Comparison of the YMCA and a Custom Submaximal Exercise Test for Determining $\dot{V}O_{2max}$

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ABSTRACT

JAMNICK, N. A., S. BY, C. D. PETTITT, and R. W. PETTITT. Comparison of the YMCA and a Custom Submaximal Exercise Test for Determining $\dot{V}O_{2max}$. *Med. Sci. Sports Exerc.*, Vol. 48, No. 2, pp. 254–259, 2016. The maximal oxygen uptake ($\dot{V}O_{2max}$) is deemed the highest predictor for all-cause mortality, and therefore, an ability to assess $\dot{V}O_{2max}$ is important. The YMCA submaximal test is one of the most widely used tests to estimate $\dot{V}O_{2max}$; however, it has questionable validity. **Purpose**: We validated a customized submaximal test that accounts for the nonlinear rise in $\dot{V}O_2$ relative to power output and compared its accuracy against the YMCA protocol. **Methods**: Fifty-six men and women performed a graded exercise test with a subsequent exhaustive, square wave bout for the verification of "true" $\dot{V}O_{2max}$. In counterbalanced order, subjects then completed the YMCA test and our new Mankato submaximal exercise test (MSET). The MSET consisted of a 3-min stage estimated at 35% $\dot{V}O_{2max}$ and a second 3-min stage estimated at either 65% or 70% $\dot{V}O_{2max}$, where $\dot{V}O_{2max}$ was estimated with a regression equation using sex, body mass index, age, and self-reported PA-R. **Results**: $\dot{V}O_2$ values from the graded exercise test and square wave verification bout did not differ with the highest value used to identify "true" $\dot{V}O_{2max}$ (45.1 ± 8.89 $mL\cdot kg^{-1}\cdot min^{-1}$). The MSET (43.6 ± 8.6 $mL\cdot kg^{-1}\cdot min^{-1}$) did not differ from "true" $\dot{V}O_{2max}$, whereas the YMCA test (41.1 ± 9.6 $mL\cdot kg^{-1}\cdot min^{-1}$) yielded an underestimation ($P = 0.002$). The MSET was moderately correlated with "true" $\dot{V}O_{2max}$ (ICC = 0.73, CV of 11.3%). The YMCA test was poorly correlated with "true" $\dot{V}O_{2max}$ (ICC = 0.29, CV of 15.1%). **Conclusions**: To our knowledge, this is the first study to examine submaximal exercise protocols versus a verified $\dot{V}O_{2max}$ protocol. The MSET yielded better estimates of $\dot{V}O_{2max}$ because of the protocol including a stage exceeding gas exchange threshold. **Key Words:** MAXIMAL OXYGEN UPTAKE, $\dot{V}O_2$ SLOW COMPONENT, CYCLE ERGOMETER TESTING, NONLINEAR OXYGEN UPTAKE

Maximal oxygen uptake ($\dot{V}O_{2max}$) is the main indicator of cardiorespiratory fitness (CRF). A low CRF level is a superior independent risk factor of all-cause mortality when compared with obesity, weight gain, smoking, hypertension, high cholesterol, and diabetes (3,9,18). Measuring $\dot{V}O_{2max}$ from a maximal graded exercise test (GXT) is expensive, requires specialized equipment, and may be impractical for unfit or diseased populations. Furthermore, a GXT requires a physician present if the patient is at risk (1). Assessing CRF in the general public via submaximal GXT is essential for determining CRF.

The YMCA cycle ergometer test is a commonly used submaximal test for predicting $\dot{V}O_{2max}$. The test predicts $\dot{V}O_{2max}$ by extrapolating heart rate (HR) responses relative to power output increases, whereby age predicted maximal heart rate (APMHR) is used to define maximal power output (12). Peak power output (W_{peak}) is then used to estimate $\dot{V}O_{2max}$ using the following metabolic equation (1).

$$\dot{V}O_{2max}\left(mL\cdot kg^{-1}\cdot min^{-1}\right) = 7 + \left[1.8\left(6.12\,W_{peak}\right)/BM\right] \qquad [1]$$

where $\dot{V}O_{2max}$ is expressed in milliliters per kilogram per minute, body mass (BM) is in kilograms, and W_{peak} is in watts.

