

A COMPARISON OF METHODS FOR ESTIMATING THE LACTATE THRESHOLD

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ABSTRACT. McGehee, J.C., C.J. Tanner, and J.A. Houmard. A comparison of methods for estimating the lactate threshold. *J. Strength Cond. Res.* 19(3):553–558. 2005.—The purpose of this study was to examine the accuracy of tests that may be used by distance runners to estimate the lactate threshold. Competitive distance runners/triathletes ($N = 27$) performed a criterion test that directly measured (blood lactate of $4.0 \text{ mmol}\cdot\text{L}^{-1}$) the lactate threshold. Subjects then performed 4 tests (VDOT, 3,200-m time trial, 30-minute time trial, Conconi) that estimate the threshold. Mean estimations of the running velocity at the lactate threshold from the 30-minute time trial (standard error of the estimate, *SEE*, $0.21 \text{ m}\cdot\text{s}^{-1}$) and VDOT (*SEE* $0.41 \text{ m}\cdot\text{s}^{-1}$) methods did not differ ($P > 0.05$) from the criterion. In terms of heart rate, the 30-minute time trial estimation did not significantly differ (*SEE* $8.0 \text{ b}\cdot\text{min}^{-1}$) from criterion. These findings suggest that the 30-minute time-trial method should be considered by coaches and distance runners/triathletes as a method for estimating both the running velocity and heart rate at the lactate threshold.

KEY WORDS. athletes, distance running, triathletes

INTRODUCTION

At a given exercise intensity, blood-lactate concentration rises exponentially; this deflection point is commonly known as the lactate threshold. The lactate threshold has been used to compare performance capability between distance runners and/or to monitor performance capability in an individual over time due to its strong relationship with distance-running performance (6, 7, 11, 12, 15). For example, in competitive endurance runners, the running velocity at the lactate threshold was the best indicator of performance after the completion of an interval training program (6). Another study (7) demonstrated that workload at the lactate threshold was the most effective method for predicting distance-running performance. Training at the threshold has also been demonstrated to provide a positive stimulus for inducing endurance-oriented physiological alterations (9, 14). For example, Sjodin et al. (14) reported that over 14 weeks, a weekly 20-minute run at the lactate threshold increased the running velocity at which the threshold was obtained, which would be anticipated to improve performance. The lactate threshold has been used to prescribe training intensities based on these (14) and other (3, 5, 9, 14, 17) findings. Such data suggest that the lactate threshold should be measured when designing training regimens with the intent of optimizing distance-running performance; in support, assessment of the threshold has been recommended as part of an effective training program for competitive endurance runners and triathletes (5, 8, 9, 13).

In a laboratory setting, determination of the lactate

threshold at a minimum requires a lactate analyzer, blood sampling, and technical expertise. In an effort to overcome such constraints, coaches and researchers have developed methods that can be implemented in the field or nonlaboratory settings to estimate the heart rate and/or running velocity at the lactate threshold. For example, in a book intended for the lay public, Daniels (5) outlined a method for calculating the running velocity at the lactate threshold from performances at various running distances (400 m to the marathon) known as the VDOT. A method for determining the threshold from heart rates and running velocities obtained from an all-out 30-minute run has also been described in the lay literature (8, 13). However, to our knowledge, these 2 methods for estimating the threshold (VDOT, 30-minute time trial) in distance runners have not been independently validated. The intent of the current study was to provide information to users of these tests (coaches/athletes) concerning the accuracy of the VDOT and 30-minute time trials for estimating the lactate threshold during running exercise. To provide additional comparisons, we also assessed the validity of 2 other methods for estimating the lactate threshold in distance runners: (a) the Conconi test (4), which is relatively established as a prediction method for the threshold, and (b) a 2-mile time trial (17) that would be relatively easy to use in the field for estimating the lactate threshold.

