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Cross-Validation of the Polar Fitness Test™ via the Polar F11 Heart Rate Monitor in Predicting VO_2 Max

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ABSTRACT

Esco MR, Mugu EM, Williford HN, McHugh AN, Bloomquist BE. Cross-Validation of the Polar Fitness Test™ via the Polar F11 Heart Rate Monitor in predicting VO_2 Max. **JEPonline** 2011;14(5):31-37. The purpose of this study was to cross-validate the Polar Fitness Test™ via the Polar F11 heart rate (HR) monitor in predicting VO_2 max in apparently healthy male volunteers. Fifty male subjects (age = 24.0 ± 5.1 yrs) volunteered to participate in the study. Each subject was instructed to assume a supine position for 10 min while the Polar F11 HR monitor predicted their VO_2 max (pVO_2 max) by way of the Polar Fitness Test. Criterion VO_2 max (aVO_2 max) was determined via a maximal graded exercise test on a treadmill. The mean values for pVO_2 max and aVO_2 max were 45.4 ± 11.3 $mL \cdot kg^{-1} \cdot min^{-1}$ and 47.4 ± 9.1 $mL \cdot kg^{-1} \cdot min^{-1}$, respectively, which were not significantly different ($p > 0.05$). The validity statistics for pVO_2 max versus aVO_2 max were $r = 0.54$ ($p < 0.05$), CE = -1.93 $mL \cdot kg^{-1} \cdot min^{-1}$, SEE = 7.69 $mL \cdot kg^{-1} \cdot min^{-1}$, TE = 10.04 $mL \cdot kg^{-1} \cdot min^{-1}$ and limits of agreement ranged from -18.0 $mL \cdot kg^{-1} \cdot min^{-1}$ to 21.8 $mL \cdot kg^{-1} \cdot min^{-1}$. Due to the moderate validation coefficient and large individual differences between the predicted and criterion VO_2 max, the Polar Fitness Test™ is limited. Therefore, one should take caution when using this method to predict VO_2 max.

Key Words: Oxygen Consumption, Aerobic Fitness, Maximal Exercise

INTRODUCTION

Maximal oxygen consumption (VO_2 max) is a measure of the body's maximum ability to take-up, transport, and use oxygen, and is considered the "gold standard" for determining an individual's aerobic fitness (15). Traditionally, VO_2 max is used to prescribe aerobic exercise intensity and assess cardiovascular adaptations to an exercise program. It is also the most useful predictor of endurance performance across the general population (15).

The precise determination of VO_2 max requires a maximal graded exercise test with direct assessment of oxygen consumption (VO_2). Unfortunately, this requires expensive equipment primarily found in exercise physiology laboratories, as well as high subject motivation. Most individuals in a fitness setting or on an athletic field do not have access to the necessary equipment. Therefore, alternative field techniques have been developed to predict VO_2 max without the use of elaborate laboratory tools.

With the advancement in technology, heart rate (HR) monitors have been developed to predict VO_2 max during the non-exercise state. The HR monitors are commonly used by individuals to measure aerobic fitness. Polar Electro Oy, Inc., a leading developer of HR monitors, has created a Polar Fitness Test™ to predict VO_2 max using self-reported variables that are programmed into the monitor by the user (i.e., age, sex, height, weight, and physical activity), in addition to those captured during a resting state by a Polar HR monitor (i.e., resting HR and heart rate variability [HRV]).

Previous investigations have examined the accuracy of Polar HR monitors in estimating energy expenditure during exercise (3,12). However, there is limited research available that has determined the accuracy of the Polar Fitness Test™ specifically for predicting VO_2 max. The purpose of this study was to cross-validate the Polar Fitness Test™ via the Polar F11 HR monitor in predicting VO_2 max in apparently healthy male volunteers.