Predicting $\dot{V}O_{2max}$ using the YMCA test has limitations. First, the APMHR equation (220 − age) recommended to predict $\dot{V}O_{2max}$ has questionable scientific merit, with a standard error of estimate ranging from 6 to 22 bpm across studies (30). The only cross validation study to our

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knowledge validating the YMCA test used 220 − age (2,12,30). Second, the YMCA test uses a low cadence (i.e., 50 rpm), which may not reflect the optimum mechanical efficiency for every subject. Lower cadences yield higher gross efficiencies for untrained and noncyclists; however, Lucia et al. (20) reported gross efficiency and preferred cadence are higher among trained cyclists (e.g., 90–100 rpm) (10,13,20,27,29). Third, the YMCA test uses predetermined power output and test termination criteria that may not enable younger and fitter subjects to surpass their gas exchange threshold (GET) (8,12). Last, the YMCA test may omit a stage above GET failing to account for the nonlinearity of oxygen uptake associated with the $\dot{V}O_2$ slow component (19,34). These limitations emphasize the need for a submaximal test that improves the validity of estimating $\dot{V}O_{2\text{max}}$.

Use of demographic data and exercise domain responses from previously published research may increase the validity of submaximal testing for determining $\dot{V}O_{2\text{max}}$. Prescribing individualized exercise intensities in the moderate and heavy domains of exercise, using a nonexercising equation validated by Jackson et al. (15), may increase the accuracy for estimating $\dot{V}O_{2\text{max}}$ via submaximal testing. Previously published normative threshold data by Davis et al. (5,6) makes it feasible to prescribe exercises intensity stages above and below estimated GET. Therefore, the purpose of this study was to develop and validate a customized submaximal cycle ergometer test that takes into account the nonlinear oxygen uptake-power output response above GET and yield a more accurate estimation of $\dot{V}O_{2\text{max}}$.

METHODS

Experimental design. The experimental design included two separate visits to the laboratory. Before testing, subjects were assessed using ACSM Risk Stratification guidelines for maximal exercising testing (1). Subjects between the ages of 18 and 39 were included in the study if stratified as moderate risk or lower. Subjects 40 yr of age or older were included in the study if stratified as low risk. Visit 1 included risk stratification, informed consent, self-reported physical activity rating (PA-R), measurements of subject's height and body mass, and administering a GXT with square wave verification bout (17). Visit 2 included two submaximal exercise tests: our new Mankato submaximal exercise test (MSET) and the YMCA cycle ergometer test (note: We chose to name the test after our affiliation to avoid confusion with the 6-min walk test). Each submaximal test was counterbalanced to avoid an order effect. There was 30-min rest period between the two submaximal tests. Before each exercise test, a 5-min warm-up was administered at 50 W, followed by a 5-min passive rest. Preferred cadence for the GXT and MSET was determined during the initial warm-up session.

Subjects. A total of 56 subjects were included in the study (31 men and 26 women; age, 28.4 ± 10.4 yr; BMI, 24.4 ± 3.2). Written informed consent was obtained before the start of the study. All subjects self-reported abstaining from the use of alcohol or engaging in heavy exercise 24 h preceding each visit. Subjects were given at least 48 h of rest between visits, and all tests were completed within 2 wk. Our institutional review board for the protection of human subjects approved all procedures for this study.

Equipment/instruments. All tests were conducted using friction-based, weight-loaded cycle ergometer (Monark 874E, Sweden). Saddle and handlebar heights/positions were adjusted to each subject's riding comfort and replicated for each trial. A metabolic analyzer (Parvo Medics, Logan, UT) was used during all trials. Subjects wore a nose clip and expired through a two-way rebreathing valve connected to the metabolic cart. HR by telemetry was recorded simultaneously (Polar Electro Inc., Lake Success, NY), and all data were evaluated using 15 s averaging. Filter replacement and calibration were performed between tests according to manufacturer's guidelines.

GXT with square wave verification bout. Demographic data, PA-R, and measurements of height and body mass were collected during the initial visit. A modified PA-R scale derived by George et al. (11) was used to accommodate a more robust population with respect to physical activity level (Table 1).

TABLE 1. Physical activity rating (PA-R) 0–15 scale.