METHODS

Experimental Approach to the Problem

The design of the study was to directly determine the running velocity and heart rate at the lactate threshold by measuring blood-lactate concentrations during a standard, incremental exercise protocol in the laboratory in competitive endurance-trained runners and to compare this criterion measurement to estimates of the threshold obtained from tests that are recommended for use in this population. Our hypothesis was that all of the indirect methods would provide relatively accurate estimates of the heart rate and running velocity at the lactate threshold; we did not attempt to predict a priori which method would provide the most valid estimation of the criterion due to the differing theoretical basis for each of the tests and the relatively sparse data available concerning the estimation methods. The main purposes of this study were to therefore determine, using standard errors of the estimate, analysis of variance, and correlations, which, if any, of the estimation methods examined provided the closest approximation to the directly measured lactate threshold. To accomplish this aim, endurance-trained athletes (24 males, 3 females; distance runners or triath-

letes) with a minimum of 3 consecutive years of competitive experience were recruited; subjects were tested in the fall of the year during a period of consistent weekly training volume and intensity. Findings were similar regardless of the inclusion/exclusion of the female athletes; data from all subjects are thus presented. Physiological characteristics of the subjects (mean \pm SE) were age, 33.2 \pm 2.5 years; height, 177.6 \pm 1.8 cm; mass, 70.8 \pm 2.1 kg; body fat, 11.2 \pm 1.0%; peak $\dot{V}O_2$, 4.0 \pm 1.3 L \cdot min $^{-1}$; peak $\dot{V}O_2$, 56.6 \pm 1.3 ml \cdot kg $^{-1}\cdot$ min $^{-1}$; years of run training, 13.6 \pm 1.5 years; and 5-km personal best 17.7 \pm 0.4 minute. Methodology was approved by the Institutional Review Board and informed consent obtained. Subjects were instructed to maintain their current training status throughout the study.

Lactate Threshold

Subjects initially performed an incremental treadmill test to directly measure the lactate threshold. Treadmill elevation was kept constant at a 1% grade to duplicate the energy cost of overground running (10). Initial treadmill velocity on a calibrated treadmill was between 2.22 and 3.57 m \cdot s $^{-1}$ (50–60% $\dot{V}O_{2peak}$), depending on the running ability of the participant. Stage duration was 4 minutes, with running velocity increasing 0.22 m \cdot s $^{-1}$ per stage to volitional exhaustion, which was reached after approximately 30–40 minutes. A fingertip whole-blood sample was taken at 3.5–4 minutes of each stage and immediately analyzed in duplicate using an automated blood-lactate analyzer (Model 2300 Stat Plus; Yellow Springs Instruments, Yellow Springs, OH). Expired gases were collected with open-circuit spirometry (TruMax 2400 Metabolic Measurement System; Consentius Technologies, Sandy, UT) and $\dot{V}O_{2peak}$ determined as the highest oxygen uptake attained for 1 minute.

An individual blood-lactate profile was created for each subject by plotting running velocity (m \cdot s $^{-1}$) at each stage of the test (*x*-axis) versus the blood-lactate concentration attained at each stage (*y*-axis). The basis of determining the lactate threshold is that there is a deflection point at a given workload (in this case, running velocity) where blood lactate exponentially increases with a corresponding increase in workload (1). While this is the case, there is no defined method for determining this inflection point. We thus used 3 methods that are commonly used in the literature for defining this inflection point: (a) LT_{visual} : the visual determination of the point of exponential elevation above baseline values (2). (b) LT_{D-max} : a line is created by connecting the 2 end points of the blood-lactate curve; the point on this line that is the maximal distance from the blood-lactate curve is identified and another line constructed that is perpendicular to the initial line. The point at which this new, perpendicular line intersects the blood-lactate curve is identified as the lactate threshold (2). (c) $LT_{\Delta 1}$: the point at which blood-lactate values rise a sustained minimum of 1 mmol \cdot L $^{-1}$ above the previous stage (16). We also used the $LT_{4.0}$ method, which is the workload at a fixed blood-lactate concentration of 4.0 mmol \cdot L $^{-1}$ (14), as this criterion is commonly used in the laboratory.

