# CRITICAL SPEED

# AND

# TRAINING INTENSITIES FOR SWIMMING

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## Introduction

Although competitive swimming is characterized as a high intensity activity of varying, though relatively short, duration, it is essentially an aerobic activity. Even the 50 and 100m 'sprints' are not true sprints as is the 100m track event, but are perhaps better described as short endurance efforts. This is borne out by the observation that elite swimmers of all distances possess a well-developed maximal oxygen consumption ($VO_2$max)(Holmer, 1972).

## $VO_2$max

The measurement of $VO_2$max has for many years now been the 'gold standard' measure of aerobic or endurance fitness. Training intensities determined as various percentages of $VO_2$max have been proposed for a variety of exercise modalities. However, because of the methodological difficulties in measurement of $VO_2$max for swimmers, its application to the sport, particularly in the field, is largely inappropriate. However, estimations of $VO_2$max intensity are still used for determining training intensities (Treffene, 1992; Touretski, 1993).

The significant contribution of aerobic (oxidative) energy supply to competitive swimming has implications for planning training programs of swimmers preparing to compete over different distances. Although many coaches still prescribe much high intensity training for sprint swimmers, there is a growing swing back to an understanding of the importance of a well-developed 'aerobic base' for all swimmers, including 'sprinters' (Touretski, 1993). However, debate continues around the appropriate intensity(ies) at which the 'aerobic base' is best developed. Critical Speed (CS) is proposed as a means for determining those intensities.

## Blood Lactate Testing

During the 1980s, and based on the publication of East German testing techniques (Mader et al. 1978), blood lactate testing was used extensively with swimmers in an effort to assess 'optimal' training intensities (Maglischo et al. 1984). These researchers proposed that the swimming speed which produced a blood lactate concentration of 4 $mmol.L^{-1}$ (the Onset of Blood Lactate Accumulation or OBLA) was an 'optimal' one for aerobic training. The basis for this was that swimmat the OBLA would elicit a maximal lactate steady-state (MLaSS) of approximately 4 $mmol.l^{-1}$. This criterion value originated from the Two-Speed Test proposed by Mader and co-workers (1978), and employed for both swimmers and runners for interpolation of training intensities. More recent evidence has shown that application of this absolute criterion value does not hold true for all individuals, the application of 4 $mmol.L^{-1}$ 'across the board' is inappropriate, and that the intensity (and blood lactate concentration) at MLaSS should be determined on an individual basis.

To do this using conventional techniques requires access to lactate testing facilities, a privilege available only to a relatively few coaches across the country. Additionally, while the procedure is relatively simple, it is nonetheless invasive. Determination of CS enables this relatively sophisticated parameter, intensity at MLaSS, to be determined with minimal equipment and an item in every swim coach's possession: a stopwatch.

## Critical Speed and Critical Power

Critical Speed (CS) is a development of the Critical Power (CP) concept, first proposed by Monod and Scherrer (1965), when they defined it as 'the maximum rate a muscle (group) can maintain for a very long time without fatigue'. CP has been examined during several different exercise modalities: cycling (Moritani et al. 1981), kayaking (Ginn, 1988), treadmill running (Hughson et al. 1984) and swimming (Faina et al. 1988; Wakayoshi et al. 1992), and has been shown to define an intensity physiologically similar to the 'anaerobic threshold' as measured by the Ventilatory Threshold (Nagata et al. 1983) or EMG (DeVries et al. 1982). During swimming (Faina et al. 1988; Wakayoshi et al. 1982), kayak (Ginn, 1988) and cycle ergometry (Jenkins & Quigley, 1990) studies was that exercise at CP elicited the MLaSS. An interesting feature of the kayak (Ginn, 1988) and cycle ergometry (Jenkins & Quigley, 1990) it was shown that exercise at CP elicited mean steady-state blood lactate values of 5.5 and 8.9 mmol.L-01 respectively, considerably higher than the 4 mmol.L-1 imposed by the OBLA procedure. This observation has been reported for kayak ergometer (Ginn & Mackinnon, 1989). These findings support the view that the application of an absolute lactate criterion value of 4 $mmol.L^{-1}$ is inappropriate, and, for the subjects in the respective studies, would have underestimated interpolated intensities determined for training prescription.

Critical Power is determined from 2, 3, 4, or even 5 exhausting exercise tests with a recovery period of at least 1-2 hours between tests. An explanation of this procedure as it applies to cycle exercise has been documented elsewhere (Jenkins & Quigley, 1991). CP for swimmers has been calculated from efforts in a swim flume, equipment which enables the intensity of exercise to be kept constant (Faina et al. 1988; Wakayoshi et al. 1992). In their swim flume study, Wakayoshi et al. (1992a) showed that CP was equivalent to CS, as determined from the $distance.time^{-1}$ ($d.t^{-1}$) relationship. It was further shown (Wakayoshi et al. 1992b) that CS obtained during flume swimming was equivalent to CS determined from the $d.t^{-1}$ relationship of data obtained during free swimming of 100 and 400m.