Select the number that best describes your overall level of physical activity for the previous 6 months
0—avoid walking or exertion, e.g., always use elevator, drive when possible instead of walking
1—light activity: walk for pleasure, routine use stairs, occasionally exercise sufficiently to cause heavy breathing and perspiration
2—moderate activity: 10 to 60 $\text{min}\cdot\text{wk}^{-1}$ of moderate activity, such as golf, horseback riding, calisthenics, table tennis, bowling, weight lifting, yard work, cleaning house, walking for exercise
3—moderate activity: more than 1 $\text{h}\cdot\text{wk}^{-1}$ of activity as described previously
4—vigorous activity: run less than 1 mile per week or spend less than 30 $\text{min}\cdot\text{wk}^{-1}$ in comparable activity such as running or jogging, lap swimming, cycling, rowing, aerobics, skipping rope, running in place, or engaging in vigorous aerobic-type activity such as soccer, basketball, tennis, racquetball, or handball
5—vigorous activity: run 1 mile to less than 5 miles per week or spend 30 min to less than 60 $\text{min}\cdot\text{wk}^{-1}$ in comparable physical activity as described previously
6—vigorous activity: run 5 miles to less than 10 miles per week or spend 1 h to less than 3 $\text{h}\cdot\text{wk}^{-1}$ in comparable physical activity as described previously
7—vigorous activity: run 10 miles to less than 15 miles per week or spend 3 h to less than 6 $\text{h}\cdot\text{wk}^{-1}$ in comparable physical activity as described previously
8—vigorous activity: run 15 miles to less than 20 miles per week or spend 6 h to less than 7 $\text{h}\cdot\text{wk}^{-1}$ in comparable physical activity as described previously
9—vigorous activity: run 20 miles to less than 25 miles per week or spend 7 h to less than 8 $\text{h}\cdot\text{wk}^{-1}$ in comparable physical activity as described previously
10—vigorous activity: run 25 miles to less than 30 miles per week or spend 8 h to less than 9 $\text{h}\cdot\text{wk}^{-1}$ in comparable physical activity as described previously
11—vigorous activity: run 30 miles to less than 35 miles per week or spend 9 h to less than 10 $\text{h}\cdot\text{wk}^{-1}$ in comparable physical activity as described previously
12—vigorous activity: run 35 miles to less than 40 miles per week or spend 10 h to less than 11 $\text{h}\cdot\text{wk}^{-1}$ in comparable physical activity as described previously
13—vigorous activity: run 40 miles to less than 45 miles per week or spend 11 h to less than 12 $\text{h}\cdot\text{wk}^{-1}$ in comparable physical activity as described previously
14—vigorous activity: run 45 miles to less than 50 miles per week or spend 12 h to less than 13 $\text{h}\cdot\text{wk}^{-1}$ in comparable physical activity as described previously
15—vigorous activity: run 50 miles over more per week or spend 13 h or more per week in comparable physical activity as described previously

TABLE 2. Measured and estimated $\dot{V}O_{2max}$ (mL·kg^{-1}·min^{-1}) measured from graded exercise test, nonexercising equation, the MSET, and the YMCA test (N = 56).

$\dot{V}O_2$ (mL·kg^{-1}·min^{-1})	Mean	SD
GXT	45.09	8.89
Nonexercising	46.81	8.67
MSET	43.55	8.67
YMCA*	41.13	9.56

*Significantly (P < 0.01) lower than other measures.

Relative $\dot{V}O_{2max}$ was estimated using a nonexercising regression equation (15) (Equation 2), and that value was subsequently used to estimate W_{peak} as shown as follows (1):

$$\begin{aligned}\text{estimated } \dot{V}O_{2max} = {} & (56.363) + (1.921 \times \text{PA-R}) \\ & - (0.381 \times \text{AGE}) - (0.754 \times \text{BMI}) \\ & + (10.987 \times \text{GENDER},\ 1 = \text{M},\ 0 = \text{F})\end{aligned} \quad [2]$$

$$W_{peak} = \left\{\left[\left(\dot{V}O_{2max} - 7\right) \times \text{BM}\right]/1.8\right\}/6.12 \quad [3]$$

where $\dot{V}O_{2max}$ is expressed in milliliters per kilogram per minute, body mass (BM) is in kilograms, and W_{peak} is in watts.

