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Reliability of the 15-s Maximal Lactate Accumulation Rate (VLamax) Test for Cycling

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Abstract: Background: The purpose of this study is to ascertain the reliability of two 15-s sprint cycling tests in men and women to estimate the maximum lactate accumulation rate (VLamax). Methods: Eighteen men and twelve women completed two sprint sessions over 1 week. A 10 min warm-up preceded the obtaining of a 3 µL blood lactate (BLC) sample, after which a 15 s sprint was completed; cyclists then rested passively while multiple lactate samples were taken until the levels peaked. Trial differences and reliability across trials were analyzed using a paired-sample *t*-test, Pearson's correlation, Intraclass correlation (ICC), and Bland–Altman analysis with $\alpha = 0.05$ for all tests; data are reported as mean ± sd. Results: Power (W) was similar across trials (773.0 ± 143.5 vs. 758.2 ± 127.4; $p = 0.333$) and the coefficient of variation (CV) of 4.7%. VLamax ($mM \cdot L^{-1} \cdot s^{-1}$) was similar (0.673 ± 0.024 vs. 0.635 ± 0.237; $p = 0.280$), but only moderately reliable across trials with CV, ICC, and R values of 18.6%, 0.661, and 0.67, respectively. Pre-BLC and peak BLC CV were 45.6 and 23.3%, respectively. Conclusions: A 15 s VLamax cycling sprint is moderately reliable, possibly 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; sprint performance

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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 is a product of (*Aerobic* + *Anaerobic*) × *Efficiency*, where the aerobic aspect is determined by VO_{2Max} and lactate threshold (LT). Whereas VO_{2Max} 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 (threshold) 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] that highlights the "anaerobic" interaction (aka, sarcoplasmic glycolysis) with the aerobic system. In short, while lactate production maintains the NAD^+ necessary for aerobic glycolysis, it also creates additional ATP for the working muscle via the intramuscular lactate shuttle [11,12]. Additionally, via the intermuscular lactate shuttle, lactate is oxidized by other organs, like the heart, or converted back to

glucose by the liver. Thus, a "boost" in glycolysis, indicated by lactate accumulation, could be a potential advantage in some competitions. While many protocols exist for quantifying the aerobic aspects of the performance model, options for assessing the anaerobic systems are more limited.

The maximum rate of lactate accumulation (VLamax) has been proposed as an estimate of the maximum anaerobic energy contribution to exercise, particularly high-power output events [13]. Utilized with other measures, like VO_{2Max}, VLamax has been used to improve training and performance programming [14]. Whether a true in vivo validation of the VLamax measurement as a measure of glycolytic capacity will be possible is unclear; furthermore, there is no consensus on what demarcates a low, moderate, or high VLamax. Nonetheless, incorporating a VLamax test with other blood lactate assessments 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 s can be used to estimate VLamax [14–18], studies examining the reliability of the VLamax test as typically performed for cycling are lacking. 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. Additionally, Quittman et al. [22] found a good reliability with VLamax in both cycling and running. Since VLamax is used to set and adjust training among many cycling coaches and athletes, knowing its reliability is paramount. Moreover, data on VLamax are generally limited among women. Therefore, the purpose of this study is to measure the reliability of two 15 s VLamax sprint cycling tests in men and women. We hypothesized that completing two tests separated by no more than 7 days result in no significant difference in a 15 s sprint performance; however, given the reported reliability in lactate values in prior studies, we expect a coefficient of variation of around 10%.

2. Results

A total of 18 men and 12 women participated in this study with summary data detailed in Table 1. Men and women differed in height and power output, but there were no differences in blood-lactate-related variables, such as Talac or VLamax; furthermore, there was no difference in power across time for either sex ($\geq$0.122). Consequently, power and lactate data were pooled for further analysis. The Shapiro–Wilk test showed that data were normally distributed; neither transformations nor non-parametric analysis were needed, and subjects were analyzed together. Absolute power (W) was similar across trails (773.0 $\pm$ 143.5 vs. 758.2 $\pm$ 127.4; p = 0.333). The corresponding CV and R values between power for the trials were strong at 4.7%, 0.94, and 0.90. VLamax ($mM \cdot L^{-1} \cdot s^{-1}$) was also similar across trials (0.673 $\pm$ 0.024 vs. 0.635 $\pm$ 0.237; p = 0.280). In contrast to the absolute power, VLamax was moderately reliable across trials with CV, ICC, and R values 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. Finally, an analysis of the individual equation components for VLamax is summarized in Table 2.

