



The Validity of the PACER Test for Predicting Maximal Oxygen Consumption

Brian Clausen, Matthew Beeler

Physical Education and Human Performance Department, Hastings College, Hastings, NE



Abstract

BACKGROUND: Indirect calorimetry has been a staple and criterion measure for estimating maximal oxygen consumption (VO₂max) in athletes. However, equipment to perform this test is costly and requires training and personnel. The Progressive Aerobic Capacity Endurance Run (PACER), was developed in 1982 and is designed to estimate VO₂max using a 20-meter shuttle run and is traditionally used to evaluate youth, although it is used in adult populations. Little evidence currently exists validating the PACER test in adult athletes, specifically highly trained aerobic endurance athletes who participate in continuous exercise events. **PURPOSE:** To determine the validity of the PACER test when compared to the criterion measure of indirect calorimetry using a graded exercise test (GET). **METHODS:** 7 collegiate cross country male athletes were recruited (Age: 20.4 ± 1.3, Height: 1.74 ± 0.08, Weight: 65.2 ± 14.3). A randomized experimental design was utilized to compare the criterion measure for VO₂max with the VO₂max as estimated by the PACER test. Subjects completed two testing sessions separated by no less than 24 hours. In one session, subjects completed the PACER test as described in the FitnessGram protocol. This consists of a 20-meter shuttle run that progressively increases the pace of running at set intervals until the subject cannot maintain the pace or voluntarily ends the test. The GET consisted of running on a treadmill using the Bruce treadmill protocol, which is a progressive staged exercise that increases in speed or grade every three minutes until volitional failure. A Parvomeds metabolic cart was utilized to measure oxygen consumption of the participants. All tests were taken to volitional failure. For the day of testing, subjects were asked to monitor their food with a food log, and replicate their meals between the two days of testing. Upon arrival, subjects completed a hydration USG test, food, sleep, footwear, and caffeine questionnaire. Subjects did a 10-minute dynamic warm up. They then performed their test until volitional failure. To compare the validity of the PACER test, we used Bland-Altman analysis to calculate the bias and limits of agreements between the two tests and performed a linear regression analysis. **RESULTS:** Figure 1 shows the results of the Bland-Altman analysis. The results of the Bland-Altman analysis shows that PACER has a bias of -4.3 ± 8.1 mL/kg/min and the limits of agreement (LOA) were -20.2 and 11.5. The results of the regression analysis showed VO₂max is not significantly predicted by the PACER. **CONCLUSIONS:** The PACER test is not a valid way to test VO₂max in endurance athletes. When interpreting the bias and LOA, we see that on average the PACER test underestimated VO₂max by 4.3 mL/kg/min. The LOA show that the true mean difference is quite wide and the PACER test may not meaningfully predict VO₂max in this population. One explanation could be that elite endurance runners rarely need to stop their forward momentum and acceleration in the opposite direction, as done in the PACER. This may lead to a reduce overall performance in the shuttle run, as excess energy is used in the deceleration and acceleration phase during change of direction. **PRACTICAL APPLICATION:** The PACER test should not be used to estimate VO₂max in endurance athletes. However, studies suggest that the PACER test is valid within the average population, adolescents, and explosive athletes.

Introduction

- Maximal oxygen uptake (VO₂ Max) can be defined as the bodies circulatory and respiratory systems ability to use oxygen (1).
- Testing VO₂ Max can give helpful insight on performance and progress in training. This measurement is more important to endurance athletes due to its influence on their athletic performance.
- The Parvomeds Metabolic Cart has been a staple in finding an individual's VO₂ Max, but what if an individual doesn't have the required equipment to perform this protocol? The PACER Test might be a better alternative due to its accessibility, duration, and simplicity.
- Similar studies have tested the validity of the PACER test in other demographics such as the average population, adolescents, and elite athletes. But this test has never been done with elite endurance athletes (1,2).
- Questions still remain if the PACER test can be a valid way to estimate maximal oxygen uptake in elite endurance athletes.

