RESEARCH ARTICLE

International Journal of
PHYSICAL EDUCATION, FITNESS AND SPORTS

DOI: 10.26524/ijpefs19110

Comparison of Cardiorespiratory Fitness Prediction Models in Young Adults Running head: Comparison of VO_2 max Prediction Models

Received 12th September 2018
Accepted 16th January 2019

www.ijpefs.com

Elizabeth Ann Tanner [a,*], **James W. Navalta** [b]

[a] Department of Biological Sciences, University of North Texas, 1155 Union Circle #305220 Denton, Texas 76203-5017.
[b] Associate Professor, Department of Kinesiology and Nutrition Sciences, University of Nevada, Las Vegas, 4505 S. Maryland Pkwy. Las Vegas, NV 89154
*Corresponding Author Email: elizabeth.tanner@unt.edu

Abstract: to compare the predictive accuracy of regression models for a non-consecutive day VO_2max/Wingate testing protocol and a same day testing protocol. Participants (N=23) completed a treadmill GXT and Wingate cycle test. Participants (n=12) completed testing on non-consecutive days (NON) and (n=11) the same day (SAME). VO_2max (L/min) and peak power (PP) were collected. Linear regression analysis of NON revealed R^2=0.808 and prediction equation $\hat{Y}$=1.499+0.004X and SAME showed R^2=0.861 and prediction equation $\hat{Y}$=1.407+0.003X. NON standard error of estimate (SEE) and standard error of estimate percent (SEE %) were 0.62 L/min and 15.23%, respectively. SAME SEE and SEE% were 0.34 L/min and 10.98%, respectively. These results indicate PP obtained the same day of VO_2max testing is a better predictor of cardiorespiratory fitness. Similarly, the SAME model is more accurate according to SEE and SEE%. This may be due to diminished effects of training adaptations that could occur 2-7 days between testing sessions during the NON testing protocol in healthy, active young adults.

Key Words: VO_2 max, Wingate, Regression analysis.

1. Introduction

Maximal oxygen consumption (VO_2max) represents the maximum rate the body can utilize oxygen [1-2]. The most common laboratory method to determine VO_2max is indirect calorimetry through a gas analysis system. According to the American College of Sports Medicine, VO_2max is an accepted method of measuring cardiorespiratory fitness and is often accepted as the superior method of assessment [1, 3] Exercise physiologists observed that increases in workrate caused increases in oxygen consumption. However, it was Hill and his colleagues who discovered that there is a point at which oxygen consumption can no longer increase with an increase in workrate [4]. This phenomenon is attributed to the physiological limitations of the cardiorespiratory system and this point is now referred to as VO_2max [1-3] Due to the connection between VO_2max and cardiorespiratory fitness, VO_2max testing has become the primary method of assessment in athletes and individuals with cardiovascular conditions [1]. The graded exercise test (GXT) is widely considered superior at eliciting VO_2max. During a GXT, as intensity increases the pathways of energy production switch from primarily aerobic to anaerobic until VO_2max is attained [3].

The Wingate cycle test is considered the superior testing method to obtain anaerobic power measures [5]. It is designed to evaluate the maximal capacity of anaerobic energy systems being utilized by active muscle tissue [5, 2]. Based on the energy systems being utilized during a GXT and Wingate cycle test it has been shown that peak power is a good predictor of VO_2max [6]. The protocol used in this pilot incorporated several days between GXT and

Wingate testing sessions. It is unclear whether a non-consecutive testing day protocol produces a more accurate predictive model compared to a same day testing protocol. Therefore, the purpose of the current study was to develop and compare the predictive accuracy of a regression model for a non-consecutive day testing protocol and a same day testing protocol. We hypothesized the regression model generated from the same day testing protocol would provide a more accurate prediction of VO_2max from peak power compared to the model generated from a non-consecutive day testing protocol.