In a post hoc analysis, we examined the individual components of the VLamax equation (Table 2). There were no significant differences between PRE BLC, PEAK BLC, or Talac; however, the associated CV for each was higher than our reported CV for VLamax, indicating that multiple areas of the VLamax measurement may need to be refined to improve its reliability. The data used for analyses are provided in Appendix A, Table A1.

Table 1. Subject characteristics. Bold emphasis on significant differences.

	Men	Women	Overall	*p*-Value
N	18	12	30	
Age (y)	32.6 ± 9.7	26.0 ± 9.0	29.9 ± 9.8	0.0731
Height (cm)	180.3 ± 6.3	165.5 ± 8.6	174.4 ± 10.3	**<0.0001**
Weight (kg)	77.4 ± 16.0	67.9 ± 16.9	73.6 ± 16.8	0.1284
Peak 15 s (W)	907.7 ± 190.9	568.7 ± 86.5	746.4 ± 218.1	**<0.0001**
Mean 15 s (W)	846.4 ± 147.7	434.9 ± 91.4	623.6 ± 206.4	**<0.0001**
Pre-BLC (mM)	2.0 + 0.9	1.9 ± 0.9	1.9 ± 0.8	0.7050
Peak BLC (mM)	9.7 ± 2.2	8.6 ± 1.9	8.7 ± 2.1	0.1569
Time to Peak BLC (s)	3.2 ± 2.0	4.3 ± 2.3	3.3 ± 1.9	0.1770
Talac (s)	3.8 ± 1.9	4.2 ± 1.4	4.1 ± 1.5	0.6012
VLamax ($mM \cdot L^{-1} \cdot s^{-1}$)	0.71 ± 0.26	0.62 ± 0.15	0.63 ± 0.24	0.3352

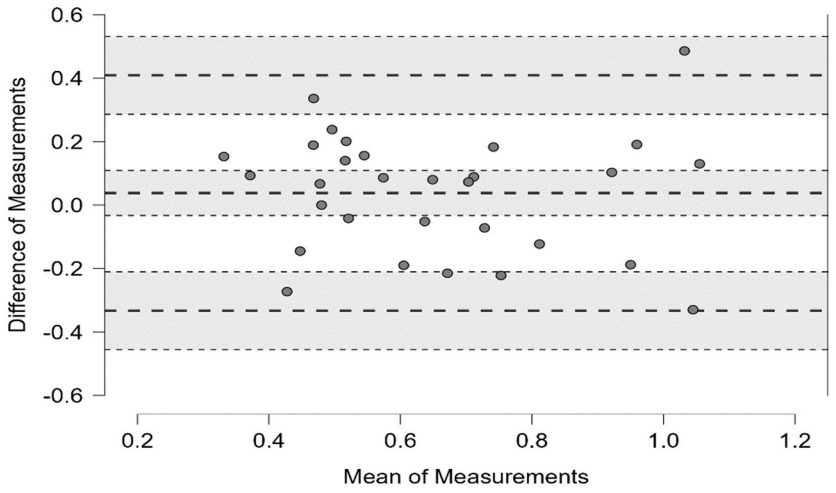

Figure 1. Bland–Altman plots comparing each athlete's first and second VLamax test.

Table 2. Comparison of data for each component of the equation used to calculate VLamax as well as *p*-values and CV.

	Test 1	Test 2	*p*-Value	Mean CV
Pre-BLC (mM)	2.0 ± 0.9	1.9 ± 0.9	0.7837	45.6%
Peak BLC (mM)	9.3 ± 2.1	8.7 ± 2.1	0.3428	23.3%
Talac (s)	4.0 ± 1.7	4.1 ± 1.5	0.8073	38.3%

3. Discussion

The purpose of this study was to assess the reliability of a 15 s VLamax cycling test. We hypothesized that there would be no significant difference in 15 s power between the two tests over a period of no more than 7 days and that VLamax values would vary by about 10%. Although mean VLamax and 15 s power were similar between trials, VLamax was only moderately reliable (CV = 18.6%), exceeding our expected outcome of around 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 sprint and 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 the historical underpinnings of VLamax [10,23], it remains our best estimate of the glycolytic rate. Additionally, coaches [17,24] and more recently researchers [13,14,17] show that the VLamax does influence lactate curves and MLSS, making its use relevant.