Methods

- We recruited 7 Hasting College Cross Country male athletes between the ages of 19-24 (table 1).
- The participant had their weight and height measured. After, participants underwent a 10-15 minute dynamic full-body warm up. Then they began their familiarization. The familiarization consisted of a half-speed PACER Test and a Parvomeds Metabolic cart mask fitting and test run.
- Once familiarization was completed, participants were divided into 2 separate sections. Section 1 subjects performed the PACER test 24 hours prior to the Parvomeds Metabolic Cart test. Section 2 performed the Parvomeds Metabolic Cart test prior to the PACER test.
- When subjects reported to the lab we employed a series of controls to confirm no other variables would obstruct our data. Subjects were asked to provide a urine sample to measure hydration, and to fill out a pre-exercise questionnaire ensuring they met the required amounts of sleep the night prior, consumed a similar meal between both sessions, and wore the same footwear for both sessions.
- Once controls were met subjects underwent a 10–15-minute dynamic warm up. After, subjects began their respective test.
- For the PACER test we used the FitnessGram protocol. This protocol called for a 20m shuttle run that progressively increases the pace of running at set intervals. The subject runs for as long as they can tolerate and the total number of laps are used to estimate VO₂ Max.
- For the Parvomeds Metabolic cart, we used the Bruce Stress Test protocol. This protocol called for 3-minute intervals where treadmill speed and elevation would increase until subjects voluntarily ended the test. We used the highest average VO₂ per 20 breathes to calculate the subjects peak VO₂ Max.
- In order to assess the agreement between the two measures, we performed a Bland-Altman analysis, calculating the bias, and upper and lower limits of agreement as well as a t-test of differences. We also performed a linear regression analysis to determine if VO₂ max is predicted by the PACER test. Alpha was set at 0.05.



Figure 1. Subject completing the Bruce Protocol

Table 1. Subject anthropometric data.

Variable	Subjects (N=7)
Age (yrs):	20.44 ± 1.33
Height (m)	1.74 ± 0.08
Weight (kg)	65.23 ± 14.27

Results

- The results of subject population descriptive statistics are present in table 1.
- Table 2 shows the results of our Bland-Altman analysis and the t-test for the differences.
- The t-test for the differences was not significant. When looking at the Bland-Altman analysis we found a relatively small bias but, from further investigation, we are shown the limits of agreement were much larger than we would expect or accept for this type of test (figure 2). The regression analysis showed VO₂ max is not significantly predicted by the PACER test.
- Figure 3 shows the individual results comparing the measured VO₂ from the metabolic cart versus the estimated PACER VO₂.