METHODS

Subjects

Fifty male subjects volunteered to participate in the study. All subjects were free from metabolic, cardiopulmonary, and orthopedic disorders. The subjects were instructed to avoid strenuous exercise and alcohol for at least 24 hrs before data collection. They were also asked to refrain from food consumption for at least 3 hrs before the testing procedures. This study was approved by the Institutional Review Board for Human Subjects.

The descriptive statistics for all participants are presented in Table 1. Height was measured using a wall mounted stadiometer (SECA, Seca Instruments Ltd, Hamburg, Germany) and recorded to the nearest 0.5 cm. Weight was measured using a digital scale (TANITA BWB-800A, Tanita Corp, Tokyo, Japan) and was recorded to the nearest 0.5 kg. Body fat percentage (BF%) was predicted by the 7-site skinfold technique (8).

Table 1. Descriptive data of the subjects.

	Mean ± SD
Age (yrs)	24.0 ± 5.1
Height (cm)	177.3 ± 6.4
Body weight (kg)	78.7 ± 11.3
BMI ($kg \cdot m^{-2}$)	25.1 ± 3.7
Body fat (%)	9.0 ± 4.5

Procedures

The prediction of VO_2 max (pVO_2 max) was performed with the Polar Fitness Test™ via the Polar F11 HR monitor (Polar Electro Oy, Kemple, Finland). The HR monitor strap was placed around the subjects' upper thorax at the level of the xyphoid process. The subjects were then asked to assume a supine position on an athletic training table. Age, gender, height, weight, and self-reported physical activity were entered into the HR monitor. Physical activity level was defined as low, middle, high, or top as described by the subjects. Once the variables were entered into the HR monitor, the Polar Fitness Test™ began. During this time, resting HR and HRV were recorded by the HR monitor while the subjects rested quietly in the supine position. Maximal oxygen consumption (VO_2 max) was predicted by the Polar Fitness Test™, which was then automatically displayed on the HR monitor. The regression equation used by the Polar Fitness Test™ could not be found within the literature. For reliability, a test-retest procedure was performed on a cohort of 20 subjects. A strong correlation was found ($r = 0.99$, $P<0.01$).

The criterion VO_2 max (aVO_2 max) was determined via a maximal graded exercise test on a Trackmaster treadmill (Full Vision, Inc., Carrollton, TX). The Bruce protocol was followed which involved a series of 3-min stages with successive increases in speed and grade until VO_2 max was achieved. During the test, a ParvoMedics TrueOne® 2400 metabolic cart (ParvoMedics Inc., Sandy, UT) was used to determine the concentration of expired oxygen and carbon dioxide gases at the mouth with a pneumotach. Before each test, the metabolic cart was properly calibrated according to the manufacturer's instructions. Maximal oxygen consumption was reached if two of the following criteria occurred: a plateau in VO_2 (< 2.0 $mL{\bullet}kg^{-1}{\bullet}min^{-1}$) with increasing work rate; RER $\geq$ 1.15; HR within 10 beats of age predicted maximum (220 – age), using the Polar F11 HR monitor; or volitional fatigue.

Statistical Analyses

All statistical analyses were completed using SPSS/PASW version 18.0. Means ± SD were determined for pVO_2 max and aVO_2 max. A Paired samples t-test was used to determine the mean difference between pVO_2 max and aVO_2 max. Pearson product correlation coefficient (r), constant error (CE), standard error of estimate (SEE), and total error (TE) were calculated for the pVO_2 max versus aVO_2 max. Bland-Altman plots (2) were used to identify the 95% limits of agreement between the criterion and predicted VO_2 max values. Statistical significance was set at $P = 0.05$.

