Determination of Blood Lactate Training Zone Boundaries With Rating of Perceived Exertion in Runners

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Abstract

Dantas, JL, Doria, C, Rossi, H, Rosa, G, Pietrangelo, T, Fanò-Illic, G, and Nakamura, FY. Determination of blood lactate training zone boundaries with rating of perceived exertion in runners. *J Strength Cond Res* 29(2): 315–320, 2015—This study aimed to determine the rating of perceived exertion (RPE) values corresponding to the blood lactate concentration (BLC) training zone boundaries (2 and 4 mmol·L^{-1}) in moderately trained runners using the Borg CR-10 scale. Moderately trained runners ($n = 95$) performed a submaximal incremental test on a treadmill, recording BLC and RPE at every stage. Simple linear regression analysis was used to determine the RPE values corresponding to the BLC training zone boundaries, which revealed that RPE was significantly and strongly correlated with BLC ($r = 0.821$, $p < 0.001$, $R^2 = 0.675$, adjusted $R^2 = 0.674$, standard error of estimate = 1.18). The prediction equation (RPE = 1.092 × BLC + 2.143) was obtained, and RPE values at the BLC training zone boundaries of 2 and 4 mmol·L^{-1} were calculated as 4.3 (95% confidence interval [CI], 3.9–4.7) and 6.5 (95% CI, 6.0–7.1), respectively. In conclusion, the RPE values at the BLC training zone boundaries of 2 mmol·L^{-1} (4.3) and 4 mmol·L^{-1} (6.5) were adequately predicted. Rating of perceived exertion (4.3 and 6.5) can be used as an affordable tool for controlling intensity to maintain the athletes in prescribed zones during training sessions.

Key Words testing, running, blood lactate concentration, training intensity

Introduction

Metabolic thresholds and training zones have been investigated to prescribe and monitor endurance training workloads (13,15,23,30,31). For blood lactate concentration (BLC) responses, 3 training zones have been defined: low lactate (≤2 mmol·L^{-1}), accommodation lactate (>2 and <4 mmol·L^{-1}), and accumulation lactate (≥4 mmol·L^{-1}) (13,23,31). Therefore, the fixed BLC of 2 and 4 mmol·L^{-1} are the 2 boundaries delimiting the training zones. Although training each session in a prescribed zone based on BLC is considered important to improve endurance performance (7,26,30), monitoring BLC on a daily basis is impractical and expensive for coaches and athletes. Although expending a large part of their time and resources on this type of monitoring is prohibitive, they still need to ensure that a training session is performed in a given target zone or across different zones following a logic of distribution of training loads (30,31). Thus, alternative methods that indirectly predict BLC and training zones are needed. These methods should determine a common intensity parameter between training sessions and physical fitness tests that will be helpful for athletes and coaches.

The rating of perceived exertion (RPE) has been suggested as an alternative marker for controlling the intensity of exercise (9,19,29,36), being highly correlated with physiological measures such as BLC, heart rate, and oxygen consumption (9,17,19,29,36). The Borg scales are used to measure RPE (4). More specifically, the category scale with ratio properties (CR-10) (3–5) has been widely used to monitor exercise both during (acute RPE) (9,36) and after training sessions (session-RPE method) (9,31), although recently the 6-20 scale has also been used to monitor training (6). Session-RPE values corresponding to the BLC training zone boundaries, obtained using the CR-10 scale, have already been determined (31). However, these cannot be used to determine intensity during exercise, because session-RPE is a method that determines the internal load postfactum. The internal load is a measure of the physiological stress imposed on athletes in response to an external load, being measured after the end of a workout (11,18). Thus, the session-RPE is conceptually different to the RPE as an intensity parameter during exercise (acute RPE) (25). However, acute RPE values corresponding to the boundaries of BLC training zones are still undetermined. Consequently, athletes and coaches cannot use the Seiler's session-RPE values during a training session because the difference between the method concepts

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Journal of Strength and Conditioning Research

does not allow the direct transfer, and therefore, acute RPE values corresponding to BLC boundaries zones need to be determined.