## Critical Speed

The plasma lactate response to swimming sets of either 6 x 400m or 12 x 200m at their individual CS was recently examined in 37 well-performed swimmers (Ginn, 1993). It was shown that swimming at CS elicited the MLaSS ($V_{MLaSS}$), while a slightly increased intensity (approximately 0.02 $m.sec^{-1}$) was sufficient

for plasma lactate to accumulate throughout the set. Figure 1 presents the plasma lactate response to swimming 6 x 400m at CS in one of these subjects. This diagram illustrates the MLaSS elicited by velocities very close to the imposed CS velocity, represented by the unbroken line across the graph.

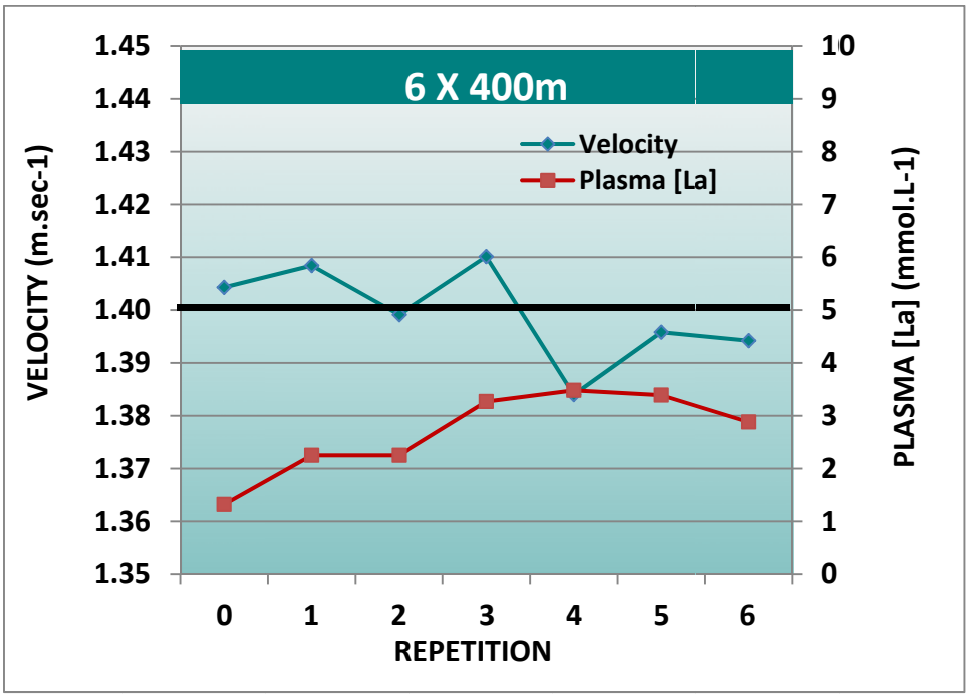


**Figure 1.** **Diagram illustrating the average velocity and plasma lactate concentration following each 400m of a set of 6 repetitions at Critical Speed**

The values of plasma lactate concentration at $V_{MLaSS}$ varied from 3.26 (distance and middle-distance swimmer, Figure 1) to 11.5 (sprinter) $mmol.L^{-1}$. These results add a great deal of support to the position that, because of the wide inter-individual variability in lactate responses to a comparable exercise intensity, the imposition of an absolute criteria is inappropriate.

## Training Intensity Levels

Commonly found in coaching literature, including that for swim coaches, is a means for prescribing training intensities based on 'training zones'. These zones are based on blood lactate levels, as illustrated in Figure 2 below.


**Figure 2. Zones for training based on blood lactate concentration**

(From: Maglischo, 1988)

In the application of these zones for training prescription, the coach is generally required to evaluate the velocity at the aerobic threshold (2mmol.$L^{-1}$), the anaerobic threshold (4 mmol.$L^{-1}$) and/or other values where applicable, from a lactate curve generated from an incremental swimming test.

In that CS represents an intensity close to the upper limit of oxidative capacity, as demonstrated by the MLaSS, it would be approximately equivalent to the Super Aerobic Training Zone in Figure 2. The wide range of plasma [La] elicited at $V_{MLASS}$ (3.26-11.5 mmol.$L^{-1}$) in the study mentioned above, and the fact that many of the swimmers achieved plasma [La] values at $V_{MLASS}$ outside the 4-6 range proposed by this means for prescribing training intensities, strongly implies that the blood [La] ranges as presented in Figure 2 would be quite inappropriate for those subjects. Further, the ordinates and nomenclature of the y-axis would need to be revised, and on an individual basis, if this procedure were to have any validity.

