42.8-63.3 ml/kg/min) and 13 females (20-22 years; 36.5-53.3 mL/kg/min), Beekley et al.[1] tested 55 males (20-54 years; 28.7-83.2 mL/kg/min) and 47 females (20-54 years; 16.9-67.7 mL/kg/min). This large, heterogeneous sample could have contributed to the higher observed validity coefficient between predicted and actual VO_{2max}. Conversely, the current study focused mainly on younger, fitter individuals between roughly the

45th to 99th percentile for both men and women, with the average value located within the "superior" category for both genders according to ACSM guidelines.[13]

In order to investigate the impact of high VO_{2max} values on YMCA test validity, a post-hoc correlation test was performed between the observed prediction error (difference of actual VO_{2max} and predicted VO_{2max}) and VO_{2max}. A significant correlation ($R = 0.74$) was observed, suggesting that as VO_{2max} increases, the magnitude of underprediction becomes greater. This could explain the findings of the current study in light of previous literature, as average VO_{2max} in the current study was higher than in previously mentioned studies where no underprediction of VO_{2max} was observed. Furthermore, Beekley et al.[1] observed that the YMCA test was more valid in females than males. It is possible that these findings were due to higher VO_{2max} values attained by the males. Moreover, the aforementioned study by Griewe et al.[10] showed a lower-sloped regression trendline (between estimated and actual VO_{2max}) compared to the line of identity. These two lines intersect at an absolute VO_{2max} value of about 2 L O_2/min, suggesting that VO_{2max} values above this VO_2 will tend to be underpredicted. However, this protocol used only 2-minute stages and factored first stage heart rate into the regression equation, which has been since modified. Additionally, a maximal cycle test was administered as the criterion measurement rather than a treadmill protocol.

Moderate test-retest correlation coefficients (0.62 and 0.53, respectively) were observed in the Monark and Viasprint trials, indicating lower YMCA submax test reliability compared to most prior literature. George et al.[2] reported test-retest R-values of 0.93 and 0.71 for women and men, respectively; Eng et al.[4], Grossmann et al.,[9] and Griewe et al.[10] reported test-retest values of 0.66-0.80, 0.71-0.75, and 0.86, respectively. George et al.[2] noted that the test-retest intraclass reliability was stronger for females ($r = 0.93$) than for males ($r = 0.74$).

The current investigation did not control for effects of daily fluctuations of ambient temperature and/or hydration status on heart rate variability or maximal oxygen consumption. While temperature and hydration are worth considering as potential sources of error of the YMCA submaximal cycle test,[17,18] they were not likely significant confounding variables given that subjects completed their respective staggered exercise tests during the same time of day, and the results are relevant in terms of outcomes when following ACSM recommendations.[13]

In conclusion, data from the present study suggest that the YMCA protocol is not a highly valid or reliable test to estimate VO_{2max} in a young, fit population. It was also observed that neither validity nor reliability of the YMCA test was improved with the use of an electrically braked ergometer. Furthermore, a correlation between prediction error and criterion VO_{2max} suggests that the magnitude of underprediction increases with increasing cardiorespiratory fitness. Future research designs should aim to adapt the YMCA bike test to more accurately extrapolate maximal work-rate for those higher VO_{2max} values. Additionally, in order to strengthen the statistical relevance of the present findings compared to other sources, a future investigation could recruit a large, normally distributed sample, containing individuals with cardiorespiratory fitness levels between the 0.1st and 99.9th percentile across all sex/age groups listed in the ACSM guidelines.[13] Ultimately, until a more accurate model has been developed using submaximal heart rates to estimate VO_{2nax}, when working with individuals of higher fitness levels, other means of estimating VO_{2max} for this population may be preferable.

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Table 1. Mean height (cm), weight (kg), age (years), and VO_{2max} (mL/kg/min) for male (n = 22) and female (n = 13) subjects.