Estimating the Lactate Threshold

Four methods of estimating the running velocity and heart rate at the lactate threshold in distance runners/triathletes were evaluated; the V-dot-O $_2$ -max (VDOT)

method (5), a 3,200-m time trial (17), a 30-minute time trial (8), and the Conconi test (4). These tests were selected because they are relatively easy for coaches and/or athletes to perform in terms of equipment and time needed, could be performed relatively frequently without inducing considerable increases in training volume and/or intensity, and were commonly used by local athletes when formulating training or racing practices. Anecdotally, the idea for this study was initiated by distance runners/triathletes contacting our lab concerning which method best predicted the lactate threshold, as the threshold was being widely recommended in lay publications and/or their coaches as an important variable for determining training and racing intensities (5, 8, 9, 13). Each athlete in the study performed 5 randomly ordered running tests within a 3–6-week period following the direct lactate-threshold test. On each day preceding testing, participants refrained from any hard running, i.e., intervals and races. All outdoor runs were performed on the same all-weather track in neutral environmental conditions (mean temperature 21° C, mean humidity 62%).

VDOT Method

The VDOT method has been recommended as a means to determine the lactate threshold through a popular book on training for distance runners by Daniels (5). Running performance at a variety of distances is entered into equations and tables derived by Daniels (5) and the running velocity at the lactate threshold (4.0 mmol \cdot L $^{-1}$), along with other important training velocities (i.e., interval pace, marathon pace), is calculated. We elected to use performance from 400- and 800-m time trials as the indices to enter into the VDOT calculations, as the short duration of these runs would allow frequent estimations of the lactate threshold during the training of a competitive distance runner. Each run was performed on a separate day and total time taken to complete the run recorded to the nearest second. As described by Daniels (5), 800-m performance time in seconds was multiplied by 2.20 and 400-m performance time (seconds) multiplied by 4.84. These calculated values for the 400- and 800-m runs were then converted to minutes + seconds and placed in the mile time column of the VDOT table (see table 3.1, pp. 63–64 in Ref. 5) and a VDOT value obtained. The lesser of the VDOT values from the 400- and 800-m runs was used to estimate the threshold (5). Running velocity at the lactate threshold (T-Pace) for the calculated VDOT was then obtained from another table derived by Daniels (table 3.2 in Ref. 5).

3,200-Meter Time Trial

This method, which, although in our experience with distance runners was not widely used, was selected due to its simplicity and potential accuracy (17). Athletes performed a maximal effort 3,200-m run on an outdoor track. Performance time was recorded to the nearest second and entered into a regression equation (running velocity at the lactate threshold [m \cdot min $^{-1}$] = 509.5 – 20.82 \times [3,200-m time, minutes]) designed to predict the running velocity at a fixed blood-lactate concentration of 4.0 mmol \cdot L $^{-1}$ (17). The running velocity obtained was compared with values from the laboratory test.

TABLE 1. Mean values of the lactate threshold from the direct lactate-threshold test.*

	Method used to identify lactate threshold			
	LT _{visual}	LT _{D-max}	LT _{Δ1}	LT _{4.0}
Lactate threshold				
Heart rate (bpm)	169.7 ± 2.5	170.7 ± 2.3	171.6 ± 2.0	175.4 ± 2.1†
Heart-rate peak (%)	89 ± 1.0	90 ± 1.0	90 ± 1.0	92 ± 1.0†
Running velocity (m/s)	3.7 ± 0.1	3.7 ± 0.1	3.8 ± 0.1	3.9 ± 0.1†
VO ₂ peak (%)	85 ± 1.0	86 ± 1.0	86 ± 1.0	90 ± 1.0†
Blood lactate concentration (mmol·L ⁻¹)	2.9 ± 0.2	3.1 ± 0.2	3.2 ± 0.2	4.0†

* Mean ± SE, N = 27.

† Significantly different from LT_{visual}, LT_{D-max}, and LT_{Δ1}. See Methods for description of lactate threshold methods.

30-Minute Time Trial

This method was selected because lay publications (8, 13) have advocated a 30-minute time trial as an accurate means for determining the lactate threshold; we also had local athletes using and inquiring about the accuracy of this test. A 30-minute time trial on a treadmill (1% grade) was performed under laboratory conditions. After a self-selected warm-up, the subject initiated the test by gradually increasing running speed to a self-selected pace deemed to be race pace for 30 minutes; at that point, timing for the trial was initiated. Running speed could be altered at any time during the test by the subject and elapsed time was provided to the athlete at 5-minute intervals; no feedback was provided in terms of distance covered or running pace. The mean running velocity (m·s⁻¹) during the 30-minute time trial was calculated by dividing the distance covered during the run (meters) by 1,800 seconds (30 minutes); this average running velocity was used as the estimate of the lactate threshold as described (8, 13). Heart rate was obtained every 5 minutes during the test from a heart-rate monitor (Polar Accurex Plus; Polar Electro, Lake Success, NY) worn by the subject. The average heart rate from the final 20 minutes was used to estimate the heart rate at the lactate threshold (8).

