Journal of Science & Cycling
Breakthroughs in Cycling & Triathlon Sciences

OPEN ACCESS

Original Article

Methodological changes to alactic time estimation fail to improve the reliability of the 15-s maximal lactate accumulation rate ($\dot{V}$Lamax) test for cycling

Chris Harnish [1,*], Tom Swensen [2] and Deb King [2]

[1] Department of Pediatrics, School of Medicine, Virginia Commonwealth University, Richmond, VA.
[2] Department of Exercise and Sports Sciences, Ithaca College, Ithaca, NY 14850, USA.

* Correspondence: (CH) christopher.harnish@vcuhealth.org

Received: 13 August 2024 **Accepted:** 14 November 2024 **Published:** 15 November 2024

Abstract: Blood lactate is used in a variety of ways to optimize performance. Many methods to estimate various aspects of endurance performance have been proposed, including for the estimation of the maximum rate of lactate accumulation ($\dot{V}$Lamax). The purpose of this study was to determine if two alternative methods to estimate alactic time improves the reliability of measuring $\dot{V}$Lamax. Methods: Sixteen men and twelve women completed two sprint sessions over 1-week. After a standardized 10-min warmup, subjects rested passively for 1-min whereupon a 3-µl blood sample was taken to assess baseline blood lactate concentration (BLC). Subjects then completed a 15-s sprint, and then rested passively while multiple blood samples were taken until blood lactate levels peaked. $\dot{V}$Lamax was calculated using either a standard 5-sec alactic time (Talac), or the time to peak power output (TTP). Differences and reliability across trials were analyzed using a paired-sample t-test, and coefficient of variation, Pearson correlation, and intraclass correlation (ICC), respectively; α was set at 0.05 and data are reported as mean ± sd. Results: Power (W) was similar across trials (773.0 ±143.5 vs. 758.2 ± 127.4; p = 0.333) with a CV of 4.7%. $\dot{V}$Lamax ($mM \cdot L^{-1} \cdot s^{-1}$) was similar across trials for Talac (0.727 ± 0.235 vs 0.682 ± 0.237; p = 0.199), and TTP (0.653 ± 0.208 vs. 0.601 ± 0.20; p = 0.201). Both methods yielded moderate reliability with CV, ICC, and R values of 16.6%, 0.636, and 0.601 for Talac and 18.1%, 0.466, and 0.47 for TTP. Conclusions: 15-s cycling sprint $\dot{V}$Lamax remains only moderately reliable even with modified Talac.

Keywords: Anaerobic Capacity, Blood Lactate, Maximal Lactate Steady State, Sprint Performance

1. Introduction

Endurance performance is widely reported as a complex interaction between aerobic and anaerobic components in conjunction with efficiency (Joyner & Coyle, 2008). In this respect, variables like $VO_{2\ Max}$ and Lactate Threshold (LT) become key components of the variation in endurance performance (Bassett & Howley, 2000; Faude, Kindermann, & Meyer, 2009; Joyner & Coyle, 2008). Blood lactate tests have long been used to assess performance potential in many athletes (Harnish, Swensen, & Pate, 2001; Hoogeveen, Hoogsteen, & Schep, 1997), set training parameters, or refine training (Beneke, Leithäuser, & Ochentel, 2011; Casado, Foster, Bakken, & Tjelta, 2023; Faude et al., 2009; Jacobs, 1986; Olbrecht, 2011). Moreover, Mader (2003) has suggested that lactate production/accumulation affects the shape of lactate (threshold) curve. Thus, measuring the accumulation rate could help elucidate contradictory or confusing interpretations of lactate tests and competition performances.

The maximum rate of lactate accumulation ($\dot{V}$Lamax) has been suggested to estimate of the maximum anaerobic energy contribution to exercise, particularly high-power output events (Wackerhage et al., 2022). Whether a true in vivo validation of the $\dot{V}$Lamax measurement as a measure of glycolytic capacity is even possible is unclear, and there is no consensus on what demarcates low, moderate, or high $\dot{V}$Lamax . Nonetheless, used in conjunction with other measures, like VO_{2Max}, $\dot{V}$Lamax has been used to optimize training and performance (Hauser, Adam, & Schulz, 2014).

