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Original Research

Challenging the Accuracy of a Single-test Lactate Threshold Protocol in Collegiate Rowers

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ABSTRACT

Int J Exerc Sci 3(4) : 206-213, 2010. Elite rowers use lactate threshold (LT) estimates as a basis for training intensity in order to achieve the greatest training volume. For convenience, LT is usually determined in a maximal LT/VO_{2max} test. This simultaneous test is problematic because it requires a large power increment, which may not give the most accurate LT. PURPOSE: To challenge the validity of a simultaneous LT/VO_{2max} test to estimate LT in rowers. METHODS: Collegiate rowers (n=20, 16F and 4M, age 19.3±1.3 years, height 171.5±7.1 cm, weight 70±14 kg, VO_{2max} 44.6±5.5 ml•kg^{-1}•min^{-1}) performed two LT tests. Participants completed an incremental VO_{2max} test with 3-minute intervals increasing by 30W and 40W for women and men respectively. The second test consisted of five 6-minute stages of 10W increments starting from 20W below the estimated LT. For both tests, blood lactate was measured at the end of each stage and LT was determined by the lactate deflection point. The difference in intensity between the first deflection point and the LT was then calculated. RESULTS: Average difference between LT_1 and LT_2 was 1.15 ± 13.4W, and were not statistically different (p=0.204). Average absolute difference was 9.95 ± 8.80W, and was different from the average (p=0.022). CONCLUSION: A second incremental test should be performed for the most precise determination of LT. This is particularly important to rowers who rely on LT to determine training intensities.

KEY WORDS: Ergometer, Rowing, Crew, Maximal Oxygen Consumption, Concept 2

INTRODUCTION

Rowing is a metabolically complex and demanding activity. A 2000m sprint race lasts between six and eight minutes and is approximately 70% aerobic and 30% anaerobic (2, 3). A typical race begins with a short sprint with high stroke frequency (lasting less than a minute), followed by a slightly reduced stroke frequency during the body, and another sprint to the finish. This method of activity has been noted as an "inefficient approach" because of the high oxygen deficit within the first minute of the race and the subsequent reliance on aerobic fitness until the final sprint where anaerobiosis occurs again (2,3). After the first minute, the duration of the race is reported to be performed between 80 and 95% of VO_{2max} (10). Due to the reliance on both aerobic and anaerobic metabolism, maximal oxygen uptake (VO_{2max}) and lactate threshold (LT) have become commonly measured physiological parameters in rowers. Not only are both variables indicative of performance (3, 4, 5, 7, 9, 10, 11, 12, 13), they can also be conveniently measured simultaneously with an incremental LT/VO_{2max} test (3, 4, 5, 7, 9, 11).

Due to the correlation of LT and VO_{2max}

with performance, these variables are often used to set parameters for intensity of training, which means that these values need to be measured accurately in order to achieve the desired training responses (3, 4, 14). While VO_{2max} testing is rather standardized, the same cannot be said of the lactate threshold which can be determined by multiple protocols, and results can often be subjective (4, 5, 9, 10, 11). There is considerable incongruity of studies regarding the validity of these lactate threshold tests, which is problematic when training is based off of LT (3, 17).

In a simultaneous LT/VO_{2max} test, blood lactate is measured throughout the step-wise test, and LT and the corresponding power and heart rate can be determined for training purposes. For example, Reichman et al. (2002) reported a correlation between power at LT and overall performance using an incremental testing protocol with a graphical method of determining LT, where LT was defined as the point where blood lactate concentration had a 1mmol·L^{-1} increase above baseline. Similar methods of others have supported these results, though with varying definitions of LT, stage lengths, and intensity intervals. Some methods define LT as the 1mmol·L^{-1} increase above baseline of Reichman et al. (2002), a universal LT at 4 mmol·L^{-1}, or the point where the linear increase of blood lactate is broken (4, 5, 9, 11).

Testing protocols for rowing present additional difficulties, as exercise intensity increases anywhere from 25W to 50W between stages (4, 5, 9, 11, 15). Not only is there variability of intensity increments, such large increments in power increase the likelihood that the LT will not be correctly identified. Naturally, if the LT is overestimated, the athlete's potential training volume will be limited, whereas in the case of underestimation, the system may not be taxed enough to improve effectiveness at and above LT (14). Smaller intensity increments would give a better representation of the lactate deflection point and potentially provide a more accurate LT; however, such a test violates the assumptions for a valid VO_{2max} test. The difficulty of the simultaneous LT/VO_{2max} test lies within the inherently contradictory objectives of this single test: constantly increasing intensity so as to tax the cardiorespiratory system while also allowing time for steady state for blood lactate levels to be reflective of the intramuscular lactate production. In order to overcome these difficulties, it is suggested that in addition to moderate intensity increments, a second sub-maximal test should be performed that includes smaller increments of intensity between stages and longer stages to induce a steady state for lactate to accumulate in the blood. Thus, the purpose of this study was to determine if a single LT/VO_{2max} test can yield an accurate LT or if a second sub-maximal test with smaller increments should be performed.