Gender	Height (cm)	Weight (kg)	Age (years)	VO_{2max} (mL/kg/min)
Male	176 ± 5.9	75.8 ± 7.8	21.7 ± 2.8	54.3 ± 6.2
Female	164 ± 4.2	62.1 ± 6.0	20.8 ± 0.7	43.4 ± 4.4

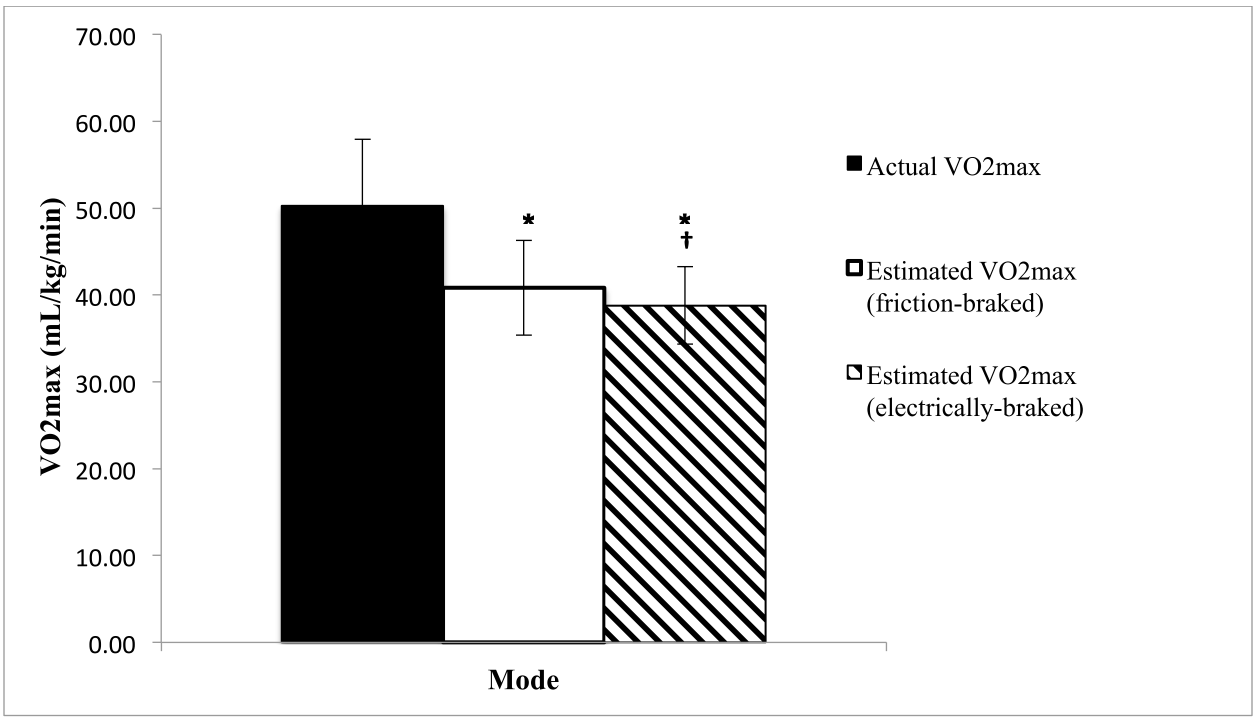

Figure 1. Comparison of actual VO_{2max} and predicted VO_{2max} using both a friction-braked Monark cycle ergometer and electrically braked Viasprint cycle ergometer. *-significantly ($p < 0.05$) lower than actual VO_{2max}. †-significantly ($p < 0.05$) lower than friction-braked estimated VO_{2max}.

