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Posted Date: 30 August 2023

doi: 10.20944/preprints202308.2084.v1

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Original Research

Reliability of the 15-Sec Maximal Glycolytic Capacity (VLa_{Max}) Test for Cycling

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Abstract: Background: The purpose of this study was to ascertain the reliability of two 15-sec sprint cycling tests in men and women to estimate the maximum rate of glycolysis or lactate production (VLa_{Max}). Methods: Eighteen men and twelve women completed two sprint sessions over 1-week. A 10-min warm-up preceded a 3 µl blood lactate (BLC) sample, after which a 15-sec sprint was completed; cyclists then rested passively while multiple lactate samples were taken until levels peaked. VLa_{Max} was calculated as (Peak BLC – Pre BLC) * (15-sec – Talac)$^{-1}$. Trial differences and reliability across trials were analyzed using a paired-sample t-test, Pearson correlation, ICC, and Bland-Altman analysis with α=0.05 for all tests; data are reported as mean ± sd. Results: Power (W) was similar across trails (773.0 ±143.5 vs. 758.2 ± 127.4; p = 0.333) and coefficient of variation (CV) of 4.7%. VLa_{Max} was similar (0.673 ± 0.024 vs 0.635 ± 0.237; p = 0.280), but only moderately reliably across trials with a CV, ICC, and R value of 18.6%, 0.661, and 0.67, respectively. Conclusions: A 15-sec VLa_{Max} cycling sprint is moderately reliable being affected both by the lactate measurement and other variables used in the calculation. More research may offer ways to improve reliability.

Keywords: Anaerobic capacity; blood lactate; maximal lactate steady state; VLa_{Max}

1. Introduction

Endurance performance is a complex interaction of processes and systems in the body. A widely regarded performance model by Joyner and Coyle[1] suggests one component of endurance performance is the velocity/power relationship; they indicate it's a product of (*Aerobic + Anaerobic*) X *Efficiency*, where the aerobic aspect is determined by $VO_{2\,Max}$ and Lactate Threshold (LT). Whereas $VO_{2\,Max}$ typically sets the "ceiling" for performance, LT is the key arbiter/predictor for much of the variation in endurance performance [1–3]. As such, blood lactate tests are used to determine the metabolic performance potential in many athletes[4,5], to set training intensity and volume, assess training adaptations, and adjust training load when applicable[3,6–9] Nonetheless, lactate testing is not without challenges, and sometimes produces inconsistent or contradictory results.

Mader[10] postulated that lactate production also affects the relationship between lactate accumulation and speed/power, whereby the ultimate position of the lactate curve, for example, may be pushed to the right or left by both production and the more dominant factor, removal. This hypothesis could explain the contradictory interpretations and paradoxes between the evaluation of lactate tests and competition performances. It also fits within the Joyner-Coyle model [1] as the "anaerobic" interaction (aka, sarcoplasmic glycolysis) with the aerobic system; while lactate production maintains the NAD^+ necessary for aerobic glycolysis, it can also create additional ATP for the working muscle via the intramuscular lactate shuttle[11,12]. Additionally, lactate is oxidized by other organs, like the heart, or converted back to glucose by the liver. Thus, a "boost" in glycolysis could be a potential advantage in some competitions. While many protocols exist for quantifying the aerobic aspects of the performance model, options for the anaerobic systems are more limited.

The maximum rate of glycolysis or lactate production (VLa_{Max}) has been proposed as an estimate of maximum anaerobic energy contribution to exercise, particularly high power output events,[13] and utilized with other measures, like $VO_{2\,Max}$, to better model training and performance [14]. Whether a true in vivo validation of the VLa_{Max} measurement will be possible is unclear, its

 doi:10.20944/preprints202308.2084.v1

application to blood lactate testing appears relevant both theoretically [1,10,13] and in practice[14]. While it is generally accepted that a maximal sprint test of 10 to 20-sec can be used to estimate VLa_{Max}[14–18], we know of no studies examining the reliability of the VLa_{Max} test for cycling. Reliability, while generally important, is essential if athletes and coaches rely on lactate testing to provide precision training guidance.