RESULTS

Mean values for pVO_2 max and aVO_2 max were 45.4±11.3 $mL{\bullet}kg^{-1}{\bullet}min^{-1}$ and 47.4±9.1 $mL{\bullet}kg^{-1}{\bullet}min^{-1}$, respectively. A paired t-test showed that the mean difference between the VO_2 max values was not significantly different ($p = 0.18$). The validity statistics for pVO_2 max versus aVO_2 max were $r = 0.54$ ($p < 0.05$), CE = -1.93 $mL{\bullet}kg^{-1}{\bullet}min^{-1}$, SEE = 7.69 $mL{\bullet}kg^{-1}{\bullet}min^{-1}$, and TE = 10.04 $mL{\bullet}kg^{-1}{\bullet}min^{-1}$. Bland-Altman Plots showed that the mean bias for the pVO_2 max was 1.9 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$ and the 1.96 SD of the bias ranged from -18.0 $mL{\bullet}kg^{-1}{\bullet}min^{-1}$ to 21.8 $mL{\bullet}kg^{-1}{\bullet}min^{-1}$ (refer to Figure 1).

DISCUSSION

The primary feature of the Polar Fitness Test™ is the prediction of VO_2 max during non-exercise conditions. This is appealing to practitioners due to its potential in monitoring physiological changes in response to endurance training and providing important information for exercise prescriptive purposes without the need for expensive, elaborate laboratory equipment.

The results of the study suggest no statistically significant mean difference between pVO_2 max and aVO_2 max. However, the SEE of 7.69 mL•kg^{-1}•min^{-1} equals a 16.2% standard error and the TE of 10.04 mL·kg^{-1}·min^{-1} corresponds to 21.2% of total error. Furthermore, the most notable finding was that, according to the Bland-Altman method, the random error range was large. The 95% limits of agreement fall between 18.0 mL·kg^{-1}·min^{-1} below to 21.8 mL·kg^{-1}·min^{-1} above the mean aVO_2 max. This is a range of 39.8 mL•kg^{-1}•min^{-1}. This finding suggests that from an individual perspective, predicted VO_2 max can be anywhere from 38% above to 46% below actual VO_2 max. Therefore, caution should be employed when using the Polar F11 to predict VO_2 max on an individual basis. In support of our results, a previous study also showed no significant mean difference between criterion VO_2max determined by a treadmill graded exercise test to predict VO_2 max by the Polar M52 heart rate monitor (4). Nonetheless, the SEE of 8.50 mL•kg^{-1}•min^{-1} in their study corresponded to an 18% standard error (4). It appears that the use of the Polar Fitness Test™ is limited.

