THE UNIVERSITY OF ALABAMA KINESIOLOGY

Accuracy of Estimating VO_{2max} from Time to Exhaustion during the Bruce Treadmill Protocol in Male Recreational Runners

Logan Minor, Andrew D. Fields, Matthew A. Mohammadnabi, Michael R. Esco

The University of Alabama, Department of Kinesiology

Abstract

PURPOSE: The purpose of this study was to determine the accuracy of estimating VO_{2max} from time to exhaustion during the Bruce treadmill protocol in adult male recreational runners. **METHODS:** Nine male recreational runners (age = 22.6 ± 5.4 years, height = 163.8 ± 6.4 cm, weight = 83.8 ± 10.8 kg) participated in the study and completed a Bruce treadmill protocol. Observed VO_{2max} was verified using direct oxygen consumption analysis via a metabolic cart during both protocols. A previously developed equation was used to estimate VO_{2max} by using the time to exhaustion as the prediction variable as follows: Predicted $VO_{2max} = 14.8 – (1.379 \times T) + (0.451 \times T^2) – (0.012 \times T^3)$, where T is the total time of the test. **RESULTS:** The mean ± SD observed and predicted VO_{2max} values were 49.9 ± 4.8 ml·kg⁻¹·min⁻¹ and 46.8 ± 2.5 ml·kg⁻¹·min⁻¹, respectively. Paired samples T-test revealed that these mean values were significantly different (p = 0.03) and Cohen'd procedure showed an effect size of 0.81. The correlations between the observed and predicted VO_{2max} values were significant (r = 0.76, p < 0.05) and the standard error of estimate (SEE) was 3.4 ml·kg⁻¹·min⁻¹. Limits of agreement (LOA) procedures demonstrated a 95% confidence interval (constant error ± 1.96 SD) of -3.1 ± 6.5 ml·kg⁻¹·min⁻¹. **CONCLUSION:** The results of this study suggest that estimating VO_{2max} from time to exhaustion during the Bruce treadmill protocol yields significantly lower values compared to direct oxygen consumption assessment. However, the significant correlation, small standard error of estimate (SEE), and limits of agreement (LOA) values indicate that the method may be reasonably accurate for use in recreational runners when a metabolic cart is unavailable. **PRACTICAL APPLICATION:** For practitioners, the use of time to exhaustion during the Bruce treadmill protocol provides a simple and reliable alternative for estimating VO_{2max}, making it a useful tool for evaluating cardiovascular fitness in recreational runners without the need for expensive metabolic cart equipment. However, due to significantly lower mean values compared to direct oxygen consumption assessment, a correction factor may be necessary. Future research with a larger and more diverse sample is warranted.

Introduction

- Maximal oxygen uptake (VO_{2max}) is widely regarded as the gold standard indicator of cardiorespiratory fitness and aerobic performance capacity (1-5).
- Direct measurement of VO_{2max} using open-circuit spirometry and a metabolic cart provides the most accurate assessment, but it requires specialized equipment, trained personnel, and can be logistically challenging, especially in field or clinical settings.
- As a result, various submaximal and field-based prediction equations have been developed to estimate VO_{2max} using performance indicators such as heart rate, workload, and time to exhaustion (1,4,5).
- One commonly used laboratory-based protocol is the Bruce treadmill test, a graded exercise test that increases in intensity every three minutes until volitional fatigue.
- Previous research has proposed predictive equations that estimate VO_{2max} from the total duration of this test (1).
- While these equations offer a convenient alternative to direct measurement, their accuracy and agreement with observed VO_{2max} values in recreational populations remain unclear.
- Therefore, the purpose of this study was to determine the accuracy of estimating VO_{2max} from time to exhaustion during the Bruce treadmill protocol in adult male recreational runners and compare predicted values to directly measured VO_{2max}.

