ORIGINAL CONTRIBUTION

Predicting Cardiorespiratory Fitness Without Exercise Testing in Epidemiologic Studies: A Concurrent Validity Study

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Maximal oxygen consumption (VO$_{2}$ max) is the criterion measure of cardiorespiratory fitness. However, because it has traditionally been regarded as a costly, labor-intense measure to obtain, VO$_{2}$ max assessment has seen only limited use in epidemiological studies. Recently, methods for predicting VO$_{2}$ max have been developed that rely on a combination of self-report variables. The purpose of this study was to determine the relationship of two multivariable equations for estimating VO$_{2}$ max in a sample of 123 females (M age=38.8±8.4 yrs.). In one equation a seven-item physical activity index was used and in the other equation a single physical activity question was used. The between-formula relationship for predicted VO$_{2}$ max values was significant (r=0.80, p<0.0001). Predicted VO$_{2}$ max values were also positively related with other indices of physical activity (r=0.26 to 0.74). Preliminary results suggest there is a high degree of correlation between the two equations studied, as well as other indices of physical activity. These formulas may be of interest to epidemiologists in situations where direct methods of VO$_{2}$ max assessment are not feasible. J Epidemiol, 1996; 6: 31-35.

Assessment of cardiorespiratory fitness (i.e., maximal oxygen uptake [VO$_{2}$ max]) is of interest to epidemiologists. Direct measures of VO$_{2}$ max, however, require both specialized equipment and trained technicians to obtain. This is often not feasible in epidemiological studies. Because of this, several indirect procedures for estimating VO$_{2}$ max have been developed, validated, and reported in the literature (e.g., submaximal cycle ergometer tests, step tests, distance runs, walking tests). Even so, epidemiologists continue to be interested in developing and using completely indirect methodologies (e.g., physical activity questionnaires). Validation studies suggest that self-report vigorous exercise may be reflecting VO$_{2}$ max rather than general physical activity. For example, in the Survey of Activity, Fitness, and Exercise (SAFE) study, age- and gender-adjusted partial correlation coefficients of 0.27 to 0.56 were found between VO$_{2}$ max and multiple self-report surveys. Researchers have recently applied this knowledge and developed multivariable VO$_{2}$ max prediction equations using self-report data. Each of the published equations suggest that it is possible to predict VO$_{2}$ max using different combinations of the following variables: age, gender, body mass index (BMI), and self-report physical activity. The main difference between the equations is the manner in which physical activity is recalled. In one equation a modified version of the full-page NASA/Johnson Space Center physical activity scale is used (referent point, previous month). In the other equation, a single physical activity question is used (referent point, previous week).

The purpose of this study was to determine the relationship between estimated VO$_{2}$ max values derived from these two multivariable equations. As both formulas relied on the same conceptual set of predictor variables (with different operational measures of physical activity) it was hypothesized that the two formulas would be highly related. Moreover, it was predicted that both would be related to a number of different self-report physical activity indices.
MATERIALS AND METHODS

Participants

A concern over potentially gender-biased physical activity recall methods has been expressed in the literature. This research suggests there is a need to continue studying and developing new physical activity recall methodologies for females. As such, females employed at a single worksite were targeted for inclusion in this study (N=178). Of those solicited, informed consent and complete data were provided by 123 (69.1%). Descriptive information regarding the characteristics of the participants are shown in Table 1.

MEASURES

To predict VO2 max, the two raw score multivariable regression equations for women were used. Independently, each equation appears to be a valid predictor of directly measured VO2 max (R^2=0.78 and R^2=0.67, respectively). One equation is: Predicted VO2 max=56.363+1.921 (Physical activity rating)-0.381 (Age)-0.754 (BMI), where “Physical activity rating” is based on participants’ response to the modified version of the NASA/Johnson Space Center physical activity rating scale. The other equation is: Predicted VO2 max=55+[-0.3 (Age) + -0.6 (BMI) +1.8 (Frequency of strenuous exercise)], where “Frequency of strenuous exercise” is based on participants’ response to the question, “Considering a 7-day period (a week), how many times on average do you do strenuous exercise (heart beats rapidly) for more than 15 minutes during your free time?” In each formula, BMI was determined using the Quetelet Index (i.e., wt. kg/ht M^2).