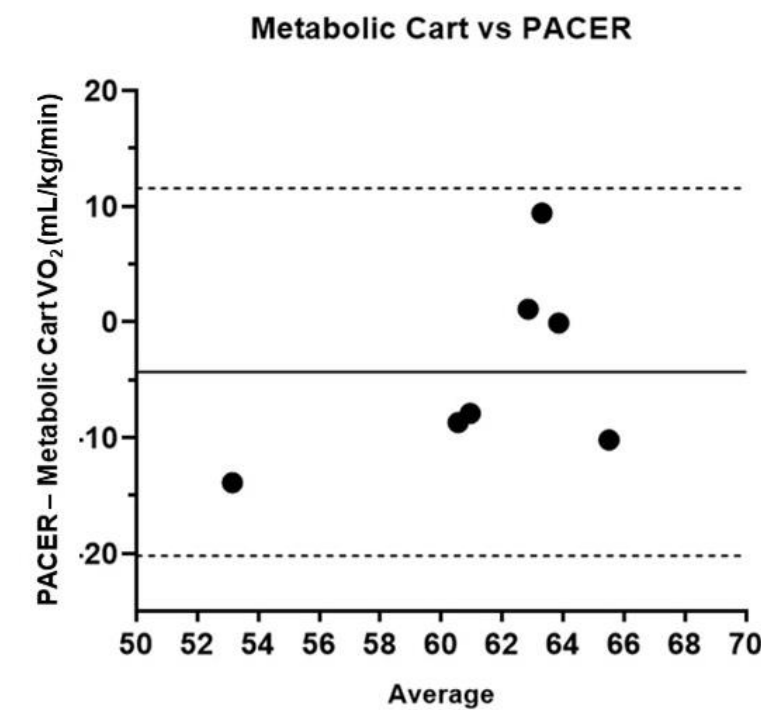


Figure 2. Bland-Altman Analysis

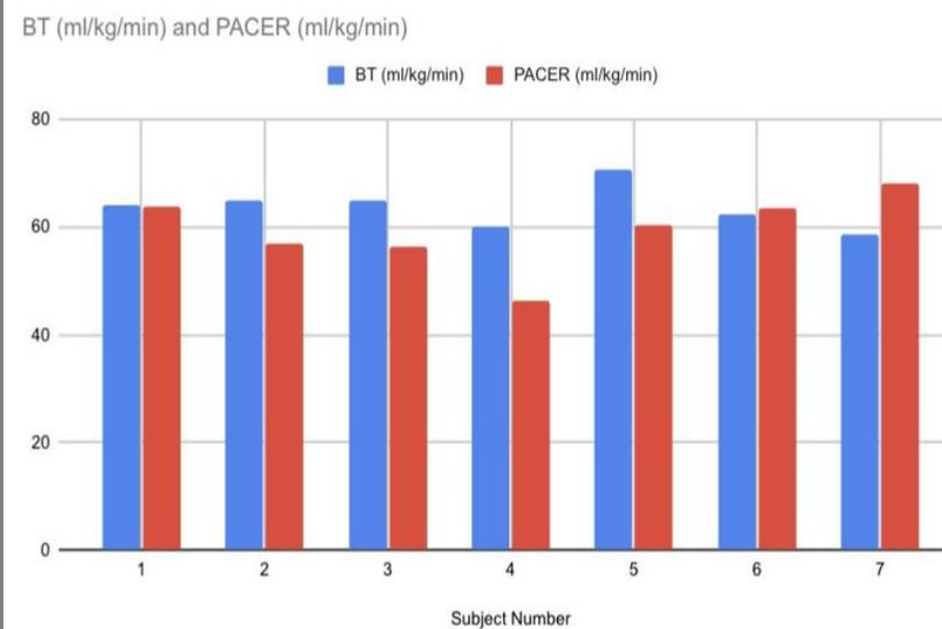


Figure 3. Subjects VO₂ Max Results

Conclusion

- Although similar studies found a similar results between the PACER test and Parvomeds metabolic cart in other demographics, in this investigation we were unable to corroborate those findings in endurance athletes.
- On average, the PACER test results underestimated the true VO₂ max by over 4 mL/kg/min compared to the Parvomeds metabolic cart. However, the t-test for the differences was not significant. Although this does not sound like a dramatic difference, the upper and lower limits were 11 and -20 respectively, this is a dramatic difference.
- The ULA and LLA show that 95% of the differences between the tests fall between those values. This leaves a very large window of possible differences between the estimated VO₂ and the true VO₂ as measured by the metabolic cart.
- Although not significantly different, we interpret a 4 mL/Kg/Min difference in VO₂ to be more than acceptable and would not allow us to accurately estimate aerobic ability in high level aerobic athletes.
- These differences could be due to the fact, during the PACER, participants are asked to stop and turn around after every 20m shuttle.
- Elite endurance athletes are conditioned to perform long bouts of exercise with little to no rest. By requiring the participants to stop and turn around this could be negatively affecting their performance.
- Both decelerating and accelerating require significant muscular work, thus wasting energy and consuming more oxygen to perform the work.

Practical Applications

- With the data we calculated, elite endurance athletes should not use the PACER test to calculate VO₂ max. Although in some cases VO₂ max was similar between the two tests, as seen in figure 2, the range of possible differences is quite large.
- However, we did have a very small subject population when performing this investigation. Future studies may be warranted in performing this test with more participants.
- Other VO₂ estimating tests for elite endurance athletes should be careful to design tests that do not include change of direction.

Table 2. Results

Bias	Upper LOA	Lower LOA	t-statistic (df)	p-value
-4.329	11.55	-20.21	6	0.2072

References

1. Chung, J, Lee, K. A Comparison of the validity of three exercise tests for estimating maximal oxygen uptake in Korean adults aged 19-64 years. Applied Sciences 12: 1371-1381, 2022.
2. Moore, SC, Patel, AV, Matthews, CE, et al. Leisure time physical activity of moderate to vigorous intensity and mortality: a large pooled cohort analysis. PLoS Med 9(11): 1-14, 2012.