The generation of lactate curves forms the basis of much of the testing for evaluation of training intensities for swimmers and other athletes. That this form of testing underestimates predicted blood [La] values (Mazza, 1991); Keskinnen et al. 1989) suggests that a more appropriate means for performing these tasks should be sought. It would appear that the cumulative effect on the blood [La] of swimming a number of intervals at increasing velocities plus the compounding influence of epinephrine and norepinephrine accumulation (Lehmann et al. 1985) would predispose the methodology to underestimation. Various methods have been suggested (Beaver et al. 1985; Hughson et al. 1987) both to describe the change in blood [La] during incremental exercise tests, and to improve the

accuracy of prediction from lactate curves, but all fall short of their principal purpose. What seems the obvious alternative to incremental testing is to prescribe training intensities based on continuous, steady-rate testing. Most swim training (and competition) activities are performed in this mode, either in a continuous, long-duration mode, or in a short-duration, steady-rate interval mode. Testing in a steady-rate mode would thus assist in the better understanding of lactate kinetics under those conditions encountered during training sessions, and at lactate values specific to the individual.

## Procedures for Calculation of Critical Speed

CS calculation is similar to that of CP, but for the majority of swimmers, it can be calculated from 2 criterion efforts only over 50 and 400m. To improve the accuracy of testing, particularly when testing for the first time, a third swim can be included to provide a check against the possibility of a less-than-suitable effort for one of the criterion swims.

The criterion swims are conducted during training (do not use competition times), when swimmers are fresh. They are to be swim from a push start, and swimmers instructed to give a maximal effort. The two swims can be conducted on the same day, but with a rest interval long enough to produce a 'best effort' for the second swim.

1. Record the times for the two swims in seconds, and apply the distances and times to the following formula:

$$CS = \frac{d_2 - d1}{t_2 - t_1}$$

where $d_2$ = 400m; $d_1$ = 50m

$t_2$ = time for 400m; $t_1$ = time for 50m (in seconds)

For example, if a swimmer performs a 50m in 30.2 seconds, and a 400m in 4m50.5s, CS is calculated as below:

$$CS = \frac{400 - 50}{290.5 - 30.2} = \frac{350}{260.3} = 1.3446 \text{ m.sec}^{-1}$$

If a third swim is performed, then the formula is:

$$CS = \frac{d_3 - d_2 - d_1}{t_3 - t_2 - t_1}$$

Where: $d_3$ = 400m, $d_2$ = 200m; $d_1$=50m; and

$t_3$= time for 400m; $t_2$ = time for 200m; $t_1$ – time for 50m
In the above example, if the time for 200m were 2m30.7s, the value for CS would be worked out thus:

$$CS = \frac{400 - 200 - 50}{290.5 - 150.7 - 30.2}$$

$$= \frac{150}{109.6}$$

$$= 1.3686 \text{ m.sec}^{-1}$$

2. The obtained value for CS is then used to determine training times for sets of different distances. For example, for a suggested set of 6 x 400m, the time per repetition would be calculated as follows (using the CS from two time trials):

$$\text{Time per repetition} = \frac{\text{distance required}}{\text{Critical Speed}}$$

$$= \frac{400}{1.3446 \text{ m.sec}^{-1}}$$

$$= 297.49 \text{ secs}$$

$$= 4 \text{ m } 57.5\text{s}$$

Critical Speed represents an intensity that is denoted by different terms in different schemes. As it can be defined as the highest sustainable work rate which enables lactate to remain in a steady-state, it is similar in definition (though not in exercise intensity) to the 'anaerobic threshold' or OBLA. As it is determined individually, it could be defined as an Individual Anaerobic Threshold (IAT), although the specific protocol to determine the IAT (Stegmann et al. 1981) is quite different in its administration from CS. Research has shown that the IAT and CP measure a similar work rate, though IAT probably represents an intensity a little lower than CP (McLellan & Cheung, 1992). The relationship between IAT and CS has yet to be examined in scientific studies.

### How to program using CS intensity

Swimming at CS represents a velocity that is ~80-85% of maximum 100m velocity, or 90-95% of maximum 400m velocity. A system of training intensities has been devised based on CS, and is presented in Table 1.

**Table 1. A simple system of training intensity levels based on calculation of Critical Speed**

| Training Level | % of CS | % of max 400m* | Touretski Classification* |
|---|---|---|---|
| Level 1 | 75 – 80% | >75 | A1 |
| Level 2 | 80 – 90% | 75 – 85 | A2 |
| Level 3 | 90 – 100% | 85 – 95 | AT |
| Level 4 | 100% | 100 | MVO2 |
| Level 5 | 100 – 110% | 105% | LT/LP |

*These are approximate only, and will vary for individual swimmers

This classification system provides intensities which approximate the categories published recently and used in the preparation of Barcelona Gold Medallist, Alexandre Popov (Touretski, 1993).

An additional level, Level 6, is suggested where short duration, maximal intensity swimming is performed. However, this intensity is not based on CS, but represents maximal velocity, and is not discussed here.

## Conclusion

This paper has sought to describe the Critical Speed Test and to suggest a system with which it can be employed to determine training intensities to promote adaptation of the oxidative and glycolytic energy systems. Its calculation determines the intensity at maximal lactate steady-state, yet the procedure is non-invasive, simple to perform, and requires very little equipment.

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