2. Methods

2.1 Participants

Twenty-three participants were recruited to complete a treadmill GXT and 30 second Wingate cycle test. Twelve participants (age 22.83±2.48 years; height 171.80±5.28 cm; weight 75.98±13.58 kg) completed testing on non-consecutive days (NON) and eleven participants (age 23.55±2.54 years; height 165.62±9.99 cm, weight 67.26±14.21 kg) completed testing on the same day (SAME). Qualifying participants met the following criteria: male 18-44 years of age or female 18-54 years of age, and classified as 'low' risk according to the ACSM Health Risk Questionnaire. Participants were excluded if they were classified as 'moderate' or 'high' risk. All participants completed approved institutional review board informed consent documentation prior to participation in study protocols.

2.2 Protocol

Participants reported to the exercise physiology laboratory to provide demographic information (age, gender), and anthropometric measures were taken (height, weight) using a stadi-o-meter (Novel Products, Inc., Rockton, IL) and scale (Mettler Toledo, Columbus, OH) respectively. The NON group (n=12) completed the GXT and Wingate cycle tests ≥48 hours apart. Participants were fitted with a Polar heart rate monitor (Polar H7, Polar Electro, Lake Success, NY), headgear and mouthpiece. Once properly fitted, participants were connected to a metabolic cart system including a treadmill (L7, Landice, Randolph, NJ), a Hans-Rudolph valve/mouthpiece, metabolic gas analyzers, and software (Moxus, AEI Technologies, Pittsburgh, PA). Participants were given a 3 minute warm up period at 80.4 m/min (3 mph) and 0% grade. After the warm up period, participants were instructed to run at a self-selected pace. The test commenced once the self-selected pace was obtained. Speed remained constant throughout the test and the grade increased 3% every 3 minutes until volitional fatigue. All participants were given similar encouragement throughout the test. The second session was scheduled ≥48 hours from the first testing session. During this session, participants were instructed to adjust the seat height of the Wattbike so the knee was slightly bent (approximately 5°) at fullest extension (Wattbike Pro, Wattbike, Nottingham, UK). Once adjusted, participants were given a 3 minute warm up period with air and magnetic resistance set at 1. After the warm up period, participant's weight was input into the 30" cycle test program to determine the amount of resistance to be applied to the flywheel during the test. Air and magnetic resistance settings were given by the test program based on each participant's weight. The resistance was adjusted according to program specifications and represented a workload that was equivalent to 7.5% of the body mass. Once the resistance was adjusted the test initialized and the participant began the test with the objective to complete as many revolutions as possible within 30 seconds. All participants were given appropriate encouragement for the duration of the test. At the completion of the test, participants were instructed to continue pedaling against air and magnetic resistance of 1 to cool down. Participants were given 3-5 minutes to cool down. The SAME group (n=11) completed both the GXT and Wingate cycle tests on the same day. Participants were fitted with a Polar heart rate monitor, headgear and mouthpiece then connected to the metabolic cart system. Participants began the GXT by walking at 80.4 m/min (3 mph) at 0% grade for 2 minutes to warm up. After the warm up period, speed was increased to 134.1 m/min (5 mph) at 0% grade for 2 minutes. After this interval, speed was increased to 160.9 m/min (6 mph) and remained constant for the duration of the test while grade was increased 2% every 2 minutes until volitional exhaustion. All participants were given similar encouragement throughout the test. Once the test ended participants were given a rest period of 15-20 minutes. After this rest period participants completed the Wingate cycle test protocol as described above.

3. Statistical Analysis

Independent t-tests were used to establish that VO_2max was elicited in each group reported as mean ± standard deviation. Prediction equations were determined by simple linear regression. Standard error of estimate (SEE) and standard error of estimate percent (SEE%) were computed to compare the predictive accuracy of the regression models. SEE shows the variance between observed VO_2max values and the predicted values. Regression models with lower calculated SEE values have greater predictive accuracy than models with higher Values when the models are generated from the same sample population. In order to compare the accuracy of prediction models generated from different sample populations, as in the current study, SEE% must be compared. SEE% was calculated using the following equation: SEE% = (SEE/mean $\dot{V}O_2max$) x 100 [7]. All statistical analyses were done using IBM SPSS Statistics 23 software (IBM SPSS Statistics 23, IBM Corporation, and Armonk, NY).