Determining the acute RPE values at these boundaries is important because RPE has been suggested as an affordable tool for controlling intensity (9,29,36). Rating of perceived exertion can be easily used on a large scale in the absence of other methods. Other factors, taken together, also support determining the acute RPE boundary values: (a) the relationship between RPE and BLC has been suggested to be unaltered after a training period (8,14); (b) RPE values corresponding to a given BLC have been shown to be stable (24); and (c) training intensity anchored by RPE has also been shown to be reliable to reproduce metabolic demands (20,21,34). Therefore, the RPE values corresponding to the BLC training zone boundaries should be determined for each endurance sport that includes continuous or high-intensity interval running in its training process. The first step in this process may be to determine the RPE values through their prediction from the data of an incremental test because this procedure is frequently performed to determine other intensity markers (e.g., speed or heart rate). This type of test is often used during the season to determine intensity parameters for training sessions. Additionally, the strong relationship between BLC and RPE suggests that the RPE values corresponding to BLC boundary zones can be predicted adequately (9,17,19,27,29,36). Thus, this study aimed to determine the RPE values corresponding to the BLC training zone boundaries of 2 and 4 $mmol \cdot L^{-1}$ in a large sample of moderately trained runners, using the Borg CR-10 scale. Our hypothesis was that these values could be predicted from the incremental test data to be used as intensity anchors to keep athletes in specific training zones such as other intensity markers.

Table 1. Anthropometric characteristics of the volunteers ($n = 95$).

	Overall Mean ± *SD*	Men ($n = 89$) Mean ± *SD*	Women ($n = 6$) Mean ± *SD*
Age (y)	40.2 ± 7.0	40.1 ± 7.1	39.5 ± 6.9
Body mass (kg)	70.1 ± 8.2	71.1 ± 7.3	53.9 ± 4.4
Height (cm)	175.3 ± 7.2	176.2 ± 6.3	160.4 ± 4.7
Body mass index ($kg \cdot m^{-2}$)	22.8 ± 2.0	22.9 ± 1.9	21.0 ± 1.2
Body fat (%)	13.0 ± 4.4	12.0 ± 3.5	23.2 ± 3.2

Methods

Experimental Approach to the Problem

This is a cross-sectional correlational study determining the RPE values corresponding to the BLC training zone boundaries (2 and 4 $mmol \cdot L^{-1}$)–as dependent and independent variables, respectively–from a large sample of runners ($n = 95$). The study used data from a sample composed of runners who performed an incremental test to determine the RPE values corresponding to 2 and 4 $mmol \cdot L^{-1}$ using linear regression analysis. All volunteers performed a single test session, which consisted of a submaximal incremental running test on a treadmill (RunRace; Technogym, Gambettolla, Italy), recording RPE and BLC data at every stage. The CR-10 scale was used because of its popularity in the training environment, as well as its ratio property (3), which permits the assumptions to perform parametric statistics such as linear regression analysis.

Subjects

Ninety-five amateur runners (89 men and 6 women) participated in this study. Their percentage of body fat was calculated from 10 skinfold thickness measurements as previously described (1) and the anthropometric characteristics are displayed in Table 1. All volunteers were healthy, without a history of cardiovascular diseases, physically active, performing regular endurance training (≥3 times per week), and they were tested during the preparation phase of their training schedule (December 2011 to June 2012). All participants had 1–5 years of running practice and had participated in at least 1 competitive race in the previous year (10–42.195 km). Before the test, the participants were asked to avoid (a) strenuous exercise for at least 24 hours, (b) alcoholic beverages for at least 24 hours, and (c) beverages and foods containing caffeine for at least 3 hours. Additionally, they were instructed to (a) eat a light meal at least 2 hours before the test, (b) ingest a minimum quantity of water (7.5 $ml \cdot kg^{-1}$, ~500 ml for a 70 kg

Table 2. Statistics regarding the independent variable from the simple linear regression.*

	β	*SE*	*t*	*p*	95% CI β
Constant	2.143	0.125	17.10	<0.001	1.896–2.389
BLC	1.092	0.038	28.55	<0.001	1.017–1.167

*β = beta coefficients; *SE* = standard error; 95% CI β = 95% confidence interval of β coefficient; BLC = blood lactate concentration.

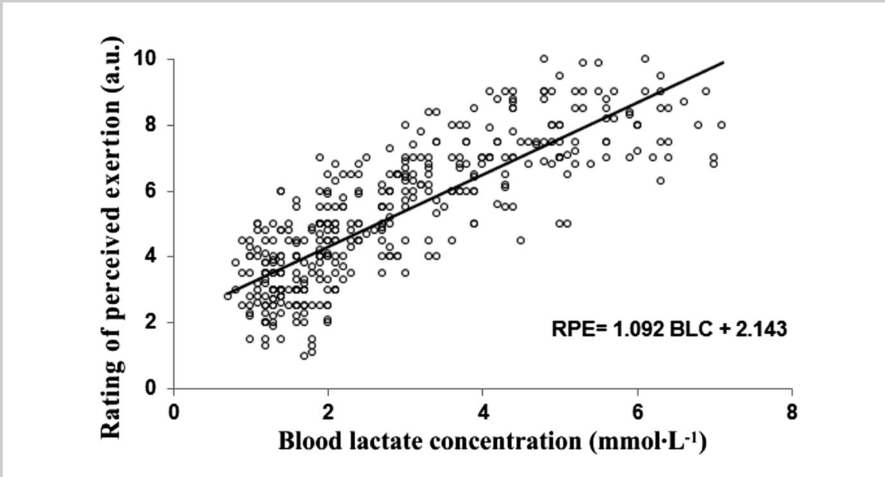

Figure 1. Simple linear regression from all BLCs and RPE data used to determine RPE values at BLC training zone boundaries. BLC = blood lactate concentration; RPE = rating of perceived exertion.