Recent studies[19,20] have raised concerns regarding the reliability of lactate values for some cycling tests. For example, Faude et al.[20] indicated that steady state lactate values vary nearly 16% between two constant load tests, while Hauser et al.[19] found a similar variation in lactate values across maximal lactate steady state (MLSS) trials. In contrast, Pallarés et al.[21] found the reliability of a range of "lactate threshold" levels demonstrated less than 4% variability, suggesting the single point estimates may be more reliable. Since VLa_{Max} is used to set and adjust training, knowing its reliability is paramount. Therefore, the purpose of this study was to measure the reliability of two 15-sec VLa_{Max} sprint cycling tests in men and women. We hypothesized that performing two tests separated by no more than 7-days would result in no significant difference in test results but an overall coefficient of variation greater than 10% as based on reliability reported in prior studies.

2. Results

A total of 18 men and 12 women participated in this study with summary data detailed in Table 1. The Shapiro-Wilkes test showed that data were normally distributed; no transformations or non-parametric analysis were needed, and subjects were analyzed together. Absolute power (W) was similar across trails (773.0 ±143.5 vs. 758.2 ± 127.4; p = 0.333). Although not a primary measure for this work, the corresponding CV and R-value between power for the trials were strong at 4.7%, 0.94, and 0.90, respectively. VLa_{Max} was also similar across trials (0.673 ± 0.024 vs 0.635 ± 0.237; p = 0.280). In contrast to absolute power, VLa_{Max} was moderately reliably across trials with a CV, ICC, and R value of 18.6%, 0.66, and 0.67, respectively. Figure 1 shows the Bland Altman results assessing bias between the mean differences plotted with 95% agreement intervals for the two trials.

Table 1. Subject characteristics.

	Men	Women	Overall
N	18	12	30
Age (yr)	32.6 ± 9.7	26.0 ± 9.0	29.9 ± 9.8
Height (cm)	180.3 ± 6.3	165.5 ± 8.6	174.4 ± 10.3
Weight (kg)	77.4 ± 16.0	67.9 ± 16.9	73.6 ± 16.8
Peak 15-sec (W)	907.7 ± 190.9	568.7 ± 86.5	746.4 ± 218.1
Mean 15-sec (W)	846.4 ± 147.7	434.9 ± 91.4	623.6 ± 206.4

Preprints (www.preprints.org) | NOT PEER-REVIEWED | Posted: 30 August 2023 doi:10.20944/preprints202308.2084.v1

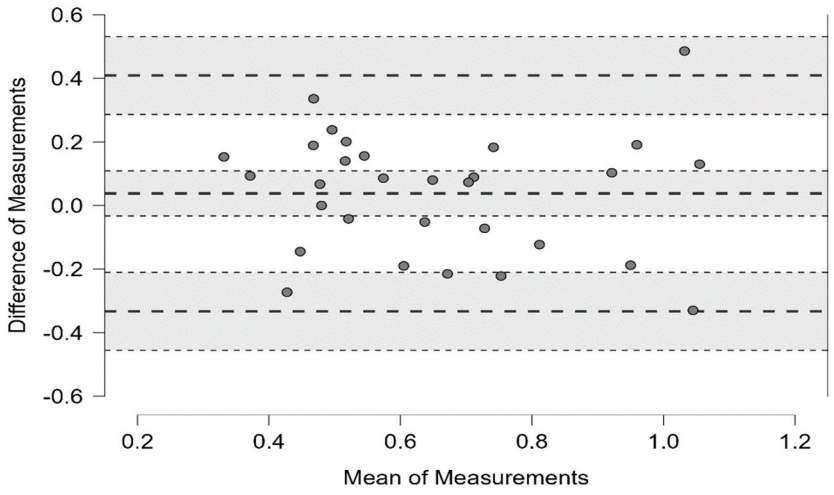

Figure 1. Bland-Altman plots comparing each athlete's first and second VLa_{Max} test.

3. Discussion

The purpose of this study was to assess the reliability of a 15-sec VLa_{Max} cycling test. We hypothesized that there would be no significant difference between the two tests over a period of no more than 7-days and that VLa_{Max} values would vary no more than 10%. While the mean VLa_{Max} values were not significantly different and 15-sec power output was tightly related, VLa_{Max} was only moderately reliable. Therefore, we reject our hypothesis that VLa_{Max} would not vary more than 10%.