4. Results

Simple linear regression analysis of NON revealed R^2=0.808 and prediction equation $\hat{Y}=1.499+0.004X$ (Figure 1) and SAME showed R^2=0.861 and prediction equation $\hat{Y}=1.407+0.003X$ (Figure 2). NON SEE and SEE% were 0.62 L/min and 15.23%, respectively. SAME SEE and SEE% were 0.34 L/min and 10.98% respectively. VO_2max (L/min) and RER were significantly higher in the NON group. F_EO_2, F_ECO_2, and HR were not significantly different between groups (Table 1).

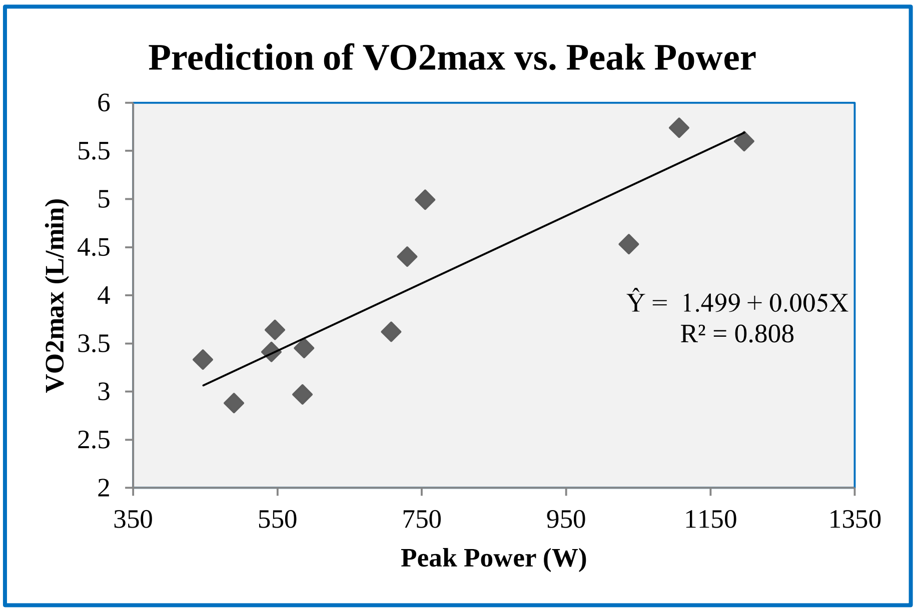

Figure 1. Simple linear regression for VO_2max predicted from PP for NON group (n = 12).

Table 1. Mean VO_2max parameters for NON and SAME groups

Group	VO_2max (L/min)	F_EO_2 (%)	F_ECO_2 (%)	RER	Maximal HR (bpm)
NON	4.05±0.98*	17.42±0.28†	3.87±0.32†	1.12±0.07*†	189.11±10.17‡
SAME	3.13±0.85*	17.36±0.57	3.73±0.59	1.05±0.03*	191.91±4.95

Note: * indicates significant difference between NON and SAME groups (p<0.05).
†n=11 due to lost data. ‡n=9 due to lost data.

