Comparison of Critical Swimming Velocity and Velocity at Lactate Threshold in Elite Triathletes

L. Martin, G. P. Whyte

Division of Sport and Performance, University of Wolverhampton, Walsall, UK

Martin L, Whyte GP. Comparison of Critical Swimming Velocity and Velocity at Lactate Threshold in Elite Triathletes. Int J Sports Med 2000; 21: 366 – 368

Accepted after revision: January 31, 2000

The purpose of this study was to determine whether the critical swimming velocity (Vcrit) corresponds to the velocity at lactate threshold (V-LT) in elite triathletes. Eight elite triathletes (5 male, 3 female; age 26 ± 4 years; height 1.7 ± 0.1 m and body mass 75 ± 4 kg) participated in the study. Vcrit, defined as the speed that could theoretically be maintained indefinitely without exhaustion, was expressed as the slope of a regression line between swimming distance covered and the corresponding times of five time trials over 100, 200, 400, 800 and 1500 m and all combinations of these. Lactate threshold (LT) was determined by visual inspection as the point of first inflection of the lactate-work rate curve following 5 × 300 m swims of increasing velocity which were paced using the Aquapacer (Challenge and Response, Inverurie, Scotland). Velocities of the 300 m swims were – 10, – 5, 0, + 5 and + 10 % of the average 100 m pace from a 1500 m time trial. Vcrit was similar regardless of the combination or number of time trials used in the linear regression. For all subjects Vcrit was significantly faster ($p < 0.05$) than V-LT (1.23 ± 0.11 m · $s^{-1}$and 1.15 ± 0.10 m · s^{-1} respectively). Blood lactate concentrations were also significantly higher ($p < 0.05$) at Vcrit (3.0 ± 1.0 mM) than at LT (1.9 ± 0.4 mM). Results from the present study demonstrate that Vcrit can be calculated from any two time trials in triathletes, however Vcrit did not represent V-LT in triathletes. Since Vcrit is faster than V-LT it is unlikely to be sustained indefinitely and consequently the notion of Vcrit should be re-evaluated in light of these findings.

Key words: Critical velocity, lactate threshold, triathlon, swimming.

Introduction

The concept of critical power was originally proposed for use with synergistic muscle groups [6] and has been adapted to total body work in sporting activities such as cycling [4], kayaking [2] and swimming [9,11 – 13,15]. With regard to total body work in swimming and running, critical velocity (Vcrit) is defined as the speed which can theoretically be maintained indefinitely without exhaustion [11], and is expressed as the slope of the regression line relating distance covered and corresponding times of a series of maximal effort time trials.

Lactate threshold (LT) is defined as the submaximal exercise intensity that invokes a sudden and sustained increase in blood lactate concentration [5]. Increased lactic acid production results from the onset of anaerobic glycolysis to supplement aerobic energy production at an individual specific exercise intensity. The associated increase in H^+ with increasing lactic acid results in metabolic acidosis, a primary vehicle of fatigue. The underlying mechanics of LT clearly indicate that at exercise intensities up to the LT, where minimal energy is supplied by anaerobic glycolysis, exercise could be maintained for a prolonged period of time without fatigue.

Triathlon requires individuals to compete for a period of 2 – 14 hours depending on the event and expertise of the athlete [8]. A determinant of success, therefore, is to complete each discipline at optimal pace without creating fatigue, thus a high lactate threshold is advantageous to the competitive triathlete [7,8]. The assessment of LT in swimming is complicated not only by the reluctance of individuals to undergo invasive blood sampling, but also to the inability to accurately control swimming speed during free swimming [12]. Recent advances in pacing systems may result in a more accurate method of pacing when determining LT.