METHODS

Male and female varsity rowers participated in two lactate threshold determination tests. The first test was a VO_{2max} test with a 3-minute stage incremental protocol to exhaustion while the second test consisted of five 6-minute stages with smaller power increments. During both tests, blood lactate was measured after each stage and then plotted. LT for each test was interpolated as the deflection point between the linear increase

and significant rise in blood lactate.

Participants

Novice and varsity oarsmen and oarswomen (n=20, 16F and 4M), all members of the Willamette University NCAA Division III crew team (age 19.3±1.3 years, height 171.5±7.1 cm, weight 70±14 kg, VO_{2max} 44.6±5.5 $ml \bullet kg^{-1} \bullet min^{-1}$), volunteered for this study. All experimental protocols were approved by the Willamette University Institutional Review Board in compliance with the appropriate guidelines for research using human participants. The participants read and signed the informed consent form during an orientation meeting before any tests were conducted.

Lactate/ VO_{2max} Initial Test (LT/VO_{2max})

Rowers completed a combined LT/VO_{2max} test on a Concept 2 Model D indoor rowing ergometer. The test was conducted similar to previous protocols (4, 5, 9, 10, 11), with 3-minute stages of progressively increasing intensity to exhaustion with 30-second rest intervals between stages in order to obtain blood lactate samples. Ventilation and heart rate were measured throughout the test with a Parvomedics True One gas analyzer and heart rate monitor. After a self-selected warm-up, the participant was asked to row at 50% power (a common intensity during practices), which was set as the initial intensity of the test. The participant was asked to maintain constant intensity (W) with a self-selected stroke rate during each stage. The intensity increased by 30W for females and 40W for males for each subsequent stage to exhaustion. All tests were determined to be valid maximal exercise tests using standard criteria.

Sub- maximal Lactate Threshold Determination Test (LT_{sMAX})

After a self selected warm up, participants completed five successive 6-minute steady-state stages. Each stage increased by 10W with the intent of participants reaching LT after the second stage. The initial intensity was set at 20W below the anticipated LT, as determined by visual inspection from the LT/VO_{2max} results, and rounded to 10W intervals. Power was kept at a constant intensity (W) with a self-selected stroke rate during each stage. There was a 30-second rest interval between stages for blood lactate and heart rate measurements.

Blood Lactate Concentration and Lactate Threshold Determination

A small blood sample (5µl) was obtained from the hyperaemized earlobe of each participant prior to each test, at the end of each stage, and 3-minutes after exercise during both tests. The blood lactate concentration was determined using a Lactate Plus analyzer (Nova Pharmaceuticals) following manufacturer's instructions. In order to avoid inter-analyzer variability, the same analyzer was used for both tests for each participant. Validity of the analyzers was ensured by verifying measured values against lactate standards according to manufacturer's instructions. The blood lactate values from the LT/VO_{2Max} test were plotted against exercise intensity (Figure 1) and lactate threshold (LT_1) was interpolated as the deflection point where blood lactate concentration increased in a non-linear fashion, similar to methods of Ingham et al. (2002). The values of blood lactate concentration from LT_{sMAX} were plotted in addition to the blood lactate concentrations from the LT/VO_{2Max} test (Figure 1) and the resulting curve was used to determine a new lactate threshold (LT_2).

Statistical Analysis

In order to determine if the two tests yielded different LT values, intensity at LT_1 and LT_2 were compared using a Student's T-test analysis ($\alpha = 0.05$).

RESULTS

The results from the LT/VO_{2max} test indicated that the experimental protocol was successful at eliciting a steady state during all stages, all participants reaching VO_{2max} (data not shown) and an identifiable LT_1 for each participant. The subsequent LT_{sMAX} also yielded a clearly identifiable LT_2 deflection point and was compared to LT_1 (Figure 1). As anticipated by the protocol, 15 participants reached LT_2 after the second stage while the remaining five reached LT_2 in the second stage. The average stage of reaching LT_2 was 3.15 ± 0.875.