Conconi Test

The Conconi test was selected because it is perhaps the most examined/validated test for estimating the lactate threshold in distance runners. Subjects performed the modified Conconi test (4). Briefly, the test was conducted on an outdoor 400-m track with cones placed at 100-m intervals. Athletes began the test by running at a speed similar to the initial speed of the direct determination of the lactate threshold; athletes were instructed to begin conservatively so that sufficient data could be obtained to calculate the lactate threshold. Subjects increased running velocity uniformly every 1 minute by an increment that increased heart rate by no more than 8 b·min⁻¹; athletes were made aware of each minute by the sounding of a whistle. Heart rate was self-monitored by the athlete via a heart-rate monitor that stored the data for downloading after the test. Time to complete each 100 increment was obtained by an investigator (J.C.M.) using an electronic stopwatch that was able to store and record splits. After the test, an average running velocity (meters/second) was calculated for each minute based on the 100-m split times obtained. Heart rates during the last 10 seconds of each minute of the test were obtained from the memory of the heart-rate monitor and used to calculate the average heart rate per minute at the recorded run-

ning speed. Athletes progressively increased speed until they were near maximal effort. At this point, the uniform increase in speed was substituted with a final phase of greater acceleration up to the athletes' maximal attainable speed. The test lasted approximately 15–20 minutes. To estimate the lactate threshold, running velocity (x-axis) was graphed against heart rate (y-axis) for each minute of the test. The Conconi estimation of the threshold is based on a dissociation or deflection point of the linear relationship between heart rate and running velocity, where heart rate increases disproportionately with an increase in running speed (4). The heart rate and running velocity corresponding to the heart-rate deflection point was visually identified as the estimated lactate threshold for the Conconi test. A heart-rate deflection point could not be discerned in 2 of the subjects.

Statistical Analyses

The criterion and estimation methods were compared with repeated measures analyses of variance (ANOVA). When a significant difference was attained, post hoc contrast-contrast testing was performed to discern where the specific difference existed. Pearson Product correlations between selected variables were also performed. Statistical significance was denoted at $p \leq 0.05$.

RESULTS

Lactate Threshold

The heart rate, percentage of peak heart rate, running velocity, percentage of VO₂ peak, and blood-lactate concentration at the lactate threshold from the LT_{4.0} method were significantly higher than for the other methods (Table 1).

Running Velocity at the Lactate Threshold

As presented in Table 1, running velocity at LT_{visual}, LT_{D-max}, and LT_{Δ1} did not differ; we selected LT_{Δ1} as a criterion measure for comparison due to the relative ease and nonsubjective nature in discerning this measure (Methods). The LT_{4.0} method for predicting running velocity at the lactate threshold was also selected because several of the estimation tests directly predict this variable (5, 17). The standard errors of the estimate (SEE) for the tests estimating the threshold vs. directly determined running velocity at LT_{4.0} were 0.41 m·s⁻¹ (VDOT), 0.47 m·s⁻¹ (3,200-m time trial), 0.21 m·s⁻¹ (30-minute time trial), and 0.55 m·s⁻¹ (Conconi). The SEE for the estimations vs. directly measured running velocity at LT_{Δ1} were 0.45 m·s⁻¹ (VDOT), 0.58 m·s⁻¹ (3,200-m time trial), 0.22 m·s⁻¹ (30-minute time trial), and 0.66 m·s⁻¹

TABLE 2. Correlation coefficients (*r*) for the estimated methods vs. directly measured running velocity at LT_{4.0} or LT_{Δ1}.*

	LT _{4.0}	LT _{Δ1}
VDOT	0.64†	0.66†
3,200-m TT	0.78†	0.77†
30-min TT	0.85†	0.87†
Conconi	0.72†	0.73†

* TT = time trial.