Determination of Vcrit in competitive swimmers has previously required the completion of a series of maximal effort swims covering distances from 50 m to 400 m [12,13]. These time trials are considerably short and the validity of calculating an indefinitely sustainable speed from time trials lasting < 5 minutes should be viewed with caution. The Vcrit of competitive swimmers has been reported to be equivalent to blood lactate concentrations of 4 mM [11]. Exercise at 4 mM blood lactate can usually be sustained for no longer than 1 hour [3] and

Int J Sports Med 2000; 21: 366 – 368

ISSN 0172-4622

therefore further questions the concept of an indefinitely sustainable velocity at Vcrit.

The aims of the present investigation were to identify the influence of long distance time trials on the calculation of Vcrit and to compare Vcrit with V-LT.

Method

Subjects

Eight elite triathletes (5 male, 3 female; age 26 ± 4 years; height 1.7 ± 0.1 m and body mass 75 ± 4 kg) participated in the investigation. Following approval by the institution's ethical committee and before participating in the study, the procedures of the study were fully explained to each subject who then gave written informed consent.

Determinations of critical velocity

Subjects were asked to complete five time trials of 100, 200, 400, 800 and 1500 m with at least 24 hours recovery between each time trial. All swims were completed from a push off and at maximal effort. The slope of the linear regression line was calculated from all possible combinations of 2 – 5 time trials (Fig. **1**). Additionally Vcrit-5TT (5 time trials) was plotted onto the lactate curve to indicate associated blood lactate concentrations.

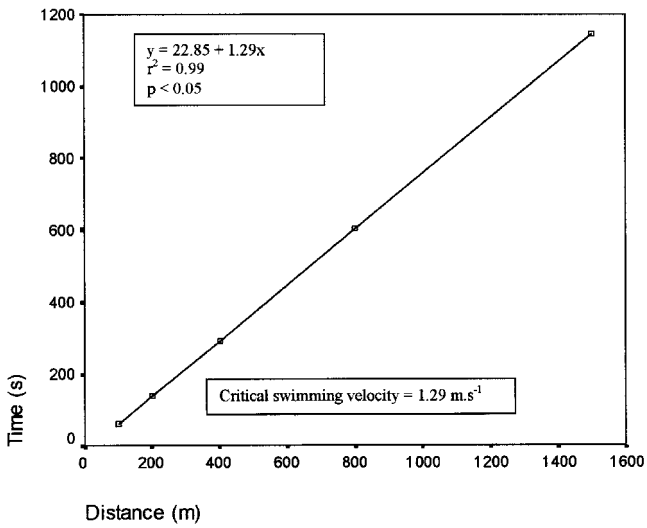

Fig. 1 Method for determining critical swimming velocity.

Determination of lactate threshold

Following a controlled 400 m warm-up, subjects completed 5 × 300 m swims of increasing velocity which were paced using the Aquapacer (Challenge and Response, Inverurie, Scotland). Velocities of the 300 m were – 10, – 5, 0, + 5 and + 10 % of the average 100 m pace from a 1500 m time trial completed the week before testing. The Aquapacer was programmed to emit a 'bleep' at designated time intervals, for an even paced swim, equivalent to the end of each length. Subjects' were instructed to 'turn on the bleep ensuring that their feet touched the wall on the bleep'. Results of a pilot study found that the reproducibility of swimming at a given pace over three separate trials was very high (ratio limits of agreement = ∗/÷ 1.00). A minute rest separated each 300 m swim and during this time a single capillary blood sample was taken from the earlobe. A calibrated lactate analyser (Analox, Hammersmith, UK) determined blood lactate concentration. Lactate threshold (LT) was determined by visual inspection, by two independent observers, as the point of first inflection of the lactate-work rate curve [14].

Statistical analysis

Dependent t-tests were used to compare critical velocity with velocity at lactate threshold and also blood lactate concentrations of each. One-way ANOVA was used to compare the values of Vcrit from all combinations of time trials. A critical level of 0.05 was set for all analyses.