It is typical to use a maximal sprint test of 10 to 20-s to estimate $\dot{V}$Lamax (Hauser et al., 2014; Niessen, Hartmann, & Beneke, 2015; Nitzsche, Baumgärtel, & Schulz, 2018; Podlogar, Cirnski, Bokal, & Kogoj, 2022; Yang et al., 2023); however, there are few studies on the reliability of $\dot{V}$Lamax testing. Authors recently reported that repeated 15-sec sprints were only moderately reliable for estimating $\dot{V}$Lamax in cyclists (Harnish, Swensen, & King, 2023). This analysis noted a number of potential sources for variation, including the methods for estimating the alactic time (Talac) (Hauser et al., 2014; Nitzsche et al., 2018; Olbrecht, 2011). Indeed, in our previous work, we found that the CV for Talac across trials was 38.3% (Harnish et al. 2023). Recent work by Dunst et al. (2023) supports our supposition; they demonstrated that even 1-s differences in Talac significantly alter $\dot{V}$Lamax calculations.

Therefore, the purpose of this study was to measure the reliability of two 15-s $\dot{V}$Lamax sprint cycling tests using prior published data using two alternative methods for estimating Talac, either a standard 5-sec value or the time to peak sprint power (Yang et al., 2023). We hypothesized that reducing the variation in Talac would improve reliability from the previously reported value of 18.6% using standard methods.

2. Materials and Method

2.1. Participants and Ethics Approval

This study was conducted at two distinct time periods and reviewed and approved by the Shenandoah University (Winchester, VA) Institutional Review Board (IRB) for the male cohort, and the Mary Baldwin University IRB for the female cohort. All men self-reported as trained cyclists that met the following *Inclusion Criteria:* apparently healthy men between the ages of 18 – 50 years. Men reported training eight or more hours each week for cycling, and they also reported significant bicycle and/or triathlon racing experience.

Women's *Inclusion Criteria* were apparently healthy women between the ages of 18 – 50 years self-reporting as actively training for cycling or other sports five or more hours each week and were familiar with very high-intensity exercise. All women in the study reported having either normal menstrual cycles or were on oral contraceptives.

Exclusion Criteria included: individuals outside the age range, as well as those reporting any known medical condition that would preclude participation, including, but not limited to cardiovascular disease, hypertension, type 2 diabetes or other metabolic diseases, anyone with significant physical limitation, or women reporting irregular menstruation or amenorrhea. All volunteers were informed of the purposes and requirements of the study and provided written consent. All participants were familiarized with the sprint test and other procedures prior to the study and each subject completed all testing.

2.2. Study Overview

Each participant completed familiarization prior to performing two sprint sessions to measure $\dot{V}$Lamax over a period of 1-week with each pair of sessions completed at a similar time of day ($\pm$3 hrs) and all sessions after 10 am. No more than 7-days for men and 4-days for women separated tests. Subjects maintained their same dietary habits during the study period and were asked to engage in no more than light activity 24-hrs prior to testing; athletes reporting significant deviations from the instructions were rescheduled for testing.

2.3. Sprint Sessions

Male participants used their own bike attached to a Wahoo Kickr direct drive trainer (v5 WFBKTR120) (Wahoo Fitness, Atlanta, GA, USA) to complete all exercise sessions, while the women completed their training and testing on a Wahoo Kickr Bike (v1 WFBIKE1) (Wahoo Fitness, Atlanta, GA, USA) fit to their body dimensions. All bikes were calibrated prior to testing as recommended by the manufacturer using the Wahoo App to complete a spin down test. A high-powered Lasko fan (Guardian Technologies Inc. Euclid, OH USA) provided cooling and subjects were encouraged to drink water as needed. All subjects completed two 15-s sprint sessions using the Zwift Cycling Platform (Long Beach, CA, USA) set with specific warm-up, start, and finish arches for sprinting, as well as providing a visual avatar. Power data were recorded and stored using Zwift for subsequent download.

Prior to each sprint, subjects completed an easy 10 min warm-up as previously described (Harnish et al., 2023). After the warm-up, subjects rested passively for 1-min on a chair. After which a 3-µl blood sample taken from the fingertip was analyzed for blood lactate using a Lactate Plus analyzer (Nova Biomedical Corporation, Waltham, MA, USA). Standard solutions were used to confirm the monitors fell within normal ranges; full details on procedures and limitations of this monitor were detailed in prior research (Harnish, Swensen, & King, 2023). The recorded lactate value served as the pretest blood lactate measure. After lactate sampling, participants remounted their bike and completed a single maximal 15-s sprint and then dismounted to sit in a chair passively while blood samples were taken at 1, 3, 5, and 7-min, and every 2-min thereafter until lactate levels peaked and then dropped by at least 1 mM to ensure the true peak BLC was measured. The PEAK and pre-test BLC samples were used to estimate $\dot{V}$Lamax (Wackerhage et al., 2022) using the formula in equation 1:

$$\frac{PEAK\ BLC - PRE\ BLC}{Test\ Time - Talac}$$

Equation (1)

Talac varied by method, and both were used for each test session: we used either a standard 5-sec value or the time to peak sprint power (TPP).