individual) within the 2 hours before the test, and (c) sleep for a minimum of 7 hours during the night before the test. This information was offered to ensure an adequate nutritional profile and hydration on the day of the test. All of them reported normal nutritional intake and at least 8 hours rest during the day before the test. All procedures in this study were conducted in accordance with the Declaration of Helsinki, and all participants signed a written informed consent document approved by the Institutional Review Board.

Procedures

The volunteers ran on a treadmill (RunRace; Technogym), starting at individual speeds according to their race performance times. Data from our laboratory indicated that at 70% of average competition speed (from 10 to 42.195 km), the BLC was consistently <2 $mmol \cdot L^{-1}$. Hence, this relative speed was chosen as the first-stage intensity. The warm-up consisted of 6-minute running at a speed corresponding to 1.5 $km \cdot h^{-1}$ less than this first-stage speed. The test protocol consisted of submaximal incremental tests (stages = 4 minutes, increments = 1.5 $km \cdot h^{-1}$, end of test = BLC >4 $mmol \cdot L^{-1}$) with 30-second intervals between stages for blood sampling. Capillary blood samples (5 μl) were taken from the earlobes of volunteers at the end of each stage, and the BLC was immediately analyzed using a portable analyzer (Lactate Pro LT-1710; Arkray, Kyoto, Japan). The device was calibrated before each test according to the manufacturer's instructions. The RPE was rated using the Borg CR-10 scale. The majority of the volunteers had already used the CR-10 scale during their training sessions or previous tests in our laboratory. In addition, before starting the test, we explained the scale to every volunteer and asked them about their RPE during the warm-up as a familiarization. During the test, the RPE was reported by the athlete (acute RPE) in the last 20 seconds of each stage. In the last stages (BLC >2 $mmol \cdot L^{-1}$), the volunteers received moderate verbal encouragement because of the submaximal characteristic of the test.

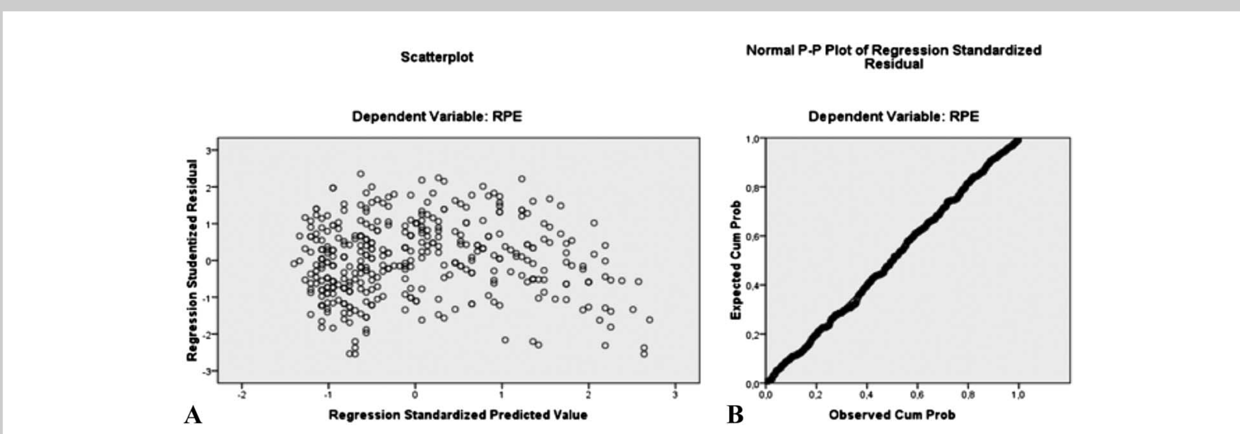

Figure 2. Assumptions of simple linear regression between BLCs and rating of perceived exertion data from all volunteers ($n = 95$). A) Scatter plot to evaluate the homoscedasticity of the residuals. B) Normal P-P plot to examine the normality of the distribution of the residuals. BLC = blood lactate concentration.

