Onset of blood lactate accumulation as a predictor of performance in top athletes

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Abstract: The main purpose of this study was to investigate whether the onset of blood lactate accumulation velocity (V_{OBLA}) is a good predictor of middle- and long-distance running performance in well-trained endurance runners. Twenty-two well-trained runners participated in this study. All participants completed a incremental test on a treadmill to determine maximal physiological variables the V_{OBLA} (4 mmol·L\(^{-1}\) of lactate concentration). The relationships between V_{OBLA} and the best 10-km (V_{10K}) and 3-km (V_{3K}) race pace were analyzed. The velocity for V_{OBLA} was 17.7 ± 1.2 km·h\(^{-1}\) and the velocities for V_{10K} and V_{3K} were 21.1 ± 0.7 km·h\(^{-1}\) and 19.0 ± 0.8 km·h\(^{-1}\), respectively. A positive linear relationship was found between V_{OBLA} and V_{10K} (r = 0.761, P < 0.05) and between V_{OBLA} and V_{3K} (r = 0.561, P < 0.05). These results indicate that V_{OBLA} is highly associated to running performance according to V_{10K} and V_{3K} in well-trained runners.

Key words: Endurance, OBLA, correlation, running.

1. Introduction

Several researchers have demonstrated that, in the endurance performance, the ability to run without accumulating lactate is more important than the maximum oxygen uptake (VO_{2max}) or the energy cost of running (Cr) (Yoshida, Udo, Iwai & Yamaguchi, 1993; Grant, Craig, Wilson, & Aitchison, 1997). This concept of anaerobic threshold was firstly proposed in order to express the loss of linear relationship between ventilation and the oxygen uptake (VO_{2}), which coincides with lactate accumulation (Wasserman & McIlroy, 1964). Later, it was redefined as the work rate or VO_{2} just below the point where lactate begins to systematically increase from its resting level exercise value during an incremental exercise test (Whipp & Davis, 1981). Since then, different blood lactate indices have been proposed to measure the ability to run without accumulating lactate, such lactate threshold (LT), maximal lactate steady state (MLSS), or the onset of blood lactate accumulation (OBLA). OBLA is the exercise intensity corresponding to 4 mmol·L\(^{-1}\) lactate concentration, which represents the maximal workload of steady-state lactate accumulation (Figueira, Caputo, Pelarigo, & Denadai, 2008) and which corresponds to the transition from a tolerable workload to a more severe intensity (Chmura & Nazar, 2010). Different studies have shown the importance of OBLA in the long distance running performance and it has also been suggested as a sensitive indicator of the training induced adaptations and a sensitive discriminator between elite and good athletes (Tanaka, 1990).

It should be noted that many of these studies where performed with only a small number of participants (Abe, et al., 1999), non-trained subjects (Tanaka, Matsuura, Kumagai, Matsuzaiku, Hikakoba & Asan, 1983) or in non-elite athletes (Sjödin & Jacobs, 1981; Grant, et al., 1997). Therefore, the main purpose of this study was to investigate if the onset of blood lactate accumulation velocity (V_{OBLA}) could be a good predictor of running performance in well-trained endurance athletes.

2. Methods

2.1 Subjects

Twenty-two well-trained runners (28.6 ± 6.4 years) participated in the study. Before participation, subjects were medically examined to ensure that they had no signs of cardiovascular, musculoskeletal and metabolic diseases. The Ethics Committee for research on human subjects at the University of Basque Country (CEISH/GIEB) approved this study. All athletes were informed about all the tests and the possible risks involved and signed a written informed consent prior to testing.

All subjects had participated in international or national level competitions. The best record in 3000 meters and 10000 meters of each subject was recorded and the pace was calculated (V_{10K} and V_{3K}, respectively). Athletes were encouraged to be well rested and to abstain from hard training sessions and competitions the days before testing.