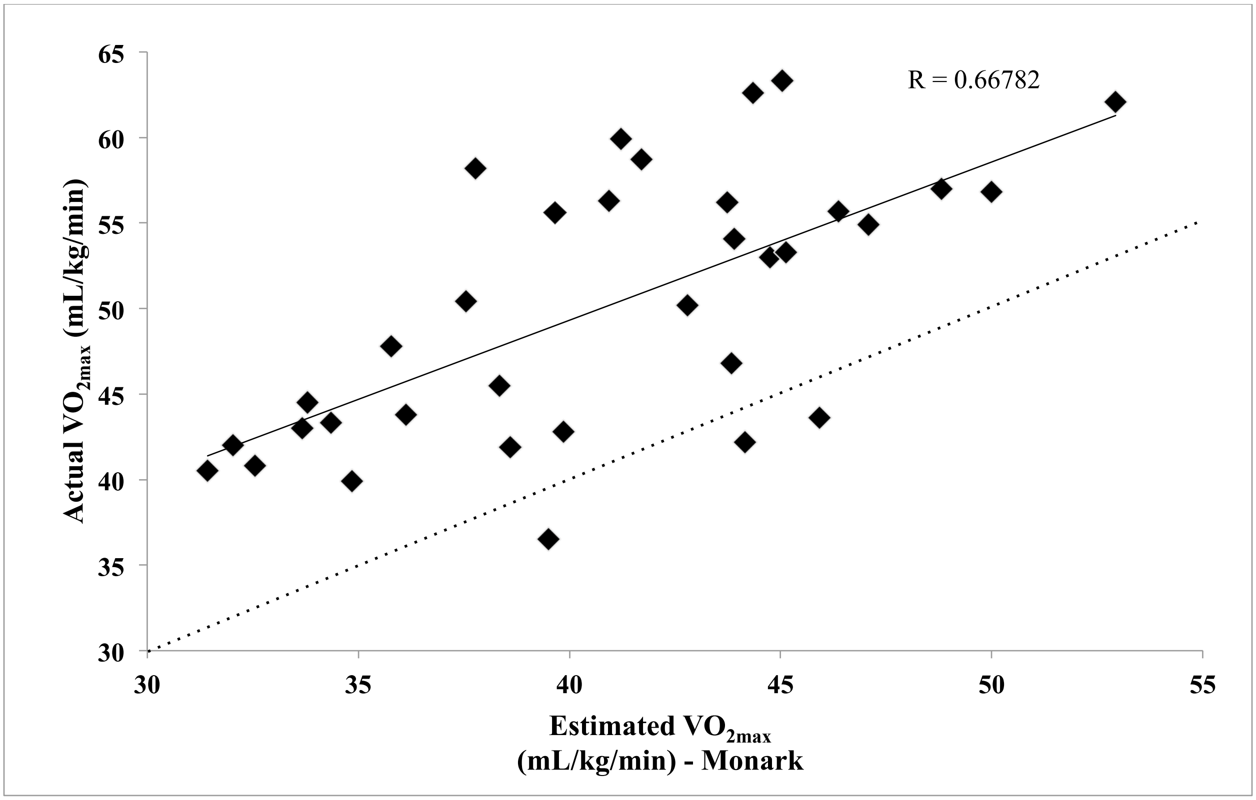

Figure 2. Estimated VO_{2max} from the YMCA Bike Test using Monark (friction-braked) cycle ergometer plotted against actual VO_{2max}. Dashed line represents line of identity.