† *p* < 0.001.

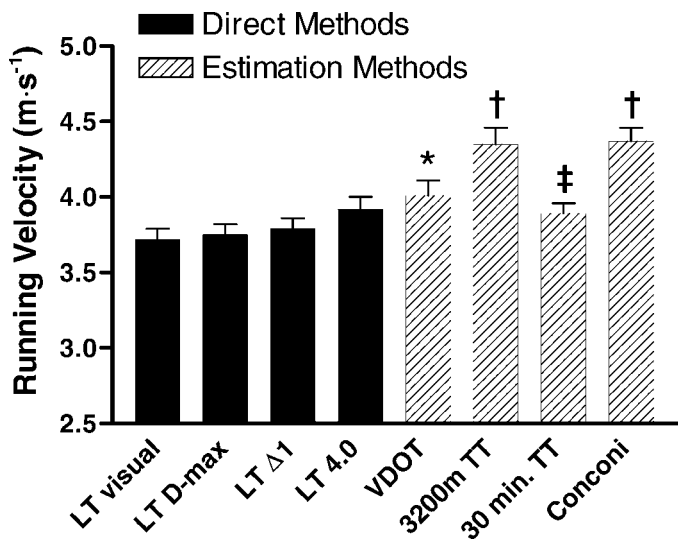


FIGURE 1. Comparison of running velocities at the lactate threshold between criterion (direct) and estimated methods. † Significant difference (*p* < 0.05) from all direct measures. * Significant difference (*p* < 0.05) from all direct measures except LT_{4.0}. ‡ Significant difference (*p* < 0.05) from direct measure LT_{visual}.

(Conconi). All of the estimation methods were significantly (*p* < 0.001) related to the running velocity at the lactate threshold for LT_{4.0} and LT_{Δ1} (Table 2).

The estimated running velocities at the lactate threshold from both the 3,200 m time trial and the Conconi test were significantly higher than all of the directly measured running velocities at the lactate threshold (Figure 1). The running velocity at the lactate threshold predicted by VDOT was significantly elevated compared with the direct measures of LT_{visual}, LT_{D-max}, and LT_{Δ1}, but not different from LT_{4.0}. The running velocity at the lactate threshold predicted by the 30-minute time trial was significantly elevated compared with the LT_{visual} method, but not different from the LT_{Δ1}, LT_{D-max}, and LT_{4.0} methods.

Heart Rate at the Lactate Threshold

The 30-minute time trial and Conconi methods predict a heart rate at the lactate threshold, while the VDOT and 3,200-m time trial methods only estimate running velocity and are thus excluded from this analysis. Mean heart rate at the lactate threshold as estimated by the both the 30-minute time trial and the Conconi test were not significantly different (*p* > 0.05) from the heart rate at LT_{4.0} (Figure 2). Heart rate at the lactate threshold predicted by the 30-minute time trial was significantly elevated compared with the direct methods of LT_{visual}, LT_{D-max}, and LT_{Δ1}. Heart rate predicted by the Conconi method was

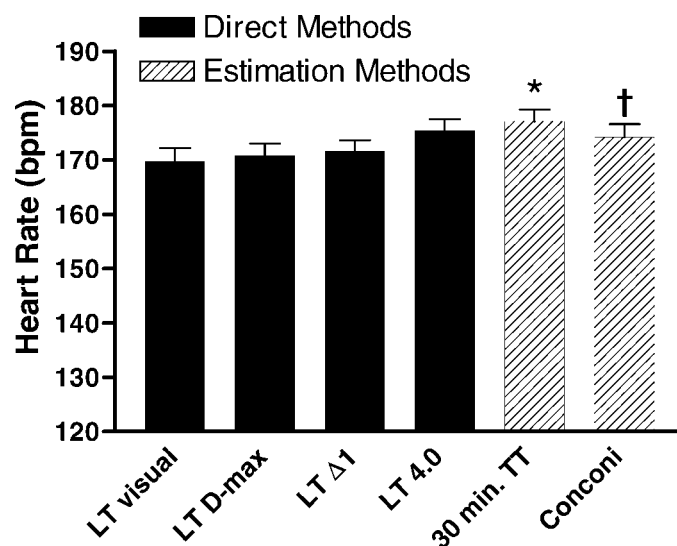


FIGURE 2. Comparison of heart rate at the lactate threshold between criterion and estimated methods. * Significant difference (*p* < 0.05) from LT_{visual}, LT_{D-max}, LT_{Δ1}. † Significant difference (*p* < 0.05) from LT_{visual}.