The estimated W_{peak} for each subject was used to prescribe a custom GXT with a time limit estimate of 10 min using the following: W_{peak}/10 min = 1 min stages (W·min^{-1}) (25). A 3-min active recovery of 50 W was administered after the GXT. Subsequently, a square wave exhaustive bout performed two gradations below W_{peak} was used to verify $\dot{V}O_{2max}$ (25). Exhaustion for the GXT and square wave verification bout was defined as a decline in cadence by 10 rpm for 10 s despite verbal encouragement. The highest $\dot{V}O_2$ data collected during the GXT and square wave verification bout were compared to determine "true" $\dot{V}O_{2max}$ values (within 1.5 mL·kg^{-1}·min^{-1}). Data from the metabolic analyzer were extracted, and detection of watts at gas exchange threshold (W_{GET}) was determined using inflection of VCO_2-$\dot{V}O_2$ (y-axis) relative to inflection of power output (x-axis) (25).

Mankato submaximal exercise test. Self-reported and demographic data were collected from the initial visit and were used to prescribe the MSET. Subjects performed the MSET at their preferred cadence determined during visit 1. The test consisted of two consecutive 3-min stages. In stage 1, all subjects cycled at 35% of estimated W_{peak} (i.e., stage anticipated below GET), followed by second stage at either 65% or 70% of estimated W_{peak} (i.e., stage anticipated above GET), which was dependent on subject's PA-R. Subjects with a PA-R of 0 to 9 cycled at 65%, and those with a PA-R greater than or equal to 10 cycled at 70% (5,6).

$$\begin{aligned}\text{stage 1 (W)} &= \text{estimated } W_{peak}(\text{W}) \times 35\% \\ \text{stage 2 (W)} &= \text{estimated } W_{peak}(\text{W}) \times 65\% \text{ or } 70\%\end{aligned} \quad [4]$$

YMCA cycle test. The YMCA test was conducted as described by *The Y's Way to Physical Fitness* (12). Subjects performed two to four 3-min consecutive stages at 50 rpm. Subjects completed a fourth minute, if HRs from second and third minutes were not within 5 bpm. All subjects began their first stage at 25 W, the second stage was determined based on HR values from the first stage (<80 bpm: 125 W, 80–89 bpm: 100 W, 90–100 bpm: 75 W, >100 bpm: 50 W). Termination of the test occurred when 2 consecutive stages were completed with a HR between 110 and 150 bpm (12). Data collected from the last 2 stages of the YMCA test and stages of the MSET were used to extrapolate estimated W_{peak}, via linear regression of power output (y-axis) and HR (x-axis). The APMHR was predicted using 208 − (0.7 × age) (32); $\dot{V}O_{2max}$ was subsequently calculated using equation 1.

DATA ANALYSIS

"True" $\dot{V}O_{2max}$ was defined as the highest measured $\dot{V}O_2$ from either the GXT or exhaustive bout. A one-way analysis of variance with repeated measures was used to assess differences between the maximal GXT and each estimate of $\dot{V}O_{2max}$. Bonferroni adjustments were used to evaluate main effects. Consistency between measured and estimated values were evaluated using a two-way mixed intraclass correlation coefficient (ICC α), SEM (i.e., typical error), and coefficient of variation (CV) (14). Pearson product–moment correlation and standard error of estimate (SEE) values are reported to facilitate comparison of measurement agreement with previous research. Separate one-way analysis of variance with repeated measures was used to evaluate $\dot{V}O_2$ and HR values sampled every 30 s from the MSET. A Bonferroni adjustment was used to evaluate differences in $\dot{V}O_2$ and HR values between 30-s time intervals. A paired sample t test was used to compare W_{GET} and prescribed power output during the second stage of the MSET. Descriptive statistics are reported using mean ± SD. Alpha for rejecting the null hypothesis was set at $P \leq 0.05$.