In the present study, we examined the reliability of VLamax in trained men and women using two VLamax 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, VLamax, although not significantly different between trials, was only moderately reliable with a CV of 18.6%. This finding is similar to the variability reported for MLSS across sustained efforts [19,20], but much higher than a range of reliability findings for various lactate thresholds [21]. One possible reason for the reliability discrepancy among these prior studies is the test structure—i.e., sustained durations with frequent lactate measures vs. 5 min incremental stages with single-point lactate determinations. Perhaps long sustained efforts (i.e., MLSS) result in modest, but significant, lactate variation across weeks, detectable through repeated lactate measures, in contrast to relatively short progressive incremental stages that use single-point measures to detect the corresponding lactate values. In this respect, VLamax, which also uses repeated lactate measurements throughout the recovery portion of the test, may reflect larger variations in lactate values across weeks than if a single-point measurement was used. Ironically, the issue with VLamax may not be that repeated lactate measurements are made, but that the measurements may need to be repeated more frequently; after this, the data may need to be smoothed.

Based on the literature, there appears to be no clear consensus on methodology for VLamax. At the time this study was conceived and based on personal communications (Olbrecht, 2017), we chose a method consistent with Olbrecht's [24,25] and sampled lactate every 2 min, which is also similar to the methods of Dunst et al. [26]. In contrast, others [14,18,27–29] have used 1 min sampling rates, and another study relied on 30 s intervals for the first 3 min after exercise [16]. As with the post-test lactate measure frequency, there is also no standardization of when the pre-test measurement is made. Only two studies [22,26] clearly articulated a rest period prior to the sprint test, which contrasts with Hauser et al., who measured pre-test lactate immediately after warm up as we did. Our results indicate that VLamax, when measured as commonly practiced [24,25], may not be precise enough to judge specific training responses or to make detailed training recommendations.

The hallmark of any physiological assessment is validity and reliability. Decades of research [11] underscore the validity of blood lactate assessments, but unlike many other reliable (CV < 5%) measures, such as power output, RPE, and HR [4,5,14,19–21], some blood lactate assessments are less reliable [19,20]. Consequently, they may lack the precision needed for some training applications even when external work rate is tightly controlled. VLamax, which utilizes a very short but intense bout of exercise, may be particularly sensitive, as even subtle variations in motor unit recruitment or pacing may alter glycolytic activation [26]. Moreover, a large part of the variation in VLamax may in fact relate to the identification of Talac.

Recent work by Dunst et al. [26] supports this supposition. They reported 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, 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 s differences in Talac significantly alter VLamax calculations.

In the present study, we noted three large sources of variation for VLamax, namely, the large variation across time in the components used to calculate it. As shown in Table 2, there are no significant differences in pre-test BLC, peak BLC, and Talac across time, but their respective CV varied from 23% to nearly 46%, suggesting the modest CV we found for VLamax may reflect the variation in the variables used to calculate it.

3.1. Limitations

Our study is not without its limitations. While we believe the differences in cycling skill or proficiency had a 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 VLamax nor dismiss its use for training, but merely attempt to inform those using the method of the potential for variability within the measure.

3.2. Practical Applications and Recommendations

The findings of this study provide cyclists, coaches, and researchers insights into the utility and potential pitfalls of using and interpreting VLamax 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. Furthermore, future research should examine the value of frequent (e.g., every 30 s) lactate measurements on the reliability of the VLamax measurement.

4. Materials and Methods

4.1. Participants and Ethics Approval

This study employed two cohorts, one of men and one of women. Each cohort was recruited and studied at two distinct time periods. The methodology was reviewed and approved by the Shenandoah University (Winchester, VA, USA) Institutional Review Board (IRB) for the male cohort. The women's study was reviewed and 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 within an age range 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. *Exclusion Criteria Included:* individuals outside the age range as well as those that reported any known medical condition that would preclude participation, including, but not limited to, cardiovascular disease, hypertension, type 2 diabetes or other metabolic diseases, or anyone with significant physical limitations.

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 within an age range of 18–50 years. Women self-reported 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. Like men, the *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 limitations, or 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.