TABLE 3. Correlation coefficients (*r*) for the estimated methods vs. directly measured heart rate at LT_{4.0} or LT_{Δ1}.*

	LT _{4.0}	LT _{Δ1}
30-min TT	0.74†	0.67†
Conconi	0.78†	0.73†

* TT = time trial.

† *p* < 0.001.

only significantly elevated compared with the LT_{visual} method. *SEE* for the estimation methods vs. heart rate at LT_{4.0} were 8.0 b·min⁻¹ (30-minute time trial) and 7.7 b·min⁻¹ (Conconi). *SEE* for the estimation methods vs. heart rate at LT_{Δ1} were 10.3 b·min⁻¹ (30-minute time trial) and 8.7 b·min⁻¹ (Conconi). The estimations and direct methods of determining heart rate at the lactate threshold were significantly (*p* < 0.001) related (Table 3).

DISCUSSION

The main finding of the current study was that methods that can be relatively easily implemented are fairly accurate in predicting the lactate threshold in competitive distance runners and/or triathletes. In terms of running velocity, both the VDOT and 30-minute time-trial methods approximated the directly measured mean running velocity at the lactate threshold (LT_{4.0}) (Figure 1) and correlated significantly with direct measurements of the threshold (Table 2). These are novel findings, as although the VDOT and 30-minute time-trial methods have been described in the lay literature (5, 8, 13) and are currently used, there is, to our knowledge, no information concerning their validity.

When comparing the methods for estimating the threshold, a distinct advantage of the 30-minute time trial was that both a running velocity and a heart rate at the lactate threshold could be accurately obtained. When using a blood-lactate concentration of 4.0 mmol·L⁻¹ as the criterion, estimations of running velocity (Figure 1) and heart rate (Figure 2) at the lactate threshold from the 30-

minute time-trial method were not different from the direct measurement of the threshold and also exhibited lower or equivalent standard errors of the estimate (running velocity, $0.21 \text{ m}\cdot\text{s}^{-1}$; heart rate, $8.0 \text{ b}\cdot\text{min}^{-1}$) compared with the other estimation methods (Results). With the recent advent of affordable and accurate heart monitors, training prescriptions using the heart rate at the lactate threshold are becoming increasingly popular (8, 9, 13). The ability of the 30-minute time trial to accurately predict both heart rate (Table 3 and Figure 2) and running velocity (Table 2 and Figure 1) at the lactate threshold, along with the relative ease in which this test can be performed and results evaluated, makes it a procedure that should be considered by coaches and endurance athletes when attempting to determine the lactate threshold for running exercise. One basis for our recommendation is that the VDOT and 2-mile time-trial methods only estimate running velocity at the threshold. The Conconi test provides both a heart rate and running velocity estimation, but was not as consistently accurate as the 30-minute time-trial method.

The VDOT method was developed by Daniels and Gilbert by integrating performance and running economy data gathered from years of coaching distance runners (5). Recent performance at distances from 400 m to the marathon can be used to calculate a pseudo $\dot{V}O_{2\text{max}}$, termed the VDOT. The VDOT value can then be used to estimate the running velocity at a fixed blood-lactate concentration of $4.0 \text{ mmol}\cdot\text{L}^{-1}$ (T-Pace). The current study indicates that the VDOT method, when using 400- and 800-m time trials as the performance criterion, provides a reasonably accurate estimate of the running velocity at the lactate threshold. The running velocity at the threshold predicted by VDOT did not differ from the directly measured velocity at a blood-lactate concentration of $4.0 \text{ mmol}\cdot\text{L}^{-1}$ (Figure 1; *SEE* $0.41 \text{ m}\cdot\text{s}^{-1}$) and there was a significant relationship between these two variables (Table 2). We selected these racing distances (400, 800 m) because such time trials could be performed relatively frequently and be used to estimate the threshold with minimal stress to the athletes. It is not known if the inclusion of additional performances into the VDOT predication method, particularly at longer race distances, would have improved the running velocity estimate derived from the VDOT method.