RESULTS

$\dot{V}O_2$ values from the GXT and square wave verification bout were 44.4 ± 8.9 and 44.6 ± 8.9 mL·kg^{-1}·min^{-1}, respectively, (ICC = 0.99, SEM = 0.99 mL·kg^{-1}·min^{-1}, CV = 2.4%) with the highest value used to identify "true" $\dot{V}O_{2max}$ (45.1 ± 8.7 mL·kg^{-1}·min^{-1}) (note: these values were similar if the average of the GXT and square wave bout was used as the criterion measure for $\dot{V}O_{2max}$.). There was a significant main effect for estimating $\dot{V}O_{2max}$, (F = 12.7, P < 0 .05). The MSET (43.6 ± 8.6 mL·kg^{-1}·min^{-1}) did not differ from "true" $\dot{V}O_{2max}$ (P = 0.50), whereas the YMCA test (41.1 ± 9.6 mL·kg^{-1}·min^{-1}) yielded an underestimation (P = 0.002) (Tables 2 and 3). The MSET was correlated moderately with "true" $\dot{V}O_{2max}$ (ICC = 0.72, CV of 11.3%). The YMCA test was correlated poorly with "true" $\dot{V}O_{2max}$ (ICC = 0.27, CV

TABLE 3. ICC, typical error, and coefficient of the variation percent between $\dot{V}O_{2max}$ measurement and estimates.

	ICC	Typical Error	CV
$\dot{V}O_{2max}$ (mL·kg^{-1}·min^{-1})	α	ml·kg^{-1}·min^{-1}	%
GXT vs. nonexercising	0.603	3.91	8.66
GXT vs. MSET	0.722	4.62	11.28
GXT vs. YMCA	0.271	5.57	15.17

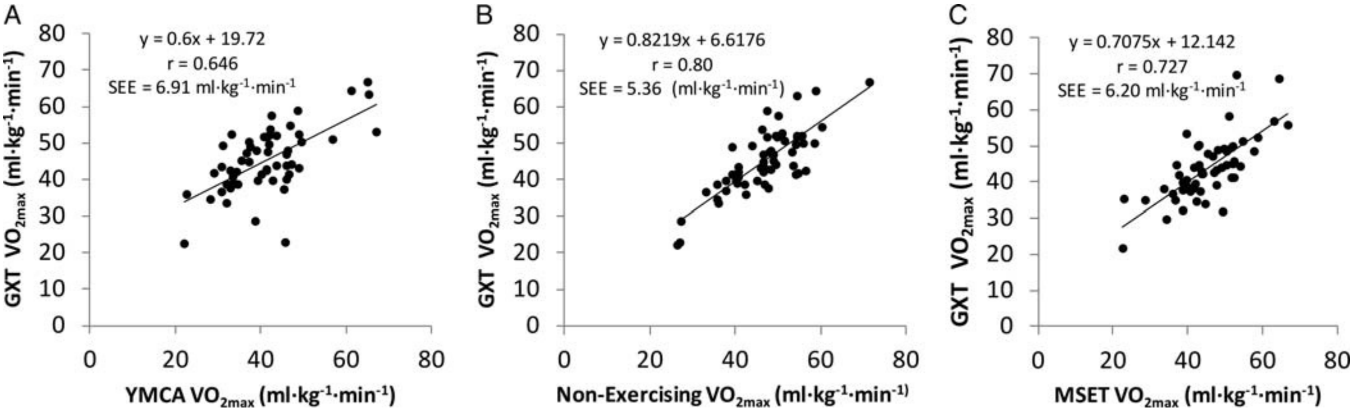

FIGURE 1—Measured versus estimated $\dot{V}O_{2max}$ (mL·kg^{-1}·min^{-1}) for (A) YMCA Cycle Test (YMCA) and (B) nonexercising equation (equation 2) and (C) Mankato submaximal exercise test (MSET). Pearson correlation and standard error of the estimate (SEE) are represented.

of 15.2%) (Table 3). The nonexercising equation did not differ from "true" $\dot{V}O_{2max}$ (46.8 ± 8.7 mL·kg^{-1}·min^{-1} (P = 0.01); however, it was correlated moderately with "true" $\dot{V}O_{2max}$ (ICC = 0.60, CV of 8.34%) (Table 3).