4.2. Study Overview

Each participant completed familiarization prior to performing two sprint sessions to measure VLamax over a period of 1 week with each pair of sessions completed at a similar time of day (±3 h) and all sessions after 10 a.m. We allowed no more than 7 days between each test for men and no more than 4 days between tests for women; Figure 2 provides a summary of the testing procedures. While the current consensus of evidence indicates that the menstrual cycle does not alter most physiological measures, including lactate [30–32], women were asked to track and then self-report when their menstrual cycle

began and ended. Women then completed both tests within the same phase (i.e., follicular or luteal) using their self-reported data. All subjects were tested in their "off-season" training period. They were instructed to maintain their same dietary habits during the study period and were asked to engage in no more than light activity 24 h prior to testing; researchers confirmed training instructions prior to testing, and any athletes reporting significant deviations were rescheduled for testing.

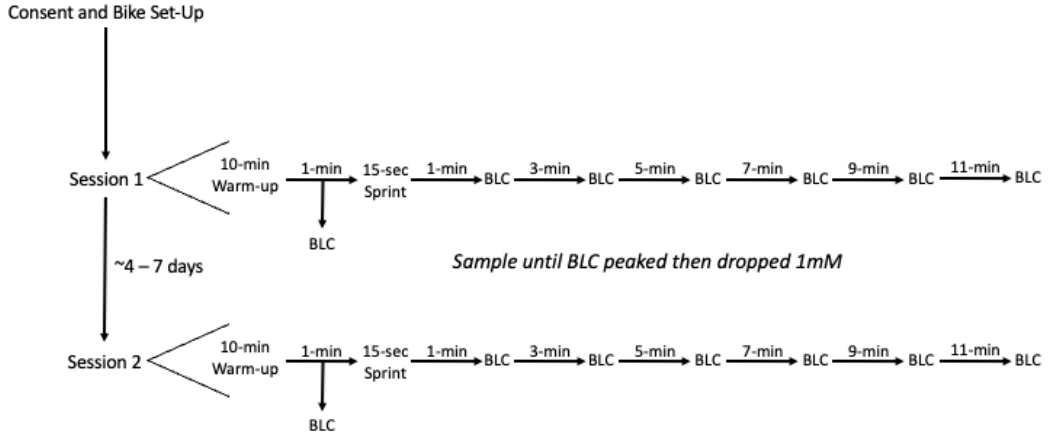

Figure 2. Graphic summary of the study procedures.

4.3. Additional Preparation for Non-Cyclists

Due to the recruitment challenges for our women's cohort, several non-cyclists, albeit NCAA athletes, were recruited for this study. To fully familiarize them with the study and sprint cycling, as well as to improve performance homogeneity, our women's cohort 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. Each interval session began with an easy 10 min warm up, concluded with a 5 min easy cool down, and lasted for about 25 min. Over the course of 5 weeks, training included two sessions using 4 × 30 s Wingate sprints with a 5 min rest, four sessions of 8 × 20 s maximal effort repeated intervals with 10 s recovery, and four sessions of 4 × 120 s intervals at maximal effort with 120 s recovery. Upon completion of training, participants rested 4 to 5 days before participating in the sprint sessions.

4.4. Sprint Sessions

Each male participant used their own bike attached to a Wahoo Kickr direct drive trainer (Wahoo Fitness, Atlanta, GA, USA) to complete all exercise sessions; prior research shows this trainer to be valid and reliable [33]. All subjects in the women's cohort completed their training and testing on a Wahoo Kickr Cycle Ergometer (Wahoo Fitness, Atlanta, GA, USA) fit to their body dimensions; like the Wahoo trainer, prior research shows this trainer to be valid and reliable. Throughout all training and testing sessions, the subjects were cooled with a high-powered Lasko fan (Guardian Technologies Inc., Euclid, OH USA) and were provided water and encouraged to drink as needed. Participants completed two 15 s sprint sessions using the Zwift Cycling Platform (Long Beach, CA, USA). The platform allowed researchers to set up specific time periods for warm up and start and finish arches for sprinting, as well as providing a visual avatar to view. All power-related data were recorded and stored using Zwift for later download.