The estimated heart rate at the lactate threshold using the Conconi test (4) was not significantly different from the criterion methods of $LT_{\Delta 1}$ and $LT_{4.0}$ (Figure 2) and was related to these criterion measurements (Table 3). This is in contrast with the inaccuracy of the Conconi method in predicting running velocity at the lactate threshold (Figure 1), which suggests that this method is most effective when estimating heart rate. However, the Conconi test was not able to estimate the lactate threshold in 2 of our subjects due to an inability to determine a heart-rate deflection point, and may thus not be suitable for all athletes. The 3,200-m time-trial method (17) was selected because this relatively short distance may permit periodic assessments of the threshold with minimal fatigue. However, in our hands, the 3,200-m method did not correspond with any of the criteria for determining running velocity at the lactate threshold (Figure 1), although it did correlate with the criterion methods (Table 2).

Although the lactate threshold is accepted as a useful tool in estimating and monitoring training intensity,

there is no accepted laboratory method for determining the threshold or indication of the cellular mechanisms that influence the threshold (1). As presented in Table 1, the LT_{visual} , $LT_{D\text{-max}}$, and $LT_{\Delta 1}$ methods provided very similar results for exercise intensity at the lactate threshold, while the determination derived from $LT_{4.0}$ was at a significantly higher exercise intensity. Nicholson and Sleivert (11) also reported that exercise intensities using the $LT_{D\text{-max}}$ and $LT_{\Delta 1}$ methods were similar but lower than $LT_{4.0}$; our findings agree with these data.

In conclusion, the current study evaluated the ability of tests used to estimate the heart rate and running velocity at the lactate threshold in competitive distance runners. Of the 4 estimation methods, the 30-minute time-trial method appeared to be the most effective due to its simplicity and ability to provide reasonably accurate estimates of both the running velocity and the heart rate at the lactate threshold. The use of 30-minute time trials should thus be considered when estimating the lactate threshold in distance runners and/or triathletes.

PRACTICAL APPLICATIONS

This study was performed because we observed that many local distance runners and triathletes were using tests that estimated the lactate threshold as a means to predict the heart rate and/or running velocity at the lactate threshold for training and racing purposes. This was particularly common in the athletes with Internet coaches, where an estimation of the heart rate at the threshold was used to provide training recommendations when coupled with the use of heart-rate monitors. The prevalent tests used were the VDOT and the 30-minute time-trial methods; we thus compared the ability of these 2 tests to estimate the threshold. We also selected 2 other estimation methods for comparison, a 2-mile run and the Conconi Test, due to their ability to be easily implemented and interpreted by coaches/athletes. We performed this study with the intent of providing practical information concerning the ability of relatively simple tests to accurately estimate the lactate threshold.

Our primary finding was that, in endurance-trained runners and triathletes, the ability to estimate the lactate threshold differed according to the estimation method used. The ability to estimate the heart rate at the lactate threshold was accomplished fairly accurately by both the 30-minute time trial and Conconi methods. The 30-minute time-trial method also accurately estimated the running velocity at the lactate threshold. Due to the simplicity of the test, the ability to obtain both a heart rate and running velocity at the threshold, ease in interpreting the results, and minimal equipment needed, we concluded that the 30-minute time-trial method should be considered by coaches/athletes when estimating the lactate threshold in an attempt to optimize run training and performance. We need to clarify, however, that, in the current study, the 30-minute time trial was performed on an indoor treadmill in order to minimize the effect of environmental conditions (i.e., heat stress, humidity). If a coach/athlete does not have access to a treadmill, the data from the present study suggests that a similar 30-minute run performed on a track or course where distance covered could be accurately determined would result in a relatively precise estimation of the lactate threshold. During such a field test, a heart-rate monitor with a memory would be used to obtain the average of the final 20 min-

utes of the run in order to calculate the heart rate at the threshold; running velocity at the threshold would be calculated by dividing distance covered (metric or English units) by 30 minutes or the appropriate time unit to obtain the desired index of running speed (i.e., miles·h⁻¹, m·min⁻¹, etc.).

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