The *r* value and SEE for the YMCA test was r = 0.64, 6.91 mL·kg^{-1}·min^{-1}, whereas the MSET was r = 0.72, 6.20 mL·kg^{-1}·min^{-1} (Fig. 1). The YMCA tests mean difference was −3.96 mL·kg^{-1}·min^{-1}, whereas the mean difference for the MSET was −1.54 mL·kg^{-1}·min^{-1}. The *r* value and SEE and for the nonexercising equation was 0.80 and 5.36 mL·kg^{-1}·min^{-1}, respectively. The power output selected for the second stage of the MSET was 17 W greater than GET ($P < 0.05$). $\dot{V}O_2$ data from stage 1 of the MSET depicts a steady state beginning at 1.5-min; $\dot{V}O_2$ data during minutes 1 and 1.5 did no differ ($P < 0.05$) (Fig. 2). $\dot{V}O_2$ data from stage 2 depicts a delayed steady state beginning at minute 5.5; $\dot{V}O_2$ data during minutes 5.5 and 6 did not differ ($P < 0.05$) (Fig. 2A); a similar trend was observed for HR (Fig. 2B).

DISCUSSION

To our knowledge, this is the first study to compare estimated $\dot{V}O_{2max}$ from submaximal exercise testing to the "true" $\dot{V}O_{2max}$ determined using a GXT and an exhaustive bout for verification. The principal findings of the present study are as follows. Our results demonstrate the MSET yields a more valid estimate of $\dot{V}O_{2max}$ compared with the YMCA test. We believe these results are due to the fact the MSET uses demographic data and the nonlinear oxygen uptake-power output relationship.

Using demographic data and PA-R (Table 1), we estimated W_{GET} through a series of three equations (equations 2–4.) (6,15). Indeed, the actual power output used in the MSET was approximately 17 W above W_{GET} determined in the GXT. By selecting an intensity exceeding the W_{GET}, we were able to discern a visible $\dot{V}O_2$ slow component (Fig. 2A).

There are a number of shortcomings associated with the YMCA test. The assumption of the YMCA test is that oxygen uptake-power output relationship is linear. Such an assumption is flawed because the relationship is nonlinear at intensities exceeding GET (4,16,19,24,33). The YMCA test equally assumes that the HR–power output relationship is linear during the YMCA test. Thus, for many people the YMCA test yields a low estimate of $\dot{V}O_{2max}$. In the present study, there was a time-dependent rise in HR relative to time (Fig. 2B), observed in the second stage of the MSET. Previous research has indicated changes in HR with

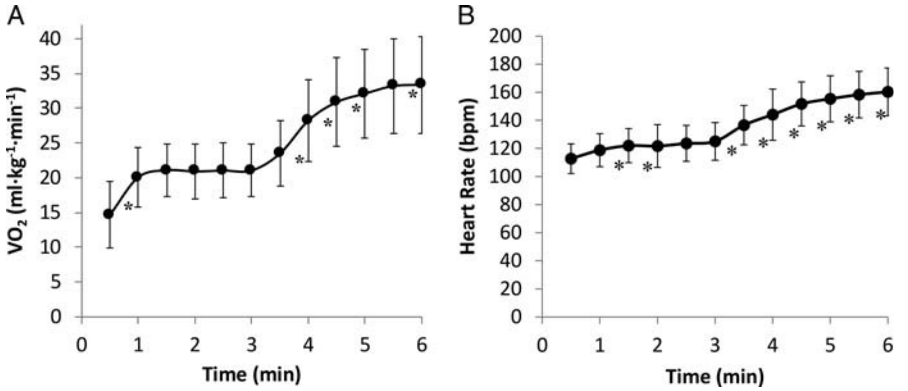

FIGURE 2—A, $\dot{V}O_2$ responses (mean ± SD) from the MSET. Note the steady state in the first stage and the $\dot{V}O_2$ slow component in the second stage. *Significant difference ($P \leq 0.05$) from preceding 30-s time sample. B, Heart rate responses (mean ± SD) from the MSET. Note the steady state in the first stage and the time-dependent rise in heart rate in the second stage. *Significant difference ($P \leq 0.05$) from preceding 30-s time sample.

changes in power output are greater for intensities above GET in comparison to intensities below GET (26).

The YMCA test prescribes predetermined intensities that fail to address differences in gender, PA-R, and age. Beekley et al. (2) observed gender differences for the YMCA protocol, including mean differences, were 9.5 and 3.9 $mL\cdot kg^{-1}\cdot min^{-1}$ for men and women, respectively (2). Observed mean differences from the YMCA test from the present study were 5.7 and 1.8 $mL\cdot kg^{-1}\cdot min^{-1}$ for men and women, respectively. Subjects from the present study exceeding 38 yr of age had mean difference of 2.8 $mL\cdot kg^{-1}\cdot min^{-1}$ for the YMCA test, whereas age did not influence the MSET (-0.2 $mL\cdot kg^{-1}\cdot min^{-1}$).