2.4. Statistical Analysis

Statistical analyses were performed using JASP (v 0.17.3). Differences in $\dot{V}$Lamax and power across trials were analyzed with a paired-sample t-test. $\dot{V}$Lamax reliability across trials was assessed with coefficient of variation, Pearson correlation, and intraclass correlation (ICC). Power reliability across trials was assessed with coefficient of variation and Pearson correlation analyses; α was set at 0.05 for all tests and data are reported as mean ± sd.

3. Results

A total of 16 men and 12 women participated in this study. Table 1 highlights key characteristics and various summary data. Shapiro-Wilkes tests showed that $\dot{V}$Lamax data determined with either the 5-sec Talac or TTP were normally distributed; hence, no transformations or non-parametric analysis were needed. Since blood-lactate related variables and power were similar across time for either sex ($p \geq 0.122$), data were pooled for subsequent analyses. We found that $\dot{V}$Lamax with a 5-sec standard Talac (VLamax5s) or with TTP (VLaTTP) were similar across trials as shown in Table 2. The reliability across trials for either alternative method was moderate; the corresponding CV, ICC, and R were 16.6%, 0.636, and 0.60 for VLamax5s and 18.1%, 0.466, and 0.47 for VLaTTP.

3.1. Tables and Figures

Table 1. Combined subject characteristics across both trials.

	Overall
N	28
Age (yr)	29.9 ± 9.8
Height (cm)	174.4 ± 10.3
Weight (kg)	73.6 ± 16.8
Peak 15-s (W)	10.1 ± 3.0
Mean 15-s (W)	8.5 ± 2.8
Pre BLC (mM)	1.9 ± 0.8
Peak BLC (mM)	8.7 ± 2.1
Time to Peak Power (s)	3.8 ± 2.0
VLa5s ($mM \cdot L^{-1} \cdot s^{-1}$)	0.70 ± 0.22
VLaTTP ($mM \cdot L^{-1} \cdot s^{-1}$)	0.63 ± 0.20

Table 2. Comparison between $\dot{V}$Lamax calculations and time to peak power (TTP) by session.

	Test 1	Test 2	p-value
VLamax5s	0.73 ± 0.24	0.68 ± 0.24	0.199
VLaTTP	0.65 ± 0.21	0.60 ± 0.20	0.210
TTP	3.9 ± 2.1	3.8 ± 1.9	0.609