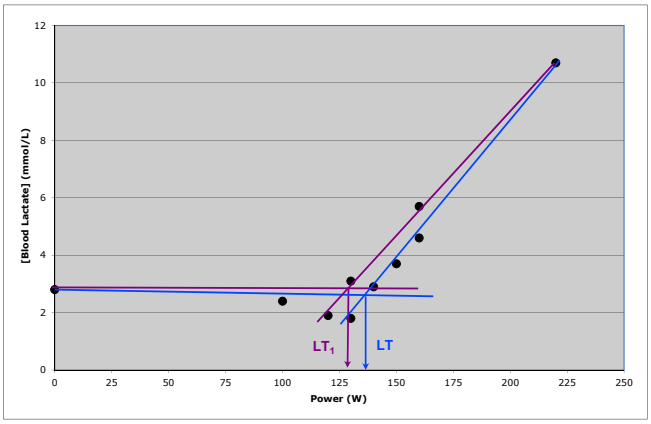

Figure 1. The combined results of LT/VO_{2max} and LT_{sMAX} showing intensities (W) at LT_1 (purple arrow) and LT_2 (blue arrow) and their difference for the same participant. Based on the LT_{sMAX} results, this participant would be training at intensity lower than the actual LT if only the LT/VO_{2max} test was performed.

The LT_2 was higher than LT_1 in 12 participants and lower in 8 participants. The difference between the two points ranged from -35W to 23W but there were no consistent patterns for these differences (Figure 2).

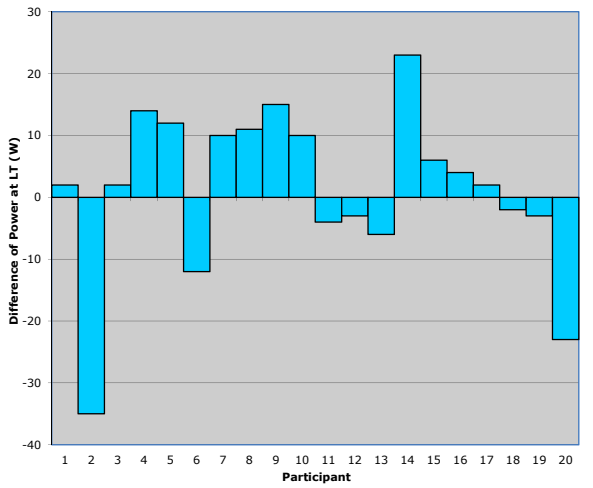

Figure 2. Differences in the power at LT_1 and LT_2 for each of the participants. The differences range from -35W to 23W with an average of 1.15 ± 13.4W and p=0.204. The disperse distribution should be noted as inconsistent.

The average difference in intensity between LT_1 and LT_2 was 1.15 ± 13.4W, and the two deflection points were not statistically different (p=0.204). However, given the disperse distribution of the LT_2 above and below the LT_1, this finding is misleading. In order to better represent the actual differences between LT_1 and LT_2 the average of the absolute difference was calculated. The absolute difference between LT_1 and LT_2 was much larger (9.95 ± 8.80W) than the true difference, and it was also significantly different from the true difference (p=0.022). No differences were determined between skill levels or gender due to the small sample sizes of these groups.

DISCUSSION

The purpose of this study was to determine if a simultaneous LT/VO_{2max} testing protocol was sufficient to determine an accurate LT, or if a second sub-maximal test with smaller intensity increments and longer stages was necessary. The results indicate that a single test to estimate LT during the measurement of VO_{2max} does not yield the same results as a similar test with longer duration and smaller increments of power. Although the LT intensity between the two tests (LT/VO_{2max} and LT_{sMAX}) was not significantly different, the absolute differences between LT_1 and LT_2 were statistically different from the actual differences between the two estimates. Also, given the large distribution of these differences (LT_2 both above and below LT_1) the two tests yielded different results, and thus care must be exercised when lactate threshold tests are performed for the purposes of determining training intensities for rowers.

Relevance

A relationship between workload intensity and LT has been shown to be related to rowing performance (3, 4, 7); therefore, the use of the LT for training and competition purposes is a very appropriate and common practice. Some training protocols use the LT or a percentage of LT to determine training intensity, which means that an accurate determination of the LT is necessary if training intensity is to be properly established. For example, Ingham et al. (2008) found that performance was higher after a training program of intensity always below LT than after a mixed training program with 70% below LT and 30% between LT and VO_{2max}. Although the mixed training program may have included too much exercise above LT, the training is still based on the LT value, thus it needs to be accurate.

In the present study, there was no consistency for the differences between LT_1 and LT_2, and these differences were of a considerable range (up to 35W). These differences reflect the issue with larger workload increments (50W) between stages in the LT/VO_{2max} test, which were necessary to qualify for a valid VO_{2max} test. The second test was performed using smaller 10W increments and longer stages around the LT in order to overcome this issue. There is little research available on the effectiveness of LT_{sMAX} at achieving LT, however previous results in our laboratory with runners (16) and cyclists (8) have indicated that this approach yields a more accurate LT value, as determined by performance during prolonged exercise. Regardless, future research should examine these findings further. Steinacker et al. (1998) explains that as intensity increases higher than LT, the maximum tolerated training time decreases. In order for maximal training time, minimal training above LT is important. If the LT was not determined accurately and a rower was to mistakenly train too high, their sustainable training volume would not be maximized, and the effect of training would not evoke the same strengthening of aerobic metabolism necessary throughout the race.