Prior to testing, the subjects washed their hands. Each session consisted of a standard 10 min self-chosen easy (RPE 3 on 10 pt scale) warm up of ~30–100 W. Following the warm up, the subjects were asked to complete a 1 min rest period. During the rest period, a 3 µL blood lactate sample from an alcohol-sterilized fingertip was analyzed for blood lactate with a Lactate Plus analyzer (Nova Biomedical Corporation, Waltham, MA, USA); the Lactate Plus is both valid and reliable compared to benchmark measures [34]. The participants then remounted the bike and rode easy until the starting arch before completing a single

maximal 15 s sprint to the finish arch. They were then asked to dismount and sit in a chair to rest passively, while their finger was again swabbed with alcohol; blood lactate samples were taken at 1 min, 3 min, 5 min, 7 min, and every 2 min afterwards until levels peaked and then dropped by at least 1 mM to ensure true peak was measured. The PEAK and pre-test (PRE) BLC samples were then used to estimate VLamax [13] using the formula below:

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

BLC = blood lactate concentration;
Talac = time (s) from time 0 to 3.5% drop in peak power (8, 14, 16).

4.5. Statistical Analysis

Statistical analyses were performed using a freely available software package (JASP v 0.17.3). Differences in VLamax and power across trials were analyzed with a paired-sample *t*-test. VLamax reliability was assessed using by calculating the coefficient of variation across trials and with Pearson correlations, intraclass correlations (ICC), and a Bland–Altman analysis [35]. Power reliability was assessed by calculating the coefficient of variation across trials and with Pearson's correlations. A significance level (α) was set at 0.05 for all tests. All data are reported as mean $\pm$ sd.

5. Conclusions

In conclusion, a 15 s VLamax cycling sprint test offers only moderate reliability when used within a one-week test period for both men and women. It appears that the overall reliability of the test is impacted both by the lactate measurements, with a moderate to lower reliability of PRE and PEAK lactate measurements, as well as the variability and inherent problems in determining the alactic time period used for the calculation. More research is needed to ascertain if other methods can improve the overall reliability of the test.

Author Contributions: Conceptualization, C.R.H. and T.C.S.; methodology, C.R.H., T.C.S. and D.K.; formal analysis, D.K.; investigation, C.R.H.; resources, C.R.H.; data curation, C.R.H. and D.K.; writing—original draft preparation, C.R.H. and T.C.S.; writing—review and editing, C.R.H., T.C.S. and D.K.; project administration, C.R.H.; funding acquisition, C.R.H. All authors have read and agreed to the published version of the manuscript.

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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. The following are the ethics committee approval numbers (Approval Codes: No. 563 and No. 20200321).

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.

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

Appendix A

Table A1. Data used for Table 1.