Methods

- Nine male recreational runners (age = 22.6 ± 5.4 years, height = 163.8 ± 6.4 cm, weight = 83.8 ± 10.8 kg) participated in the study and completed a Bruce treadmill protocol.
- Observed VO_{2max} was verified using direct oxygen consumption analysis via a metabolic cart during both protocols.
- A previously developed equation was used to estimate VO_{2max} by using the time to exhaustion as the prediction variable as follows:

$$\text{Predicted } VO_{2max} = 14.8 – (1.379 \times T) + (0.451 \times T^2) – (0.012 \times T^3), \text{ where T is the total time of the test.}$$
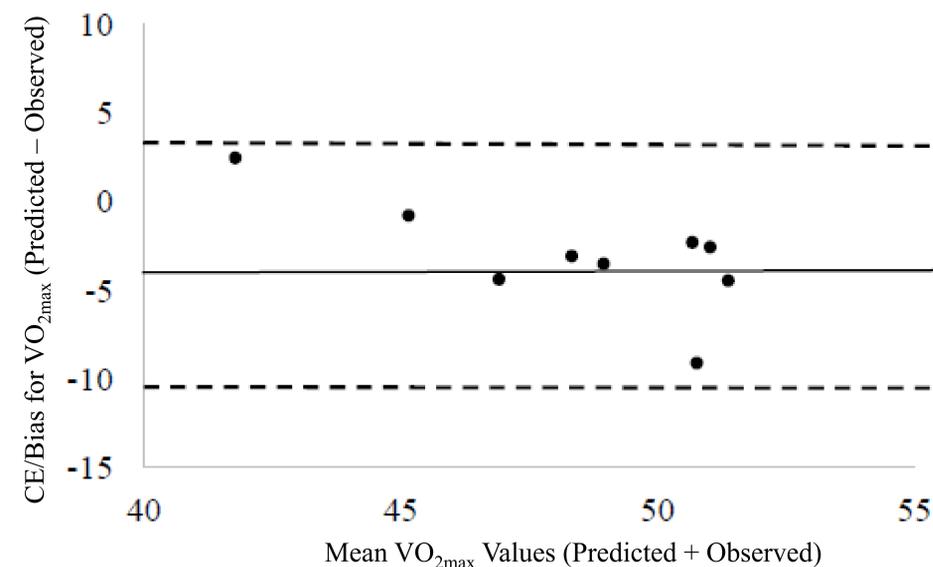
Results

Table 1. Agreement statistics comparing predicted and observed VO_{2max}. (ml·kg⁻¹·min⁻¹)

	Mean ± SD	p	ES	r	SEE	CE ± 1.96 SD	Upper	Lower
Observed	49.9 ± 4.8							
Predicted	46.8 ± 2.5	0.03	0.81	0.76*	3.4	-3.1 ± 6.5	3.4	-9.6

SD = standard deviation, p = probability, *r* = correlation coefficient, SEE = standard error of the estimate, CE = constant error.

*Indicates statistical significance for correlation (p < 0.05)

Figure 1. Bland-Altman plots comparing predicted and observed VO_{2max} measurements. The solid line represents the constant error (CE). The dashed lines represent the upper and lower 95% limits of agreement.

Conclusions

- This study found that VO_{2max} values estimated from time to exhaustion during the Bruce treadmill protocol were significantly lower than directly measured values using a metabolic cart in recreational male runners.
- While the average difference was statistically significant, the prediction equation demonstrated a strong positive correlation with observed VO_{2max}, a moderate effect size, a relatively low standard error of estimate, and acceptable limits of agreement.
- These results suggest that, although the prediction method tends to underestimate VO_{2max}, it does so in a consistent and predictable manner.
- Therefore, it may still serve as a practical estimation tool when direct measurement is not feasible.
- The underestimation bias could be addressed in future research through development of population-specific correction factors or modified prediction equations.

Practical Applications

- The prediction equation in this study uses time to exhaustion during the Bruce treadmill protocol to estimate VO_{2max} (1).
- This method provides practitioners with a simple and reasonably accurate alternative for estimating VO_{2max} in recreational runners.
- Therefore, it appears to be a useful tool for evaluating cardiovascular fitness without the need for expensive metabolic cart equipment.

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