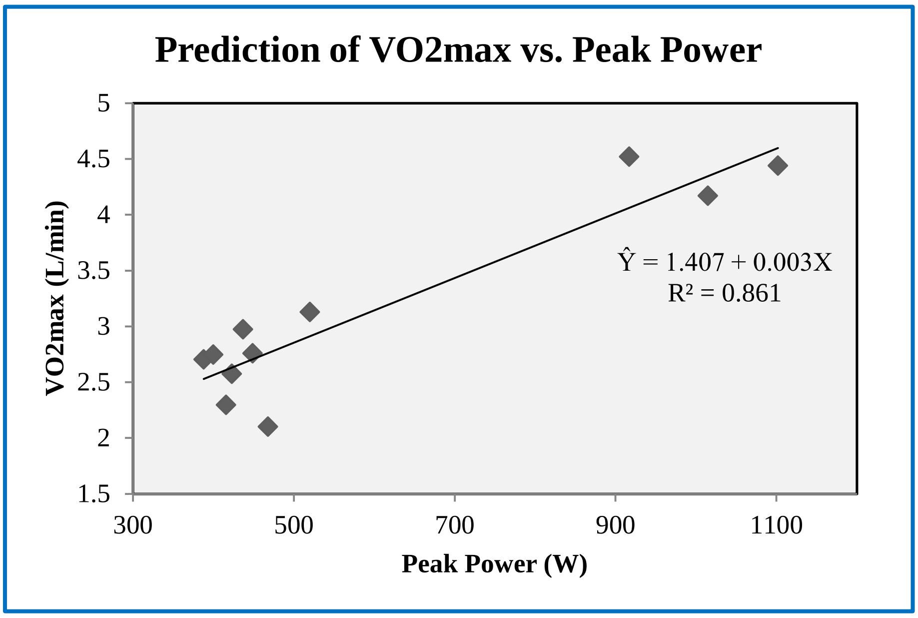

Figure 2. Simple linear regression for VO_2max predicted from PP for SAME group (n = 11).

5. Discussion

The purpose of the current study was to compare the predictive accuracy of VO_2max prediction equations for a non-consecutive day testing protocol and a same day testing protocol. We hypothesized the regression model developed for the same day testing protocol would provide a more accurate prediction of VO_2max. Results showed that PP obtained during the SAME protocol accounted for 86.1% of the variance in the predicted values for VO_2max while PP measured during the NON protocol accounted for 80.8%. This indicates PP obtained the same day of VO_2max testing is a better predictor of cardiorespiratory fitness. The accuracy of NON and SAME regression models as determined by SEE were 0.62 L/min and 0.34 L/min, respectively. These data show the variance between predicted and measured VO_2max values. Application of NON SEE to a reference individual (70 kg) results in an error of 8.86 $ml \cdot kg^{-1} \cdot min^{-1}$ or 2.5 METs. The same application of SAME SEE to a 70 kg individual results in a 4.86 $ml \cdot kg^{-1} \cdot min^{-1}$ or 1.4 METs error in the predicted value. To compare the accuracy of these regression models SEE% was used, which showed the model generated from the SAME protocol is 4.25% more accurate than the NON protocol model.

To date no research has compared the predictive accuracy of regression models for non-consecutive day exercise protocols and same day protocols. The vast majority of predictive modelling research has investigated the development of regression models for VO_2max from a variety of aerobic capacity testing modalities. The predictive accuracy of these models is typically compared to others in order to determine which is the best prediction method for the desired outcome [8-13]. Due to the novelty of the current study there is no literature, to our knowledge, to compare the results found for the comparison of NON and SAME exercise testing protocols. Therefore our conclusions are made solely on the results of this investigation.

Based on the results, a SAME exercise testing protocol provides a more accurate predictive model than a NON exercise testing protocol. This may be due to the diminished effect of potential training adaptations that could occur 2-7 days between testing sessions during the NON testing protocol in healthy, active young adults. The data obtained during the SAME protocol does not allow these potential adaptations to occur. Therefore, the data obtained provides cardiorespiratory fitness (VO_2max) and peak anaerobic power (PP) when the participant is at the same physical fitness and minimizes any confounding changes in fitness level. However, comparing predictive accuracy of prediction equations developed from two separate sample populations usually provides little insight into generalizability. In situations when comparing equations generated from the same sample population are not feasible, the comparison of equations is still possible by using SEE%. Therefore, inaccuracies of comparing regression models developed from two different groups are reduced in the current study.

Continued research into prediction exercise testing methods should extend to other cardiorespiratory fitness prediction studies. As noted above, the majority of cardiorespiratory fitness prediction research has focused on determining regression models for a variety of different modalities (recumbent stepping, walking, cycling, etc.) [8-13]. Studies which used a NON exercise testing protocol should be reassessed utilizing a SAME exercise testing protocol to determine whether the results of the current study extend to other modalities. It may also be beneficial to develop multiple linear regression equations for cardiorespiratory fitness utilizing the same protocols outlined in this investigation to elucidate whether the findings are limited to simple linear regression analysis. Most importantly this design should be repeated with a larger sample size composed of the same individuals. A larger sample size will provide more accurate regression models while participants that complete both the NON and SAME protocols will provide a better analysis of predictive accuracy. Extended investigations into this area will allow those conducting cardiorespiratory fitness prediction research insight into exercise testing sequence and time frame along with testing modality.