Subj #	Sex	Wgt	Session	HLa-1	Pk BLC	Time to Pk	VLamax	Talac	Peak 15 s Watts	Peak W/kg	AVG 15 s	Avg W/kg	kJ
1	M	71.1	1	0.9	11.6	5	0.973	4	851	12.0	793	11.2	12
1	M	71.1	2	1	9.7	1	0.870	5	864	12.2	771	10.8	12
2	M	62.7	1	1.3	12.9	1	1.055	4	771	12.3	688	11.0	10
2	M	62.7	2	1.6	11.1	3	0.864	4	796	12.7	697	11.1	11
3	M	65.9	1	0.8	7.3	7	0.500	2	892	13.5	720	10.9	11
3	M	65.9	2	1.7	8.2	3	0.542	3	878	13.3	706	10.7	11
4	M	92.6	1	2.6	7.7	1	0.510	5	1217	13.1	1017	11.0	15
4	M	92.6	2	3.9	9.5	3	0.700	7	1182	12.8	1046	11.3	16
5	M	65.6	1	1.4	9.4	3	0.615	2	799	12.2	740	11.3	11
5	M	65.6	2	3.2	8.1	7	0.377	2	812	12.4	713	10.9	11
6	M	70.7	1	2.6	13.8	1	1.120	5	964	13.6	870	12.3	13
6	M	70.7	2	1.4	11.3	1	0.990	5	782	11.1	748	10.6	11
7	M	103.5	1	2.1	10.3	5	0.586	1	1222	11.8	1036	10.0	16
7	M	103.5	2	1.6	7.4	5	0.446	2	1124	10.9	935	9.0	14
8	M	76.7	1	3	10.4	1	0.617	3	972	12.7	814	10.6	12
8	M	76.7	2	2.1	9	3	0.531	2	923	12.0	809	10.5	12
9	M	73	1	1.9	10	3	0.623	2	667	9.1	579	7.9	9
9	M	73	2	1.5	7.1	1	0.467	3	808	11.1	700	9.6	11
10	M	76.7	1	1.9	9.6	5	0.856	6	792	10.3	660	8.6	10
10	M	76.7	2	1.5	10.9	1	1.044	6	727	9.5	603	7.9	9
11	M	56.7	1	2.3	11.3	1	0.692	2	739	13.0	635	11.2	10
11	M	56.7	2	2.4	10.8	5	0.764	4	891	15.7	710	12.5	11
12	M	68.3	1	2.6	7.2	5	0.511	6	634	9.3	585	8.6	9
12	M	68.3	2	1.8	5.8	5	0.444	6	600	8.8	546	8.0	8
13	M	67.1	1	1.3	5.9	3	0.418	4	787	11.7	664	9.9	10
13	M	67.1	2	1.4	5.3	3	0.325	3	851	12.7	737	11.0	11
14	M	80.1	1	0.8	7.6	3	0.756	6	784	9.8	663	8.3	10
14	M	80.1	2	0.5	8.5	3	0.667	3	765	9.6	665	8.3	10
15	M	70.5	1	1.7	9.6	1	0.564	1	929	13.2	744	10.6	11
15	M	70.5	2	0.7	11.6	1	0.779	1	899	12.8	675	9.6	10
16	M	122.8	1	2.1	9.5	7	0.740	5	1232	10.0	959	7.8	14
16	M	122.8	2	1.7	9.7	7	0.667	3	1110	9.0	873	7.1	13
17	M	81.2	1	2.9	13.1	3	1.275	7	1179	14.5	1005	12.4	15
17	M	81.2	2	3.2	10.3	3	0.789	6	1122	13.8	1005	12.4	15
18	M	88.6	1	4.3	7.5	3	0.291	4	907	10.2	743	8.4	11
18	M	88.6	2	1.2	7.4	3	0.564	4	864	9.8	710	8.0	11
19	F	71.3	1	1.6	10.4	5	0.880	5	592	8.3	411	5.8	6
19	F	71.3	2	1.1	13.2	5	1.210	5	394	5.5	312	4.4	5
20	F	54.8	1	2.8	11.8	3	0.750	3	461	8.4	374	6.8	6
20	F	54.8	2	2.1	11.7	3	0.873	4	471	8.6	390	7.1	6
21	F	66.2	1	3	7.9	3	0.408	3	555	8.4	323	4.9	5
21	F	66.2	2	3	5.8	1	0.255	4	506	7.6	321	4.8	5
22	F	103.8	1	1.5	8.3	5	0.618	4	634	6.1	441	4.2	7
22	F	103.8	2	1.8	6.8	5	0.417	3	540	5.2	232	2.2	3

Table A1. *Cont.*

Subj #	Sex	Wgt	Session	HLa-1	Pk BLC	Time to Pk	VLamax	Talac	Peak 15 s Watts	Peak W/kg	AVG 15 s	Avg W/kg	kJ
23	F	100.6	1	3.3	10.8	5	0.833	6	658	6.5	482	4.8	7
23	F	100.6	2	1.8	8.3	3	0.650	5	589	5.9	473	4.7	7
24	F	58.7	1	2	6.5	5	0.375	3	452	7.7	316	5.4	5
24	F	58.7	2	2.8	8	5	0.520	5	434	7.4	339	5.8	5
25	F	61	1	1.9	8.1	9	0.689	6	468	7.7	371	6.1	6
25	F	61	2	1.6	8.3	5	0.609	4	544	8.9	404	6.6	6
26	F	63.9	1	1	8.7	7	0.642	3	615	9.6	439	6.9	7
26	F	63.9	2	1.3	10.8	3	0.864	4	599	9.4	473	7.4	7
27	F	58.2	1	1.1	8.4	5	0.562	2	477	8.2	388	6.7	6
27	F	58.2	2	3.7	7.8	7	0.373	4	536	9.2	471	8.1	7
28	F	50.9	1	2.8	9.8	1	0.636	4	637	12.5	511	10.0	8
28	F	50.9	2	3.4	7	1	0.300	3	539	10.6	497	9.8	7
29	F	64.1	1	1.2	6	1	0.480	5	706	11.0	624	9.7	9
29	F	64.1	2	1.5	6.3	3	0.480	5	670	10.5	607	9.5	9
30	F	60.9	1	0.6	6.1	3	0.611	6	569	9.3	539	8.8	8
30	F	60.9	2	0.9	6.2	1	0.663	7	572	9.4	541	8.9	8

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