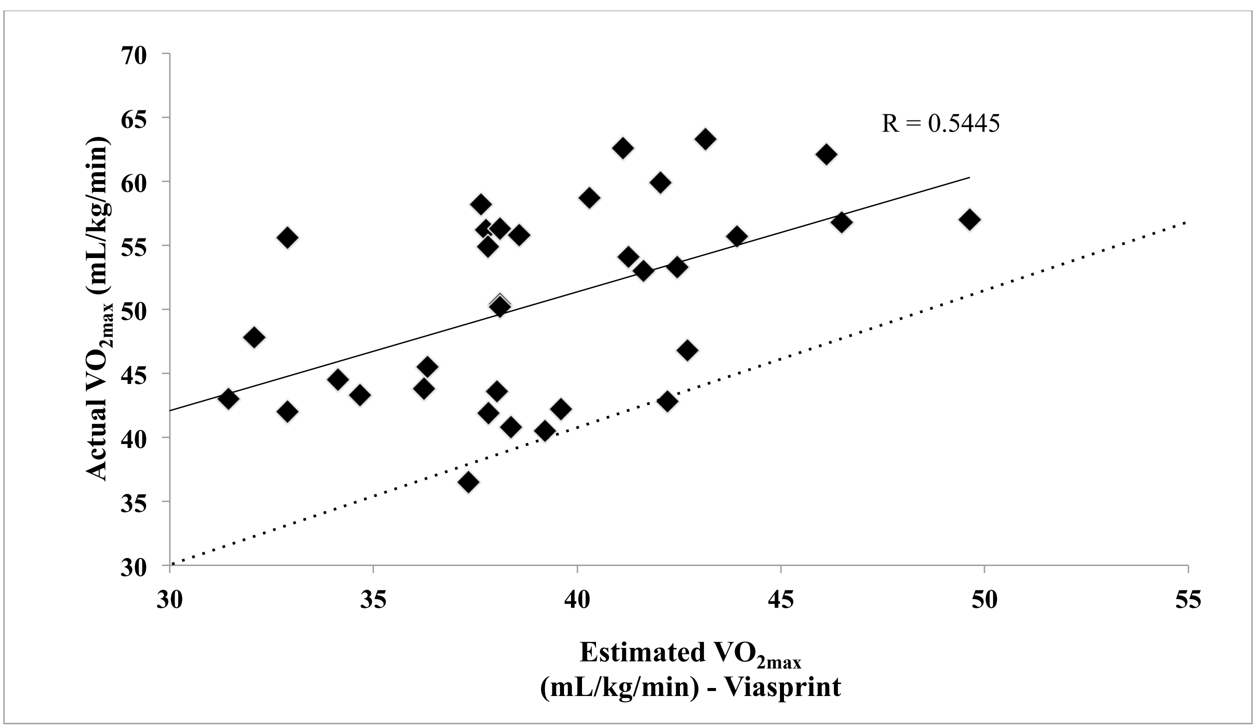

Figure 3. Estimated VO_{2max} following YMCA Bike Test using Viasprint (electrically braked) cycle ergometer plotted against actual VO_{2max}. Dashed line represents line of identity.