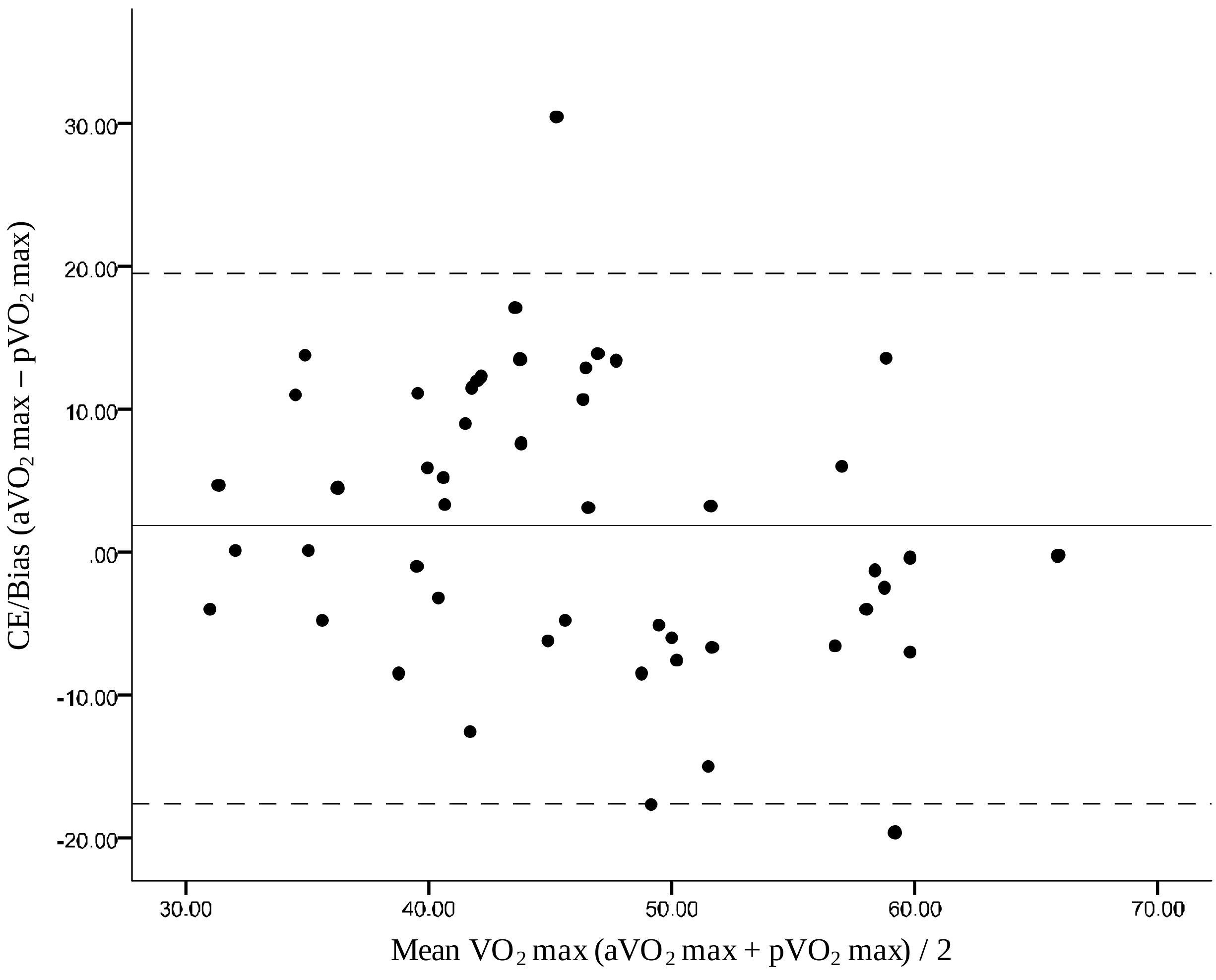

Figure 1. Bland Altman plot comparing the pVO_2 max value with the criterion value (i.e., aVO_2 max). The middle line indicates the mean difference between predicted and the actual VO_2 max values; the two outside dashed lines indicate the ± 1.96 SD of the difference.

The results of previous investigations that cross-validate other commonly used non-exercise field estimates of VO_2 max report prediction errors much less than our findings. Heil and colleagues (6) cross-validated a non-exercise model that utilized age, gender, percent body fat, and physical activity rating to predict peak oxygen consumption. They found a SEE of 4.90 mL•kg^{-1}•min^{-1} which corresponds to 12.7% of VO_2 max (6). Malek et al. (13) reported SEE and TE values of about 10% to 13% when they cross-validated several commonly used non-exercise VO_2 max prediction equations among measurements of VO_2 max from cycle ergometry. Jackson and colleagues (7) developed two multiple regression models that predicted functional aerobic capacity (i.e., VO_2 peak) without the use of exercise testing. Cross-validation of the models resulted in SEE values of between 5.00 to 5.70 $mL \cdot kg^{-1} \cdot min^{-1}$ and TE values of between 6.30 to 6.90 $mL \cdot kg^{-1} \cdot min^{-1}$ (7,19). It appears that the non-exercise regression models mentioned above show similar accuracies to models that employ submaximal exercise protocols (9,13,19). Thus, when predicting VO_2 max via established non-exercise methods, acceptable SEE and TE values are considerably lower than the values found when cross-validating the Polar Fitness Test™ in the current study. Practitioners should seek other alternatives and valid methods for predicting VO_2 max in field settings rather than the Polar Fitness Test™.