Results

The number or combination of trials used in the linear regression did not result in a significantly different Vcrit ($p > 0.05$) (see Table **1**). Combinations of trials where shorter time trials were predominant over the longer distance time trials resulted in a faster Vcrit compared with Vcrit-5TT ($p > 0.05$). Mean Vcrit-5TT ($1.23 \pm 0.11\ m \cdot s^{-1}$) was significantly faster ($p < 0.05$) than mean V-LT ($1.15 \pm 0.10\ m \cdot s^{-1}$) and this was true in all subjects. Similarly, mean blood lactate concentrations were significantly higher ($p < 0.05$) at Vcrit-5TT (3.0 ± 1.0 mM) than at LT (1.9 ± 0.4 mM).

Table 1 Mean ± (S.D.) of Vcrit on selected combinations of time trials

Time trials	Vcrit ($m \cdot s^{-1}$)
100/200/400/800/1500 m	1.23 (0.10)
100/200/400/800 m	1.24 (0.10)
200/400/800/1500 m	1.22 (0.11)
100/200/400 m	1.27 (0.12)
200/400/800 m	1.24 (0.10)
200/400/1500 m	1.22 (0.11)
400/800/1500 m	1.22 (0.11)
100/200 m	1.25 (0.09)
200/400 m	1.28 (0.13)
200/1500 m	1.22 (0.11)
400/1500 m	1.22 (0.11)
800/1500 m	1.21 (0.13)

$F = 0.332$ ($p > 0.05$)

Discussion

The inclusion of 800 m and 1500 m time trials had no significant effect on the resultant Vcrit (Table **1**). In support of these findings Wakayoshi et al. [13] reported that 800 m and 1500 m time trials lay very close to the regression line calculated for distances between 200 m and 1500 m in a pilot study of competitive swimmers. In contrast, Wright and Smith [15] reported that Vcrit 50/200/600/1200 m was significantly slower than

Vcrit 50/200/600 m ($p < 0.05$). These different findings may be related to the relationship between swimming speed and swimming economy which varies from swimmer to swimmer. Vandewalle et al. [10] indicated that calculation of Vcrit in swimming may be invalid due to complexities of this relationship, however, the consistent linearity between distance and speed regardless of number and combination of trials in the present study indicates that swimming economy was relatively constant for the triathletes.

The results of the present study indicate that Vcrit-5TT does not represent V-LT in elite triathletes. For all subjects, Vcrit-5TT was significantly faster than V-LT ($p < 0.05$). It could be argued that the increments in velocity in the LT test were relatively severe and that consequently LT may be underestimated. Comparison of Vcrit-5TT to V-LT, however, reveals that in most subjects Vcrit-5TT was more than one increment above the V-LT implying that Vcrit-5TT would still have been faster than V-LT if smaller increments in swimming velocity had been used.

Differences in Vcrit-5TT and V-LT are best illustrated through an example of the practical application of the results. V-LT may be utilised to prescribe a specific swimming pace to be used in a training programme to develop LT. By calculating limits of agreement [1] it is possible to indicate the range of Vcrit-5TT compared to the V-LT. From the results of the present study, a 300 m swim pace at Vcrit-5TT may vary by as much as 30 s either side of the pace equivalent to V-LT. Such a range in pace would invoke a variety of metabolic demands from the athlete rather than specifically being focused on the LT.

The blood lactate concentration associated with Vcrit-5TT in the present study is slightly lower than previously reported values. Wakayoshi et al. [11] reported a mean blood lactate value of 4.23 ± 0.67 mM at Vcrit in male swimmers, although Vcrit was slower ($1.16\ m \cdot s^{-1}$). Differences in Vcrit and blood lactate at Vcrit between triathletes and competitive swimmers are likely to reflect the different metabolic demands of competitive swimming and competitive triathlon and the training programmes employed by the two athletic groups.

Although the aims of the investigation were not to validate Vcrit from a theoretical perspective, the findings of the study have resulted in the need to question the physiological meaning of Vcrit from the current definition. It is unlikely that a swimming velocity that generates a blood lactate concentration of 3.2 mM (Vcrit-5TT) could be sustained indefinitely since in the subject population 3.2 mM is above the LT. Swimming at Vcrit-5TT would, for the triathletes, be inducing a degree of metabolic acidosis to occur. Although this acidosis would be relatively small, it would nevertheless lead to the onset of fatigue prior to the depletion of fuel stores. Future research should focus on clarifying the physiological nature of Vcrit and examine its implications to performance.