No longer considered a dead-end waste product, lactate is widely seen as an important fuel source [11,12], and represents an important modulator during prolonged endurance performance.[1] The current literature suggests that one's glycolytic ability impacts endurance performance and influences training decisions [8,12–14,17]; therefore, it is important for sports scientists, coaches, and athletes to have a reliable method for assessing an athlete's "anaerobic" energy production. Based on historical underpinnings of VLa_{Max} [10,22], it remains our best estimate of the glycolytic rate. Additionally, coaches[17,23] and more recently researchers[13,14,17] show that the VLa_{Max} does influence lactate curves and the maximal lactate steady state (MLSS), making its use relevant.

In the present study, we examined the reliability of VLa_{Max} in trained men and women using two VLa_{Max} tests conducted no more than a week apart. Using standardized procedures, our participants produced very similar physical performances with a CV of less than 5%. However, VLa_{Max}, though not significantly different between trials, was only moderately reliable with a CV of 18.6%. This finding is similar to variability reported for MLSS across sustained efforts[19,20], but much higher than a range reliability findings on lactate thresholds[21]. One obvious reason for the discrepancy between these prior studies is the time frame of the tested efforts (i.e., sustained durations vs. 5-min incremental stages). Thus, we believe that perhaps long, sustained efforts result in more lactate flux, and VLa_{Max}, which uses lactates values measured during recovery, is more similar with matched efforts. In contrast, despite following standard test procedures, our results indicate that VLa_{Max} may not be precise enough to use for judging specific training responses, nor for providing detailed training recommendations.

The hallmark of any physiological assessment is validity and reliability. Decades of research[11]underscore the utility and validity of blood lactate to make such assessments, but unlike many other reliable (CV <5%) measures such as power output, RPE, and HR[4,4,5,14,19–21], blood lactate may not be as reliable. As supported by previous work[19,20], blood lactate measurements may not offer the precision needed for some training applications that other measurements provide, even when external work rate is tightly controlled. VLa_{Max} in particularly, utilizes a very short but intense bout of exercise, where even subtle variations in motor unit recruitment or pacing may alter

glycolytic activation[24]. Moreover, a large part of the variation in VLa_{Max} may in fact relate to the identification of Talac, which may contribute to some of the variability VLa_{Max} estimates. The work of Dunst et al.[24] support this supposition. They report on the key weaknesses of the current use and assumptions of Talac, especially the time to reach peak power (t_{Ppeak}). They suggest that the 3.5% drop in power (i.e., as Talac is defined), may not accurately capture biochemical activity during the initial period of maximal energy production where glycolysis is minimal. Additionally, they demonstrate that even 1-sec differences in Talac significantly alter VLa_{Max} calculations. In the present study, we noted three large sources of variation. A close inspection of the individual components of the VLa_{Max} equation (supplemental table 1) used from our data indicates that there are no significant differences between pre-test (Pre) BLC, peak BLC, or Talac. However, the average CV between test 1 and test 2 for each of those variables ranged from 23% to nearly 46%. Thus, reliability issues appear to result from several points in the equation.

Limitations

Our study is not without its limitations. While we believe the differences in cycling skill or proficiency had minimal impact on the overall findings of this study, we cannot discount that this may have inflated our CV for the test. We also must acknowledge the potential error in peak lactate values by not taking continual measurements, however, impractical this may be. Nonetheless, as described, our methodology was likely more stringent than common sports coach practice might be. Finally, we do not discount the utility of the concept of VLa_{Max} nor dismiss its use for training, but merely attempt to inform those using the method of the potential for variability within the measure.

Practical Applications

The findings of this study provide cyclists, coaches, and researchers insight into the utility and potential pitfalls of using and interpreting VLa_{Max} values between tests. Everyone must decide whether the ~18% variability precludes the tests use for at least some of its applications. These authors of this paper recommend care when interpreting the results across time or for precise training recommendations.