6. Conclusion

To our knowledge there is no current research focused on assessing the predictive accuracy of regression models for non-consecutive day and same day high-intensity exercise testing. The current study provides a unique insight into the execution of data collection for future predictive modelling research. We found the same day exercise testing protocol produces a 4.25% more accurate predictive model compared to the non-consecutive day exercise testing protocol for cardiorespiratory fitness. From a practical standpoint, same day testing is more efficient for both researchers and participants, in that there is reduced travel and equipment calibration time associated with a multiple day testing format. These findings provide evidence that same day testing is appropriate when further research into the prediction of maximal oxygen consumption from a high-intensity anaerobic test is carried out (i.e. in a wider sampling of the population, special populations groups, etc.). It is likely that same day testing minimizes the influence of potential training adaptations that may have occurred between testing sessions during non-consecutive testing days. These results add to the body knowledge by providing evidence for predictive modelling study design. Future predictive modelling in cardiorespiratory fitness and other areas now have a guide for appropriate exercise testing sequence and time frame to improve predictive accuracy.

References

[1] C. Akalan, L. Kravitz, R. R. Robergs, $\dot{V}O_{2max}$: Essentials of the most widely used test in exercise physiology, *ACSM'S Health & Fitness Journal,* 8 (2004) 5-9.

[2] S. K. Powers, E. T. Howley, (2009) Exercise Physiology Theory and Application to Fitness and Performance, *McGraw-Hill Higher Education*, New York.

[3] E. T. Howley, Jr. D. A. Basset, H. G. Welch, *Criteria for maximal oxygen uptake: review and commentary, Medicine and Science in Sports and Exercise,* 27 (1995) 1292-1301.

[4] A. V. Hill, H. Lupton, Muscular Exercise, Lactic acid, and the Supply and Utilization of Oxygen, *Ergebnisse der Physiologie,* 16 (1923) 135-171.

[5] J. F. Patton, A. Duggan, An Evaluation of Tests of Anaerobic Power, *Aviation Space and Environmental Medicine*, 58 (1987) 237-242.

[6] E.A. Tanner, J.W. Navalta, (2016) Prediction of Cardiorespiratory Fitness from Maximal Anaerobic Capacity, Poster presented at the Annual Meeting of the Southwest American College of Sports Medicine, Costa Mesa, CA.

[7] P. B. Palmer, D. G. O'Connell, Regression analysis for prediction: Understanding the process, *Cardiopulmonary Physical Therapy Journal*, 20 (2009) 23-26.

[8] B. E. Ainsworth, M. T. Richardson, D. R. Jacobs, A. S. Leon, Prediction of cardiorespiratory fitness using physical activity questionnaire data, *Medicine Exercise Nutrition and Health,* 1 (1992) 75-82.

[9] K. H. Cooper, A Means of Assessing Maximal Oxygen Intake Correlation Between Field and Treadmill Testing, *Journal of the American Medical Association,* 203 (1968) 135-38.

[10] J. D. George, W. J. Stone, L. N. Burkett, Non-exercise VO2max estimation for physically active college students, *Medicine and Science in Sports and Exercise,* 29 (1997) 415-423.

[11] J. S. Maritz, J. F. Morrison, J. Peter, H. B. Strydom, C. H. Wyndham, A practical method of estimating an individual's maximal oxygen intake, *Journal of Ergonomics,* 4 (1961) 97-122.

[12] J. McCulloch, D. Lorenz, M. Kloby, S.C. Aslan, M. Love, D. Terson de Paleville, Prediction of maximal oxygen consumption from rating of perceived exertion (RPE) using a modified total-body recumbent stepper, *International Journal of Exercise Science,* 8 (2015) 414-424.

[13] R. Ramsbottom, J. Brewer, C. Williams, A progressive shuttle run test to estimate maximal oxygen uptake, *British Journal of Sports Medicine,* 22 (1988) 141-44.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors

Competing Interests: The author declares to have no competing interests

About The License