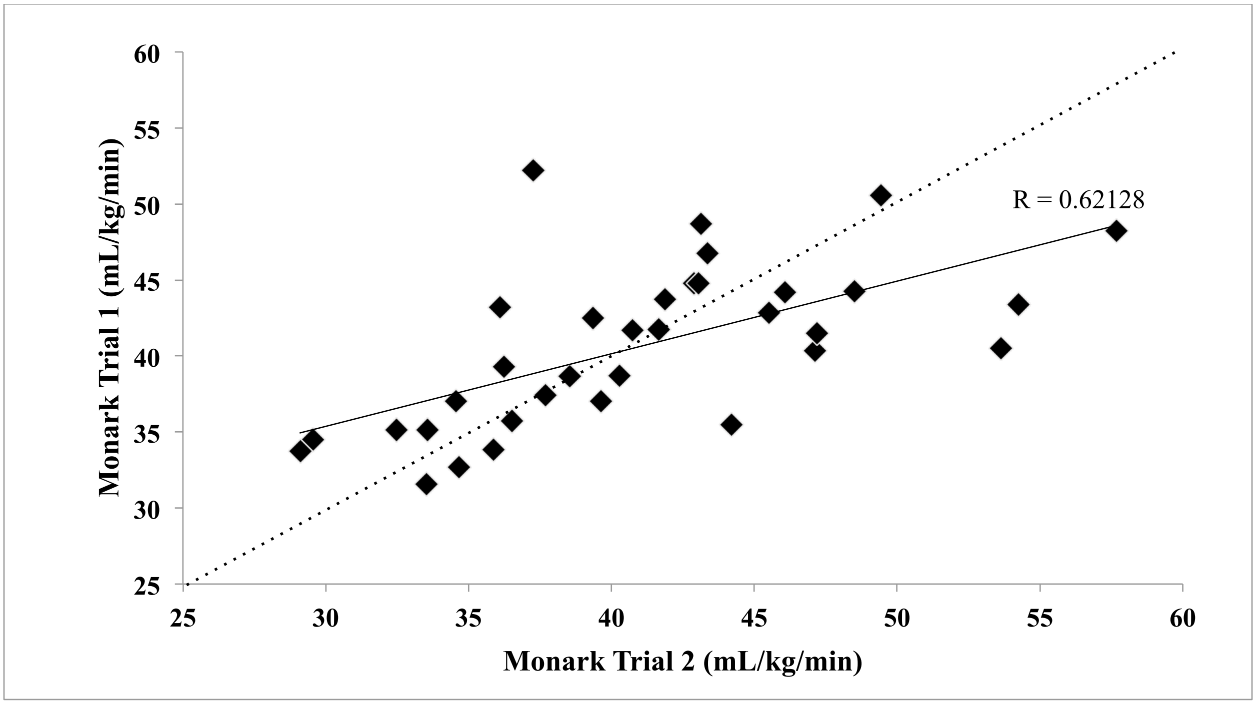

Figure 4. Estimated VO_{2max} values of Trial 1 plotted against Trial 2 of the YMCA Bike Test using a Monark (friction-braked) cycle ergometer. Dashed line represents line of identity.

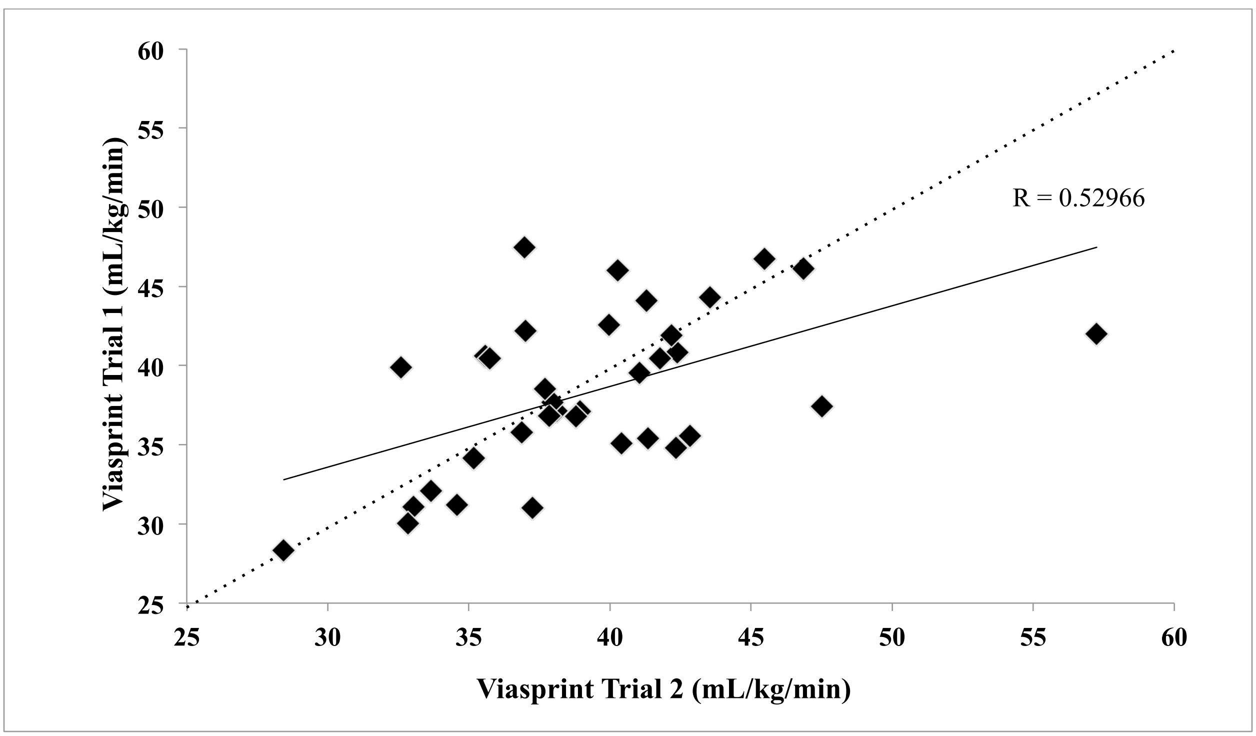

Figure 5. Estimated VO_{2max} values of Trial 1 plotted against Trial 2 of the YMCA Bike Test using a Viasprint (electrically braked) cycle ergometer. Dashed line represents line of identity.