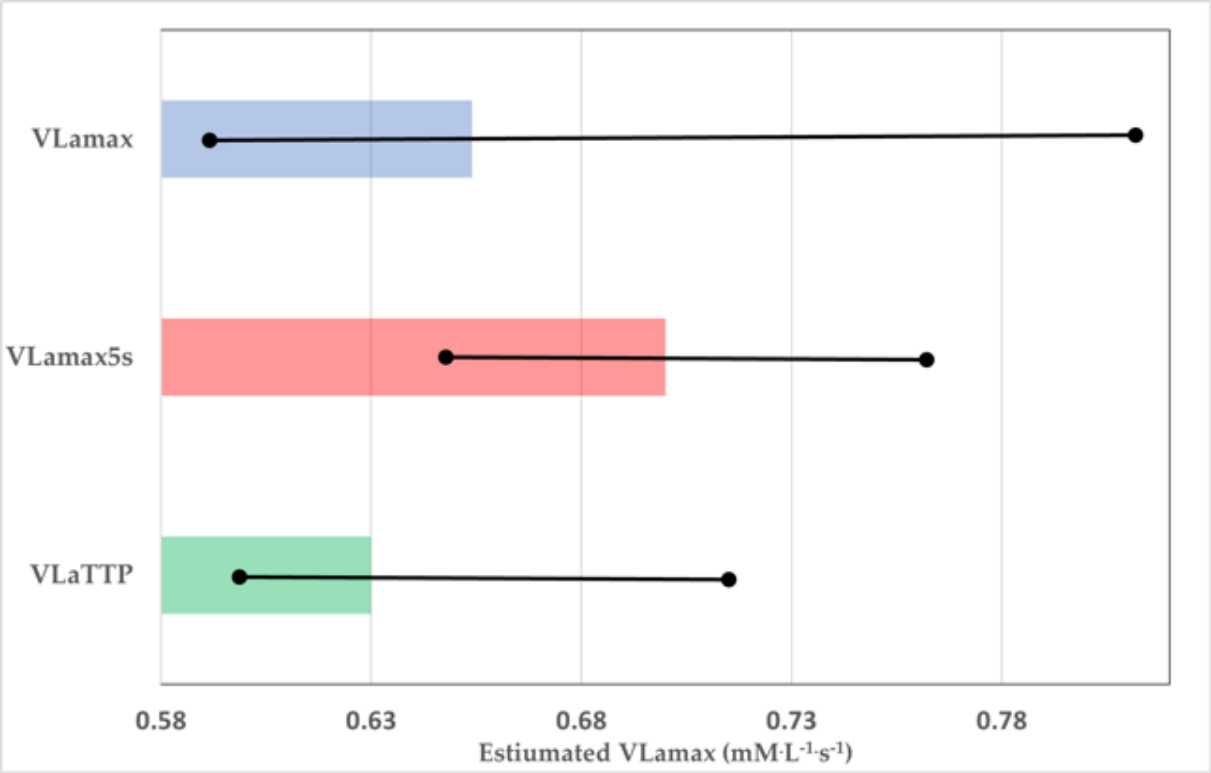

Figure 1. Graphic depiction comparing $\dot{V}$Lamax as reported by (Harnish et al., 2023) with the VLamax5s and VLaTTP presented as means (color bars) and 95% CI.

4. Discussion

The purpose of this study was to assess the reliability of a 15-s $\dot{V}$Lamax cycling test using two alternate estimations for Talac. We hypothesized that reducing the variation in the estimation of Talac would improve the reliability of $\dot{V}$Lamax. We found that using a standard 5-sec Talac or TTP yielded similar reliability outcomes for $\dot{V}$Lamax as standard methods to estimate Talac. The corresponding CV, ICC, and R were 16.6%, 0.636, and 0.60 for VLamax5s and 18.1%, 0.466, and 0.47 for VLaTTP. As reported previously, the corresponding CV, ICC, and R for $\dot{V}$Lamax with standardized procedures to estimate Talac were 18.6%, 0.661, and 0.67, respectively (Harnish et al., 2023). Figure one shows the range of values and 95% confidence intervals for $\dot{V}$Lamax using the two alternate methods to estimate Talac and the traditional method as recently published (Harnish et al., 2023). Collectively, these data

suggest that using different methods to estimate Talac modestly influences the reliability of $\dot{V}$Lamax.

Consequently, more work is needed to improve $\dot{V}$Lamax testing methodology and therefore its reliability, especially if one wishes to use this test to assess a metabolic parameter or training intervention, or to inform fitness programming. We believe the overall methodology, previously outlined in detail, best represents the application of published testing procedures. Given the results across studies, it is unlikely that minor procedural modifications will improve $\dot{V}$Lamax reliability. Instead, perhaps we ought to focus on the lactate measurements, such as the equipment used and blood draw methods. As noted previously, the CV for PRE and PEAK BLC were 45.6% and 23.3%, respectively.

5. Practical Applications

The findings of this follow-up study should give cyclists, coaches, and researchers insight into the utility and potential pitfalls of using $\dot{V}$Lamax. While it may be that the variability of the test limits its application, perhaps greater work on the lactate measures themselves will lend better clarity on how to best determine $\dot{V}$Lamax and therefore increase its usefulness to assess fitness interventions and optimize annual training programming.

6. Conclusions

We conclude that a 15-s $\dot{V}$Lamax cycling sprint test is only moderately reliable across a one-week period in men and women regardless of how Talac is estimated. It appears that the overall reliability of the test may be most heavily impacted by the lactate measurements. Care should be exercised when interpreting the results of this test given its wide variability across assessments.

Funding: The research presented here was made possible with the support of the Sports Resource Group, Inc.

Acknowledgments: The authors wish to thank the following student researchers for their assistance with this study Tasi Ann Ada, Emma O'Reilly, Paula White, and Anna Fisher.

Conflicts of Interest: The authors declare no conflict of interest.

References

Bassett, D. R., & Howley, E. T. (2000). Limiting factors for maximum oxygen uptake and determinants of endurance performance. *Medicine and Science in Sports and Exercise*, *32*(1), 70–84.

Beneke, R., Leithäuser, R. M., & Ochentel, O. (2011). Blood lactate diagnostics in exercise testing and training. *International Journal of Sports Physiology and Performance*, *6*(1), 8–24.