Participants physical activity and exercise behavior was concurrently assessed using a measure of average daily free-living physical activity and a measure of weekly leisure-time exercise. On the first instrument, participants reported the amount of time spent engaged in vigorous and moderate physical activities during the previous week. On the basis of the information provided, average daily free-living physical activity metabolic equivalents (METS) were calculated by multiplying the time spent at each given intensity level by its assigned MET value (i.e., 8, 4, 1.5, and 1 for vigorous, moderate, light, and sleep activities, respectively). The instrument assumes participants sleep an average of eight hours each night and that time spent in light activity is equal to 168 hours minus the sum of the hours spent in vigorous, moderate, and sleep activity for the week. Therefore, weekly free-living physical activity METS equals the sum of: [(8* Vigorous hours) + (4* Moderate hours) + (1.5* Light hours) + (1* Sleep hours)]. To obtain average daily free-living physical activity METS, the sum of this equation is divided by seven. In multiple studies, the instrument has shown satisfactory test-retest reliability (rs=0.82 to 0.87) and validity (relation with VO2 max, r=0.61).

Table 1. Participant Characteristics

| Variate            | M   | SD  | %   |
|--------------------|-----|-----|-----|
| Age (yrs.)         | 8.8 | 8.4 | --  |
| Height (cm)        | 163.9 | 6.6 | --  |
| Weight (kg)        | 72.3 | 14.2 | --  |
| BMI (kg/m^2)       | 27.3 | 5.5 | --  |
| Ethnicity/Race     |     |     | 63.4|
| African-American   | --  | --  | --  |
| Caucasian          | --  | --  | 29.3|
| Hispanic/Latino    | --  | --  | 6.5 |
| Native American    | --  | --  | 0.8 |
| Educational Attainment |   |     | 14.6|
| High School Diploma| --  | --  | --  |
| Some College       | --  | --  | 59.4|
| Bachelor's Degree  | --  | --  | 21.1|
| Master's Degree    | --  | --  | 4.9 |
| Employed Full-time in a |   |     | 100.0|
| Clerical Occupation| --  | --  | --  |
Participants were mailed a survey instrument comprised of the aforementioned measures using the worksite’s inter-office mailing system. Through multiple mailings and phone call reminders, a 69.1% return rate was achieved (N=123).

**Analysis**

Means (M) and standard deviations (SD) were computed for each variate and Pearson’s correlation coefficients (r) were computed between variates. To determine if predicted VO2 max values differed between ethnic/racial groups, two separate one-way analysis of variance (ANOVA) were performed. Alpha was established at the p<0.05 level.

**RESULTS**

Means, standard deviations, and between-variate correlations for the 123 participants are shown in Table 2. Of the 21 correlations studied, all but one exceeded the p<.05 criterion and all correlations were in the predicted direction. ANOVA revealed no between ethnic/racial group differences for VO2 max values derived from either the Ainsworth et al.10) (F=2.15, p>0.12) or Jackson et al.11) (F=1.29, p>0.28) prediction equations.

**DISCUSSION**

In this study, two hypotheses were examined. The first was that there would be a high degree of association between estimated VO2 max values derived from two different multivariate equations. The second was that both formulas would be highly related to a number of different self-report physical activity indices. Both hypotheses were confirmed.

Most of the variables used to predict VO2 max in this study are routinely collected in epidemiological studies (i.e., age, BMI, gender). Furthermore, one of the equations10) requires only the addition of a single frequency of strenuous exercise question. In combination, this set of variables can then be entered into a multiple regression equation that allows for a surrogate measure of cardiopulmonary fitness (i.e., VO2 max). As VO2 max is a ratio level variable, it may offer epidemiologists a better mechanism (in comparison to existing nominal, ordinal, and interval level physical activity indices) for examining the relationship between morbidity, mortality, and physical fitness.