Appendix A

Informed Consent Form

Consent to Participate in Research

Identification of Investigators & Purpose of Study

You are being asked to participate in a research study conducted by Christopher J. Womack, Ph.D. and Justin M. Kidd from James Madison University. The purpose of this study is to determine whether different types of exercise bikes (manual versus electric) effect how well a particular exercise test predicts your aerobic capacity.

Potential Risks

If you choose to participate in this study, you will perform five separate exercise tests; one on a treadmill, two on an electrically braked ergometer, and two on a friction-braked ergometer. The treadmill test is a maximal test while both the tests on the ergometers are submaximal tests.

During the testing you may experience: fatigue, shortness of breath, cramping, general discomfort, and in unusual instances, heart attack, stroke or death may result. Prior to your participation in this study, you will be asked to complete a Health History Questionnaire (HHQ), which will evaluate your current health status and history in order to maximize your safety to participate in these exercise tests. Furthermore, at least one member of the testing team will be CPR certified.

Potential benefits from participation in this study include:

Your participation will contribute to research that may help to improve the validity of submaximal tests for measuring cardiorespiratory fitness. You will also be informed as to your maximal oxygen consumption score (VO2max). Also, the results of our findings may help educate exercise professionals on the accuracy of submaximal cycling tests for assessing maximal oxygen consumption.

Research Procedures

Should you choose to participate in this research study, you will be asked to sign this consent form. We ask for you to perform all five tests around the same time of day on separate occasions spanning a two to three week period. We ask you to abstain from consuming food, caffeine, nicotine or alcohol 3 hours prior to testing.

<u>Treadmill Maximal Test:</u>

You should allot approximately an hour for this test due to the length of the testing period and time required to set up the equipment. Multiple pieces of equipment will be used in order to take necessary measurements. A monitor wrapped around your chest will track your heart rate. You will breathe through a mouthpiece while your nose is clipped in order to monitor your expired air for oxygen content. The test will start at a slow (walking) speed and progress every minute until you are at 6.0 miles/hour. From that point, the elevation of the treadmill will increase every minute until you indicate that you can no longer continue the test.

<u>ACSM Submaximal Testing on Monark and Electrically braked Ergometer:</u>

Four submaximal tests will be performed using the same protocol. Two trials will be completed on a Monark mechanically braked ergometer while the other two will be completed on an electrically braked ergometer. These are incremental tests consisting of a maximum of 4 three-minute stages. After each stage, the resistance will progressively increase depending on your heart rate at the conclusion of the first 3 minute stage. You will begin with a short 3 minute warm up at 50 revolutions per minute (50 RPM). Once again a monitor around your chest will provide us with your heart rate throughout the test at regular intervals. Allot yourself approximately 30-40 minutes for these tests due to the testing period and time required for equipment set up as well as warm up and cool down.

Confidentiality

The goal of this research study aims to publish the results in exercise science journals. However, your identity will not be disclosed with the results of this study. Should you wish to have your data removed, notify the researchers involved prior to publication. The researcher retains the right to use and publish non-identifiable data. While individual responses are confidential, aggregate data will be presented representing averages or generalizations about the responses as a whole. All data will be stored in a secure location accessible only to the researcher. Final aggregate results will be made available to you upon request.

Participation & Withdrawal

Realize that your participation is voluntary and you are free to choose not to participate at any time. There are no consequences if you choose to withdrawal.

Questions

If you have questions or concerns before, during or after your participation in this study contact Christopher J. Womack, Ph.D. at womackcx@jmu.edu or by phone at 540-568-6515.