2.2. Procedures

Anthropometry. Height (cm) and body mass (kg) were measured with the use of a precision stadiometer and a balance (Seca, Bonn, Germany), and body mass index (BMI) was calculated. Eight skinfold sites (biceps, triceps, subscapular, supraspinade, abdominal, suprailiac, mid-thigh, and medial calf) were measured in duplicate with a skinfold caliper ( Holtain, Crymych, UK) by the same researcher and the sum of skinfolds was determined. The body fat percentage was calculated for each athlete, as described elsewhere (Vihus, 1974).

Peak treadmill lactate test. All subjects completed a maximal incremental running test at a 1% gradient on a treadmill (ERGelek EG2, Vitoria-Gasteiz, Spain). The test started at 9 km·h\(^{-1}\) without previous warm up. Velocity was increased by 1.5 km·h\(^{-1}\) every 4 minutes until volitional exhaustion, with a minute recovery between each stage. The treadmill was calibrated using a measuring wheel (ERGelek, Vitoria-Gasteiz, Spain) with a measurement error <0.5m per 100m interval.

Testing sessions were performed under similar environmental conditions (20-24°C, 45-55% relative humidity).

During the test gas exchange ratio (RER) were continuously measured using a calibrated gas analyzer system (Ergocard, Medisport, Sorinnes, Belgium). The gas analyzer was calibrated prior to each session according to the manufacturer’s instruction. Volume calibration was performed at different flow rates with a 3 L calibration syringe (Medisport,
Sorinnes, Belgium) allowing an error of 2%, and gas calibration was performed automatically by the system using both ambient and precision reference gases (CO$_2$ 4.10%; O$_2$ 15.92%) (Linde Gas, Germany). VO$_2$ was also normalized per kg$^{-1}$ to reduce the influence of body mass (Helgerud et al., 2010). Heart rate (HR) was recorded by a heart rate monitor (Polar RS800, Kempele, Finland).

Immediately after each exercise stage, capillary blood samples from the earlobe were obtained and lactate concentration was determined with the use of a portable lactate analyzer (Lactate Pro, Akray, KDK Corporation, Kyoto, Japan.). This system has been validated previously (Tanner, Fuller & Ross, 2010).

Athletes were considered to have attained their maximal ability when three of the following criteria were fulfilled: 1) a plateau in VO$_2$; 2) RER > 1.15; 3) HR within 5 beats·min$^{-1}$ of theoretical maximal HR (220-age); 4) lactate concentration > 8 mmol·L$^{-1}$; 5) RPE= 10.

**Determination of V$_{OBLA}$** V$_{OBLA}$ was calculated by interpolation, expressing the collected blood lactate concentration of each subject in the peak treadmill lactate test as a function of running velocity. A quadratic equation was used to perform the regression of the lactate concentration and velocity

### 2.3. Statistics

Statistical analyses of data were performed using the Statistical Package for the Social Sciences 15.0 software package (StatSoft, USA). Results are all presented as means, standard deviation (SD) and coefficient of variance (CV, SD·mean$^{-1}$·100). The relationships between V$_{OBLA}$ and the average velocities of the individual’s running performance were evaluated using a linear regression analysis. Significance for all analyses was set at $P<0.05$.

### 3. Results

Table 1 shows the results of the anthropometrical parameters and running performance data. The CV was lower than 10% in the height, mass and BMI, despite the big variations in factors related to body fat. A small CV of the athlete’s performance was observed according to

![Figure 1](image-url) shows the relationship of V$_{OBLA}$ and running performance (V$_{2peak}$ and V$_{10k}$). V$_{OBLA}$ was closely correlated with V$_{2peak}$ and V$_{10k}$($r=0.561$, $P<0.05$ and $r=0.762$, $P<0.01$, respectively) despite the small variation among subject’s running performance.

![Image](image-url)

**Figure 1.** The realationship between running velocity corresponding to the onset of blood lactate accumulation ($V_{OBLA}$), and the running performance according to the 3000 meter race velocity ($V_{3K}$) and 10 km race velocity ($V_{10K}$).