4. Materials and Methods

Participants and Ethics Approval

Two cohorts in this study were tested at two distinct time periods. The methodology was reviewed and approved by the Shenandoah University (Winchester, VA) Institutional Review Board (IRB) for the male cohort, while our women's study was approved by the Mary Baldwin University IRB. All men were self-reported trained cyclists recruited from the local area that met the following *Inclusion Criteria:* apparently healthy men between the ages of 18 – 50 years, training eight or more hours each week for cycling, and who reported significant bicycle and/or triathlon racing experience. *Exclusion Criteria included:* individuals outside the age range and those with any known medical condition that would preclude participation. Due to significant difficulties in matching our men's cycling cohort, the women's criteria were modified to the following *Inclusion Criteria:* apparently healthy women between the ages of 18 – 50 years 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. *Criteria included:* individuals outside the age range and those with any known medical condition that would preclude participation. All volunteers were informed of the purposes and requirements of the study and provided consent. Participants were familiar with the sprint test and completed all testing.

Study Overview

Participants performed two sprint sessions to measure VLa_{Max} over a period of 1-week with no more than 7-days between tests for men and 4-days between tests for women. While most evidence

 doi:10.20944/preprints202308.2084.v1

indicates that the menstrual cycle does not alter most physiological measures, including lactate[25–27], women self-reported when their menstrual cycle began and completed both tests within the same phase using self-reported data.

Additional Preparation for Non-Cyclists

Due to the recruitment challenges for our women's cohort, several non-cyclists, albeit NCAA athletes, were used in this study. To improve performance homogeneity, this group of student athletes engaged in a high-intensity interval training program 2 – 3 days each week for 5-weeks prior to completing the sprint trials. Interval sessions were ~25-min and included sessions using 30-sec Wingate sprints, 20-sec repeated intervals, and 120-sec intervals. Upon completion participants rested at least 4-days before participating in the sprint sessions.

Sprint Sessions

Each participant used their own bike attached to a Wahoo Kickr direct drive trainer (Wahoo Fitness, Atlanta, USA) to complete all exercise sessions; prior research shows this trainer to be valid and reliable[28]. A high-powered fan provided cooling and subjects were encouraged to drink to thirst. Participants completed two repeated sprint sessions consisting of a standard 10-min easy warm-up at ~100 W. A 1-min rest period was then provided and a 3 µl blood lactate sample from the fingertip and analyzed for blood lactate using a Lactate Plus analyzer (Nova Biomedical Corporation, Waltham, MA, USA). Participants then performed a single maximal 15-sec sprint, at which point they dismounted and sat in a chair to rest passively while blood lactate samples were taken 1-min, 3-min, 5-min, and so on until levels peaked and then dropped at least 1-mM. These samples were used to estimate VLa_{Max}[13] using the formular below:

$$\frac{\textbf{(PEAK BLC – PRE BLC)}}{\textbf{(Test Time – Talac)}}$$

BLC = blood lactate concentration
Talac = Time (sec) from time 0 to 3.5% drop in peak power[8,14,16]

Statistical Analysis

Differences in VLa_{Max} across trials were analyzed with a paired-sample t-test, Pearson correlation, ICC, and a Bland-Altman analysis. Differences in power across trials, a secondary consideration, were examined with a paired-sample t-test and Pearson correlation (JASP v 0.17.3). α was set 0.05 for all tests; data are reported as mean ± sd.

5. Conclusions

In conclusion, a 15-sec VLa_{Max} cycling sprint test offers only moderate reliability when used within a one-week test period for men and women. It appears that the overall reliability is impacted both by the lactate measurements themselves and the variability in determining the alactic time period used for the calculation. More research is needed on methods to improve the overall reliability of the test.

Author Contributions: Conceptualization, CH and TS.; methodology, CH, TS, DK; formal analysis, DK; investigation, CH; resources, CH; data curation, CH, DK; writing—original draft preparation, CH and TS; writing—review and editing, HC, TS, and DK; project administration, CH; funding acquisition, CH. All authors have read and agreed to the published version of the manuscript.

Funding: This study received material support the Sports Resource Group.

Institutional Review Board Statement: This study was conducted in accordance with the Declaration of Helsinki and approved by the Institutional Review Board of both Shenandoah University (Winchester, VA) for the male cohort, while our women's study was approved by the Mary Baldwin University IRB.
Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The authors declare that deidentified data can be made available upon request.

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 conflicts of interest.

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