As mentioned previously, the Polar Fitness Test™ predicts VO_2 max with the use of HRV. The assumption that VO_2 max is related to HRV may be a potential source of error. Some researchers have found a significant relationship between HRV and aerobic power (1,14,20) while others have not (11,17). One possible explanation for the discrepancy, as well as the large limits of agreement found in the current study, may be related to the association of VO_2 max, HRV, and respiratory rate (5). For example, Melanson and Freedson (14) reported an increase in HRV after a 12-wk endurance training program. Pre- and Post-HRV assessments were performed under a paced breathing condition (e.g., 10 $breaths \cdot min^{-1}$). The results are in agreement with other studies showing endurance training-induced improvements of HRV assessed during paced-breathing circumstances (1,20).

On the other hand, Liomaala et al. (11) reported no change in HRV after 5-months of aerobic training, but breathing rate does not appear to be controlled for in the study. Furthermore, Lee et al. (10) examined the effect of a short-term, 2-wk endurance training program on HRV that was assessed under differing conditions that included paced versus non-paced breathing states. After the endurance training program, HRV was shown to be improved during the paced-breathing condition, but no change was reported during non-paced, spontaneous breathing (10). This shows the importance of accounting for breathing rate when examining the relationship between HRV and VO_2 max. Current instructions for the Polar Fitness Test™ do not require attention given to pace breathing. Perhaps controlling for breathing pattern may improve the accuracy of the Polar Fitness Test™ in predicting VO_2 max. More research is warranted to explore the importance of adding HRV to non-exercise VO_2 max prediction equations. Similar to the current study, Turner et al. (16) also reported a large SEE (i.e., 7.68 $mL \cdot kg^{-1} \cdot min^{-1}$ or 17%) with a comparable HR monitor that also incorporated HRV in the VO_2 max prediction equation. They concluded that VO_2 max predictions made by equations that include HRV are not valid (16).

The addition of other variables may improve upon the accuracy of the Polar Fitness Test™ in predicting VO_2 max. For example, it is well known that body composition is strongly related to aerobic power. Thus, non-exercise regression models commonly use selected body composition variables for predictive purposes (6,7). When body fat percentage is added to a non-exercise VO_2 max regression model, it yields a greater prediction accuracy compared to different non-exercise models that incorporate other body composition parameters (7,18). Since the Polar Fitness Test™ uses height and weight as prediction variables, retrospective correlations were evaluated in the current study between aVO_2 max and the following selected body composition parameters: height, weight, BMI, and body fat percentage. This analysis showed that body fat percentage had the strongest relationship to aVO_{2max} ($r = -0.57$, $P < 0.01$) compared to height ($r = 0.08$, $P > 0.05$), weight ($r = -0.45$, $P < 0.01$), and body mass index ($r = -0.50$, $P < 0.01$). Body fat percentage was therefore the greatest body composition predictor of VO_2 max. Due to these findings, it is reasonable to conclude that the addition of body fat percentage to the regression equation should improve upon the accuracy of the Polar Fitness Test™ in predicting VO_2 max.

This present study used a sample of mostly young-adult men and only examined the accuracy of the Polar F11 HR monitor. It would not be appropriate to generalize the findings to women and other HR monitoring devices. However, although we found no significant difference in mean VO_2 max between the criterion and prediction methods, Lowe et al. (12) actually found a significant difference between mean VO_2 max predicted with the Polar F6 HR monitor and actual VO_2 max in a group of female subjects.

CONCLUSIONS

This investigation sought to determine the accuracy of the Polar Fitness Test™ via the Polar F11 HR monitor for predicting VO_2 max in a group of male subjects. Due to the large individual differences between the predicted and criterion VO_2 max, one should take caution when using the Polar Fitness Test™ for predicting VO_2 max. Practitioners should be aware of the limitations of the Polar Fitness Test™ for predicting VO_2 max in individuals. Individual fitness levels may be greatly under- or over-predicted by several fitness categories using this method. Misrepresentation of actual VO_2 max could be problematic, especially if determining exercise intensity based on the VO_2 max predictions made by the Polar Fitness Test™.

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