**4. Discussion**

The major finding in this study was the observed significant relationship between V$_{OBLA}$ and the middle and long distance running performance according to the 3000 and 10000 meters race velocity. These results are in agreement with previous studies, which have shown the validity of V$_{OBLA}$ as a predictor of aerobic performance (Billat, 1996), especially in marathon (Sjödin & Jacobs, 1981) and in those running events of 16 km or shorter distances (Tanaka, 1990). In contrast, Abe et al. (1999) did not find a relationship between V$_{OBLA}$ and 10-km performance and suggested the use of HR obtained at OBLA instead of V$_{OBLA}$ itself. Indeed, their findings may have possibly been influenced by out of laboratory testing conditions and/or a small sample size.

Several studies have demonstrated that V$_{OBLA}$ is significantly related to middle distance running performance in elite female athletes (Yoshida, et al., 1993) and non-elite male athletes (Grant, et al., 1997). However, the current study was the first finding a significant relationship between V$_{OBLA}$ and middle distance performance according to the 3000 meters race pace in well-trained male athletes. Although significance was found between these variables, the correlation coefficients in our study only explain a small percentage of the 3- and 10-km performances of the well-trained male athletes. Thus, the evidence from our study investigating well-trained endurance male athletes cannot be fully suggested as a predictor for middle- and long-distance running performances.

It is also known that exercise intensity associated to a fixed blood lactate concentration can vary widely as a result of nutrition, prior stress, site of blood acquisition as well as the method of blood sampling (Roborgs, Chwalbinska-Moneta, Mitchell, Pascoe, Houmard & Costill, 1990; Coyle, 1995; Roecker, Schotte, Niess, Horstmann & Dickhuth, 1998; Felin, et al., 1999). Researchers have also proposed that 4 mmol·L$^{-1}$ blood lactate does not take into account inter-individual variability of the LT, thus may not be objective (Steinmann & Kindermann, 1982).

These considerations together with the above-mentioned findings imply that the fixed 4 mmol·L$^{-1}$ blood lactate may not represent the same exercise intensity in runners of varying athletic ability.

Despite the significant correlations found between V$_{OBLA}$ and performance times in this study and previous studies (Sjödin & Jacobs, 1981; Tanaka & Matsura, 1984; Föehrenbach, Mader & Hollmann, 1987), several researchers have argued against V$_{OBLA}$ (Gladden, 2004). It has been found that lactate values measured in the blood are not necessarily indicative of the levels of lactate produced in active muscles (Gladden, 2004). It is also proposed that well-trained runners are likely to have an enhanced lactate clearance capacity (Donovan & Pagliassotti, 1989). Therefore, the use of V$_{OBLA}$ should be strictly standardized, if not should be used cautiously when programming training sessions, evaluating aerobic capacity or predicting running performance.

In summary, a high relationship between V$_{OBLA}$ and V$_{10K}$ and V$_{2peak}$ was observed in current study, which may indicate that this parameter...
is an appropriate index to predict the running performance. However, despite a significant relationship between $V_{\text{OBLA}}$ and both $V_{\text{ran}}$ and $V_{\text{fix}}$, the obtained correlation coefficients only accounted for a small part of the variance in the performance of well-trained athletes in our study. Therefore, we conclude that $V_{\text{OBLA}}$ is associated with both middle- and long-distance race performances but caution should be taken when relying on this measure to determine performance times.

5. Conclusions

- $V_{\text{OBLA}}$ is associated with both middle- and long-distance race performances and therefore could be considered as an adequate measure for training status and performance monitoring in athletes of similar athletic ability and different distance specialization.
- Although, $V_{\text{OBLA}}$ should be used cautiously because it does not take into account inter-individual variability in the lactate threshold and it only can explain a small percentage of the running performance.

6. References