Protocols

Since the basis of this investigation was the objection over the use and validity of the 'hybrid' LT/VO_{2max} test for the purpose of determining the LT, selection of an appropriate VO_{2max} protocol was necessary. One of the largest variations in the LT/VO_{2max} test is the duration of each

stage. Some studies used 2-minute stages (6, 11, 15, 18); however, this may not be enough time for lactate to fully enter the blood stream, especially at the higher intensities. Others used 4-minute stages (4, 5, 10), but these may be problematic in terms of the overall duration of the VO_{2max} test. Similar to two previous studies, the present study used 3-minute stages with 30-second rest intervals in order to avoid the problems of lactate accumulation noted above (7, 9). The protocol described by Perkins and Pivarnik (2003) was altered in order to ensure blood lactate steady state. 30-second rest periods are shown to have minimal effects on blood lactate concentration, and do not interrupt the progression of the VO_{2max} test (15). Contrastingly, the 3- minute stages and 90-second rest used by Perkins & Pivarnik (2003) may be too much rest time between stages to ensure steady blood lactate concentrations. Too much rest may allow enough time for the body to begin clearing excess lactate and thus would be counterproductive to the test.

Another issue with the LT/VO_{2max} test is the significant increase in power between each stage. Although the stages are long enough to reach a lactate steady state, the LT may be elicited within a rather large intensity range of 50W. Given the large intensity increments, the LT can easily deviate from the true value, and both outcomes are problematic when a maximum sustainable training volume is desired. The LT_{sMAX} used only 10W increments in order to overcome the broad range of power required for a VO_{2max} in the LT/VO_{2max} test. This is hypothesized to give a more precise estimate of LT, however more research is needed.

Limitations and Future Research

The participants had a wide range of abilities, some being novice and some varsity. With regard to the testing protocol, the use of the rowing ergometer for metabolic testing has been shown to be an acceptable alternative to boat testing (2). Physiological testing is most commonly performed on an indoor ergometer because water measurements are difficult. Using the ergometer has not only been shown to produce similar results to on the water, but can produce better results because the skill level of the rower does not affect performance (11). Therefore, the effect of the range of abilities of the participants was minimized as much as possible with the use of a rowing ergometer. The results indicate that the absolute differences between LT_1 and LT_2 were different from the actual workload differences between these two estimates. Nevertheless, it would be beneficial to minimize the variability of the results which can be partly attributed the broad fitness range of the participants. Many rowers had never competed in a varsity sport before joining the rowing team, and others were just beginning to learn the sport. If this protocol were reproduced, the participants should be experienced varsity rowers who are more familiar with maximal exertion and would allow more standardization of stroke frequency. Due to the small number of varsity rowers, it was not possible to determine differences based on experience. As well, an investigation comparing male and female responses may also be beneficial. Due to the small size of the team there were not enough males to complete the tests, and comparison between sexes was not possible.

Due to the flaws of a simultaneous LT/VO_{2max} test, the novel LT_{sMAX} test has little supporting research beyond our lab. For this reason, future research should examine this new approach in order to determine the validity of LT_2. During LT_{sMAX}, ventilation was not measured and heart rate was measured at the end of each stage. Although all rowers reached steady state during the LT/VO_{2max} test, it should not be assumed that this is so in the LT_{sMAX}. Future research should consider a similar protocol with constant ventilation and heart rate measurements to determine the validity of the LT_2 estimation.

Conclusions

The purpose of this research was to challenge the effectiveness of the simultaneous LT/VO_{2max} test in determining an accurate LT compared to a second sub-maximal lactate test. Our results indicate that the two tests did not yield significantly different powers at the LT; however, this is due to the disperse response. The absolute difference between the two tests was statistically different from the average difference, which partly explains the lack of statistical significance. These results are based on the use of LT_2 as a legitimate measure of LT, and while confirmed in some previous research (8,16), further examination of the LT_{sMAX} test is pivotal for improving LT determination procedures. In the case of training, an incorrect LT is harmful if the goal is maximized training volume in order to increase performance. Such differences could significantly impact competition; if a participant were to row a 2000m race at the two estimated LTs, average intensities of 170W and 178W, a 2000m time would be eight seconds different (7:32.02 vs. 7:24:11). Placed in perspective, the results between the gold and silver medals for single sculls during the 2008 Beijing Olympics was 0.72 seconds for women and 0.80 seconds for men. For these reasons, the variation between LT_1 and LT_2 are different enough that future research should examine the second test, as well as use it as precautionary to achieve the highest training volume possible.

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For additional information about the study please contact: Stasinos Stavrianeas; Sparks Center 209; Willamette University; 900 State Street; Salem, OR 97301; Tel: 503-370-6392; stas@willamette.edu.

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