Casado, A., Foster, C., Bakken, M., & Tjelta, L. I. (2023). Does Lactate-Guided Threshold Interval Training within a High-Volume Low-Intensity Approach Represent the "Next Step" in the Evolution of Distance Running Training? *International Journal of Environmental Research and Public Health*, *20*(5), 3782.

Dunst, A.K.; Hesse, C.; Feldmann, A.; Holmberg, H.C. A Novel Approach to Determining the Alactic Time Span in Connection with Assessment of the Maximal Rate of Lactate Accumulation in Elite Track Cyclists. *Int. J. Sports Physiol. Perform.* **2023**, *18*, 157–163.

Faude, O., Kindermann, W., & Meyer, T. (2009). Lactate Threshold Concepts: How Valid are They? *Sports Medicine*, *39*(6), 469–490. doi: 10.2165/00007256-200939060-00003

Harnish, C. R., Swensen, T. C., & King, D. (2023). *Reliability of the 15-Sec Maximal Glycolytic Capacity (VLaMax) Test for Cycling* [Preprint]. Medicine and Pharmacology. doi: 10.20944/preprints202308.2084.v1

Harnish, C. R., Swensen, T. C., & Pate, R. R. (2001). Methods for estimating the maximal lactate steady state in trained cyclists: *Medicine and Science in Sports and Exercise*, *33*(6), 1052–1055. doi: 10.1097/00005768-200106000-00027

Hauser, T., Adam, J., & Schulz, H. (2014). Comparison of calculated and experimental power in maximal lactate-steady state during cycling. *Theoretical Biology and Medical Modelling*, *11*(1), 1. doi: 10.1186/1742-4682-11-25

Hoogeveen, A. R., Hoogsteen, J., & Schep, G. (1997). The Maximal Lactate Steady State in Elite Endurance Athletes. *The Japanese Journal of Physiology*, *47*(5), 481–485. doi: 10.2170/jjphysiol.47.481

Jacobs, I. (1986). Blood lactate: Implications for training and sports performance. *Sports Medicine*, *3*(1), 10–25.

Joyner, M. J., & Coyle, E. F. (2008). Endurance exercise performance: The physiology of champions: Factors that make champions. *The Journal of Physiology*, *586*(1), 35–44. doi: 10.1113/jphysiol.2007.143834

Mader, A., & Heck, H. (1986). A theory of the metabolic origin of "anaerobic threshold." *International Journal of Sports Medicine*, *7 Suppl 1*, 45–65.

Mader, Alois. (2003). Glycolysis and oxidative phosphorylation as a function of cytosolic phosphorylation state and power output of the muscle cell. *European Journal of Applied Physiology*, *88*(4), 317–338. doi: 10.1007/s00421-002-0676-3

Niessen, M., Hartmann, U., & Beneke, R. (2015). Estimation of Maximum Glycolytic Rate from Capillary Blood at Running Sprints of Different Durations: 2827 Board #142 May 29, 2. *Medicine & Science in Sports & Exercise*, *47*, 769. doi: 10.1249/01.mss.0000478836.88998.64

Nitzsche, N., Baumgärtel, L., & Schulz, H. (2018). Comparison of Maximum Lactate Formation Rates in Ergometer Sprint and Maximum Strength Loads. *German Journal of Sports Medicine/Deutsche Zeitschrift Fur Sportmedizin*, *69*(1).

Olbrecht, J. (2011). Triathlon: Swimming for winning. *Journal of Human Sport and Exercise*, *6*(2), 233–246.

Podlogar, T., Cirnski, S., Bokal, Š., & Kogoj, T. (2022). Utility of INSCYD athletic performance software to determine Maximal Lactate Steady State and Maximal Oxygen Uptake in cyclists. *Journal of Science and Cycling*, *11*(1), 30–38. doi: 10.28985/1322.jsc.06

San-Millán, I., & Brooks, G. A. (2018). Assessment of metabolic flexibility by means of measuring blood lactate, fat, and carbohydrate oxidation responses to exercise in professional endurance athletes and less-fit individuals. *Sports Medicine*, *48*, 467–479.

Wackerhage, H., Gehlert, S., Schulz, H., Weber, S., Ring-Dimitriou, S., & Heine, O. (2022). Lactate thresholds and the simulation of human energy metabolism: Contributions by the cologne sports medicine group in the 1970s and 1980s. *Frontiers in Physiology*, 1308.

Yang, W.-H., Park, S.-Y., Kim, T., Jeon, H.-J., Heine, O., & Gehlert, S. (2023). A modified formula using energy system contributions to calculate pure maximal rate of lactate accumulation during a maximal sprint cycling test. *Frontiers in Physiology*, *14*, 566.