In conclusion, longer time trials have no effect in calculating Vcrit in triathletes assuming efficient technique throughout. Additionally, Vcrit cannot be used as a simple non-invasive alternative in the determination of LT in triathletes since it consistently over estimates the V-LT.

References

[1] Bland JM, Altman DG. Statistical methods for assessing agreement between two methods of clinical measurement. Lancet 1986; 1: 307 – 310

[2] Clingeleffer A, McNaughton LR, Davoren B. The use of critical power as a determinant for establishing the onset of blood lactate accumulation. Eur J Appl Physiol 1994; 68: 182 – 187

[3] Jacobs I, Sjodin B, Kaiser P et al. Onset of blood lactate accumulation after prolonged exercise. Acta Physiol Scand 1981; 112: 215 – 217

[4] Jenkins DG, Quigley BM. Endurance training enhances critical power. Med Sci Sports Exerc 1992; 24: 1283 – 1289

[5] Kumagai S, Tanaka K, Matsura Y, et al. . Relationships of the anaerobic threshold with the 5 km, 10 km and 10 mile races. Eur J Appl Physiol 1982; 49: 15 – 23

[6] Moritani T, Nagata A, De Vries HA, Muro M. Critical power as a measurement of physical work capacity and anaerobic threshold. Ergonomics 1981; 24: 339 – 350

[7] O'Toole ML, Douglas PS. Applied physiology of triathlon. Sports Med 1995; 19: 251 – 267

[8] Sleivert GG, Rowlands DS. Physical and physiological factors associated with success in the triathlon. Sports Med 1996; 22: 8 – 18

[9] Toussaint HM, Wakayoshi K, Hollander AP, Ogita F. Simulated front crawl swimming performance related to critical speed and critical power. Med Sci Sports Exerc 1988; 30: 144 – 151

[10] Vandewalle H, Vautier JF, Kachouri M, Lechevalier J-M, Monod H. Work-exhaustion time relationship and the critial power concept – a critical review. J Sports Med Phys Fit 1997; 37: 89 – 102

[11] Wakayoshi K, Ikuta K, Yoshida T, Udo M, Moritani T, Mutoh Y, Miyashita M. Determination and validity of critical velocity as an index of swimming performance in the competitive swimmer. Eur J Appl Physiol 1992; 64: 153 – 157

[12] Wakayoshi K, Yoshida T, Udo M, Kasai T, Moritani T, Mutoh Y, Miyashita M. A simple method for determiming critical speed as swimming fatigue threshold in competitive swimming. Int J Sports Med 1992; 13: 367 – 371

[13] Wakayoshi K, Yoshida T, Udo M, Harada T, Moritani T, Mutoh Y, Miyashita M. Does critical swimming velocity represent exercise intensity at maximal lactate steady state? Eur J Appl Physiol 1993; 66: 90 – 95

[14] Weltman A, Snead D, Stein P, Seio R, Schurrer R, Rutt R, Weltman J. Reliability and validity of a continuous incremental treadmill protocol for the determination of lactate threshold, fixed blood lactate concentrations, and $\dot{V}O_2$max. Int J Sports Med 1990; 11: 26 – 32

[15] Wright B, Smith DJ. A protocol for the determination of critical speed as an index of swimming endurance performance. In: Miyashita M, Mutoh Y, Richardson AB (eds). Med Sci Aquatic Sports. Basel: Karger, 1994: 55 – 59

Corresponding Author:

Louise Martin, BSc (Hons), MSc

University of Wolverhampton
Gorway Road
Walsall WS1 3BD
UK

Phone: + 44 (1902) 323144
Fax: + 44 (1902) 323042
E-mail: in6078@wlv.ac.uk