In the absence of direct gold standard comparisons to measured VO2 max, the validity of the VO2 max estimates observed within this sample are reliant upon the prior validation of these formulas. Thus, the validity of the VO2 max estimates observed are limited despite their high degree of interformula correlation and relationships with other self-report physical activity indices. The use of only female adults also should be viewed as a limitation. Future studies using more diverse and larger sample sizes will be required to determine the generalizability of the findings. Finally, as with all self-reports, data are limited by factors such as recall and item-interpretation.

The implications of this preliminary study relate to the manner in which physical activity and fitness are quantified in epidemiological studies. On the basis of the present study, the simpler physical activity measure14) may produce as valid a prediction of VO2 max as the more complex physical activity measure12,13), when used in conjunction with a multivariable regression equation10). If confirmed in future studies, this would allow for the use of the simpler method in epidemiological studies where direct methods of VO2 max measurement are not always feasible to obtain.

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| Variate | 1    | 2     | 3     | 4     | 5     | 6     | M   | SD  |
|---------|------|-------|-------|-------|-------|-------|-----|-----|
| 1.  BMI |      |       |       |       |       |       | 27.3| 5.5 |
| 2.  PAMETS | -.18*|       |       |       |       |       | 34.7| 3.1 |
| 3.  ExMETS | -.20*| .65****|       |       |       |       | 18.2| 23.4|
| 4.  PAR | -.25**| .35***| .37****|       |       |       | 0.5 | 1.5 |
| 5.  FSE | -.12 | .21* | .65****| .36****|       |       | 2.8 | 2.2 |
| 6.  VO2 max | -.73****| .35***| .39****| .74****| .26**|       | 26.5| 8.1 |
| 7.  VO2 max | -.74****| .30***| .47****| .41****| .56****| .80****| 27.9| 5.8 |

* = p < 0.05  ** = p < 0.01  *** = p < 0.001  **** = p < 0.0001

Note: Where 1 is “body mass index”16), 2 is “average daily physical activity METS”17), 3 is “weekly leisure-time exercise METS”14), 4 is “activity rating”10), 5 is “frequency of strenuous exercise”14), 6 is “predicted maximal oxygen uptake”11), and 7 is “predicted maximal oxygen uptake”10).
APPENDIX A

Physical Activity Measures

Abridged versions of each physical activity and/or exercise measure used in the present study are included in this Appendix. The original references should be consulted for unabridged versions of each measure and details regarding their appropriate use, participant directions, and scoring procedures.

Physical Activity Rating Scale 12

I. “Do not participate regularly in programmed recreation, sport, or heavy physical activity.”
0 “Avoided walking or exertion (e.g., always used the elevator, drove whenever possible).”

II. “Participated regularly in recreation or work requiring modest physical activity, such as golf, horseback riding, calisthenics, gymnastics, table tennis, bowling, weight lifting, or yard work.”
3 “Over one hour per week.”

III. “Participated regularly in heavy physical exercise such as running or jogging, swimming, cycling, rowing, skipping rope, running in place or engaging in vigorous aerobic type activity or exercise such as tennis, basketball or handball.”
5 “Ran 1 to 5 miles per week or spent 30 to 60 minutes per week in comparable physical activity.”
7 “Ran over 10 miles per week or spent over 3 hours per week in comparable physical activity.”

* Items 1, 2, 4, and 6 are available in the original instrument.

Weekly Leisure-Time Exercise Questionnaire 14

1. “Tremendous exercise (Heart beats rapidly; e.g., basketball, cross-country skiing, football, hockey, jogging, judo, roller-skating, soccer, squash, running, vigorous swimming, vigorous long distance bicycling, etc.).”
2. Moderate exercise (Not exhausting; e.g., alpine skiing, badminton, baseball, easy bicycling, easy swimming, fast walking, popular and folk dancing, tennis, volleyball, etc.).
3. Mild exercise (Minimal effort; archery, bowling, easy walking, fishing from a river bank, golf, horseshoes, snowmobiling, yoga, etc.).

Seven-Day Free-Living Physical Activity Recall Questionnaire 27

1. “Vigorous activity (e.g., jogging or running, swimming, strenuous sports such as singles tennis or racquetball, digging in the garden, chopping wood, brisk walking, etc.).”
2. “Moderate activity (e.g., sports such as golf or doubles tennis, yard work, heavy housecleaning, bicycling on level ground, etc.).”

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