The nonexercising equation had a more favorable SEE, *r* value, typical error, and CV%, compared with either submaximal test and did not differ from "true $\dot{V}O_{2max}$" (Fig. 1 and Table 2). We must point out that the nonexercising consistently overpredicted $\dot{V}O_{2max}$, as demonstrated by the ICC (Table 3). Conversely, the MSET had a higher ICC than the nonexercising equation (0.73 versus 0.63, receptively).

To our knowledge, the present study is the first to test the validity of the YMCA test and MSET against a GXT with a square wave exhaustive verification bout to determine "true" $\dot{V}O_{2max}$. Widely used criteria for determining a successful GXT are as follows: $\dot{V}O_2$ plateau of 150 $mL\cdot min^{-1}$ or lower, an RER of 1.10 or greater, and APMHR of ±10 bpm (22). Previous research has refuted the need for a $\dot{V}O_2$ plateau to achieve a $\dot{V}O_{2max}$. For example, Day et al. (7) found that only 17% of their subjects achieved a $\dot{V}O_2$ plateau (7). Mier et al. (23) observed similar results where only 7 of the 35 college athletes tested achieved a $\dot{V}O_2$ plateau (23). Achieving an RER of 1.10 or greater has been refuted by previous research as well (21). Subjects either fail to obtain an RER of 1.10 or greater during long GXT durations (>13 min) or reach an RER of 1.10 or greater before reaching $\dot{V}O_{2max}$ (17,28). Lastly, using APMHR to determine a successful GXT has been criticized. Poole et al. (28) demonstrated that subjects within their study achieved within 10 bpm of APMHR at 76% of $\dot{V}O_{2max}$. The present study demonstrated a CV from the GXT and submaximal verification bout was 2.4%, which is consistent with previous research (17,31).

Previous study by Beekley et al. (2) raised questions about the validity of the YMCA test and, to our knowledge, is the only group to validate the YMCA test against a cycle ergometer GXT. Interestingly, their prediction error was considerably larger than our study and overpredicted the YMCA test, demonstrating a mean difference of 6.83 versus -3.96 $mL\cdot kg^{-1}\cdot min^{-1}$) (2). Beekley et al. (2) used a different APMHR equation (220 − age) for the extrapolation of their YMCA test data; the validity of this equation has been questioned (30).

Our results indicate that the MSET is valid for cycle ergometry. Therefore, we recommend research using this procedure for other modes of exercise. A noteworthy difference would be identification of a suitable prediction equation to replace equations 1 to 4 for different modes. For example, researching predicted $\dot{V}O_{2max}$ with a nonexercising equation for upper body ergometry.

There are a number of practical conveniences distinguishing MSET from the YMCA test. First, our protocol provides the freedom for the individual to select their preferred cadence. Second, the protocol is two stages and completed in 6 min, thus making the test time efficient. Third, the decision making related to setting each stage is determined before initiating the test, thus eliminating error. We have provided supplemental digital spreadsheet (http://links.lww.com/MSS/A574) so that the MSET may be administered by a wide range of practitioners.

The primary limitations of the study centered on our demographic restrictions. Most institutional review boards for the protection of human subjects are unfamiliar with the use of a verification bout for the determination of $\dot{V}O_{2max}$. Essentially, each subject is being "stressed" to their maximum effort twice within a single visit. Such a procedure, while emerging as a preferred method for determining "true" $\dot{V}O_{2max}$, is not included in leading position stands and cardiopulmonary exercise testing guidelines. Omission of the verification stage for $\dot{V}O_{2max}$ assessment is indirectly limiting procedural advancements (e.g., our review board prohibited us from testing subjects with a BMI >30 who had an added risk factor).

Assigning a stage above GET will account for the nonlinear oxygen uptake-power output relationship thereby enhancing its validity. Application of the GXT with verification has emerged as the most appropriate method for assessing submaximal test validity. In conclusion, the MSET has greater validity than the YMCA test for estimating $\dot{V}O_{2max}$ because of using demographic data for test administration.

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The results of the present study do not constitute endorsement by the American College of Sports Medicine.

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