Questions about Your Rights as a Research Subject

Dr. David Cockley
Chair, Institutional Review Board
James Madison University
(540) 568-2834
cocklede@jmu.edu

Giving of Consent

I have read this consent form and understand what is being requested of me as a participant in this study. I freely consent to participate. I have been given satisfactory answers to my questions. The investigator provided me with a copy of this form. I certify that I am at least 18 years of age.

______________________________	______________________________
Name of participant (Printed)	Name of Researcher(s) (Printed)
______________________________	______________________________
Name of participant (Signed)	Name of Researcher(s) (Signed)
______________________________	______________________________
Date	Date

Appendix B

Health Status Questionnaire

James Madison University
Department of Kinesiology
Health Status Questionnaire

Instructions: Complete each question accurately. All information provided is confidential.

Part I: General Information

1. Subject #

2. Local Phone Email: ______________________________________

3. Gender (circle one) Male Female

4. Date of Birth (Month/ Day/ Year)

Part II: Medical History

5. Circle any that died of heart attack before age 50: Father Mother Brother Sister Grandparent

6. Date of last medical exam: ______________ Last physical fitness test: ________________

7. Circle operations you have had: Back Heart Kidney Eyes Joint Neck Ears Hernia

Lung Other _________________

8. Please circle any of the following for which you have been diagnosed or treated by a physician or health professional:

Alcoholism	Diabetes	Kidney Problems
Anemia (sickle cell)	Emphysema	Mental Illness
Anemia (other)	Epilepsy	Muscular Injury
Asthma	Eye Problems	Neck Strain
Back Strain	Gout	Obesity
Bleeding trait	Hearing Loss	Orthopedic Injuries
Bronchitis, chronic	Heart Problem	Phlebitis
Cancer	High Blood Pressure	Rheumatoid arthritis
Cirrhosis, liver	Hypoglycemia	Stroke
Concussion	Hyperglycemia	Thyroid problem
Congenital defect	Infectious Mononucleosis	Ulcer

Other ______________________

9. Circle all medications taken in the last six months:

Blood thinner	Epilepsy medication	Nitroglycerin
Diabetic pill	Heart-rhythm medication	Other ___________________
Digitalis	High-blood pressure medication	
Diuretic	Insulin	

10. Any of these health symptoms that occur frequently is the basis for medical attention. Circle the number indicating how often you have each of the following:
5 = Very often   4 = Fairly often   3 = Sometimes   2 = Infrequently   1= Practically never

a. cough up blood 1 2 3 4 5	f. chest pain 1 2 3 4 5
b. abdominal pain 1 2 3 4 5	g. swollen joints 1 2 3 4 5
c. low back pain 1 2 3 4 5	h. feel faint 1 2 3 4 5
d. leg pain 1 2 3 4 5	i. dizziness 1 2 3 4 5
e. arm or shoulder pain 1 2 3 4 5	j. breathless on slight exertion 1 2 3 4 5

Part III: Health Related Behavior

11. Do you smoke? Yes No

12. If you are a smoker, indicate the number of smoked per day:

Cigarettes:

40 or more   20-39   10-19   1-9

Cigars or pipes only:

5 or more or any inhaled   less than 5, none inhaled

13. Do you exercise regularly? Yes No

14. How many times in a week do you spend at least 30 minutes in moderate to strenuous/vigorous exercise?

1   2   3   4   5   6   7   days per week

15. Can you walk 4 miles briskly without fatigue? Yes No

16. Can you jog 3 miles continuously at a moderate pace without discomfort? Yes   No

17. Weight now: __________ lb. One year ago: __________ lb   Age 21: __________ lb

Appendix C

YMCA Data Table and

Submaximal Prediction Equation

YMCA Cycle Ergometer Test

Date:
Subject #:
Height:
Weight:
Ergometer: Monark ViaSprint

Stage	Power Output	Heart Rate

Submaximal Prediction Equation:

VO_{2max} in mL/kg/min = {1.8*[slope*(220 - age) + y-intercept]}/[(body weight in kg) + 3.5 + 3.5]

note: slope and y-intercept determined using linear regression of multiple points representing heart rates (bpm) at submax workloads

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