Statistical Analyses

The data are presented as mean ± *SD*. Simple linear regression analysis was used to determine the correlation between BLC and RPE (as independent and dependent variables, respectively) and the predictive equation, which allowed determination of the RPE values corresponding to the boundaries of the BLC training zones. All the BLC data and their respective RPE from every volunteer were used in this procedure. The assumptions to validate the linear regression were tested. The Shapiro-Wilk test and normal P-P plots were used to examine the normality of the distribution of the residuals. Homoscedasticity was determined visually using scatter plots and evaluated through the Pearson's product-moment correlation coefficient (r) between the studentized residual and the standardized predicted values. These assumptions were verified to evaluate the generalization and predictive power of the simple linear regression. Subsequently, the equation obtained was used to estimate the RPE values corresponding to the BLC training zone boundaries (2 and 4 $mmol \cdot L^{-1}$). The coefficient of determination (R^2) and the adjusted R^2 were used to verify the robustness of the linear regression. The significance level adopted was 5% ($p \leq 0.05$). All data were analyzed using Microsoft Excel 2010 software (Microsoft Corporation, Redmond, WA, USA) and SPSS 17.0 statistical software (SPSS, Inc., Chicago, IL, USA).

Results

All volunteers had BLC <2 $mmol \cdot L^{-1}$ after the first stage and completed at least 3 stages before achieving BLC >4 $mmol \cdot L^{-1}$.

Simple linear regression analysis revealed that RPE was strongly correlated with BLC ($r = 0.821$, $p < 0.001$, $R^2 = 0.675$, adjusted $R^2 = 0.674$, standard error of estimate = 1.18). The statistics regarding the independent variable (BLC), the β coefficients, and 95% confidence intervals (95% CIs) are shown in Table 2.

The RPE values corresponding to the BLC training zone boundaries predicted from linear regression were 4.3 (95% CI = 3.9–4.7) and 6.5 (95% CI = 6.0–7.1), respectively (Figure 1). Homoscedasticity was shown by the scatter plot (Figure 2A) and confirmed by the nonsignificant correlation ($r = 0.000$, $p = 0.987$) between the studentized residual and the standardized predicted values. The normal P-P plot (Figure 2B) and the Shapiro-Wilk test confirmed the normality of the residuals ($p = 0.161$). Consequently, RPE could be adequately estimated at each BLC according to the equation $RPE = 1.092 \times BLC + 2.143$ because of the goodness of fit and with all assumptions satisfied.

Discussion

This study aimed to determine the RPE values corresponding to the BLC training zone boundaries in amateur runners using the Borg CR-10 scale. Our results showed that RPE values of 4.3 and 6.5 correspond to BLC of 2 and 4 $mmol \cdot L^{-1}$, which allows us to ensure that amateur runners train in specific zones during training sessions.

Our initial hypothesis was that the RPE values corresponding to the boundaries of BLC training zones could be determined from incremental test data, being posteriorly used as an intensity marker during training sessions. The theoretical background used to support our hypothesis came from evidence that RPE allows noninvasive regulation of lactate-based exercise intensity prescription (8,14,17,20,21,24,33). To our knowledge, this is the first study that has determined the acute RPE values corresponding to these boundaries using the CR-10 scale. Although a previous study had already determined the session-RPE values corresponding to the boundaries of BLC training zones using the CR-10 scale (31), these session-RPE values cannot be used to determine intensity during exercise because they reflect the internal load determined after a training session (11,18), whereas the acute RPE measured, for the first time, in this study can provide reference values to control intensity during a training session.

The linear regression data showed an adequate linear regression fitting between BLC and RPE. The large study sample (95 volunteers) and the narrow CIs of the β coefficients allowed a reliable prediction of the RPE values at fixed BLC to be obtained. The good linear fit between BLC and RPE–obtained from the Borg CR-10 scale–was probably caused by the tendency to quadratic response of these 2 variables (27), which tends to cause direct proportionality.

The acute RPE values presented in this study provide a solution for controlling training intensity in a practical environment. Training intensity distribution in zones has been shown to be a key factor in endurance training adaptation (7,13,30,31). The polarized training concept has been suggested as being more effective (7,26,30), but the threshold training concept has also shown positive effects for moderately trained runners such as the volunteers in our sample (28). Regardless of the training distribution adopted, controlling the performance intensity of each training session within the BLC prescribed zone has become crucial to achieve the target adaptations, but monitoring BLC during the training sessions is expensive and impractical for athletes and coaches. Our study provides RPE anchor values to determine boundaries of the BLC zones during training sessions making it easier for coaches and athletes to control intensity. Acute RPE seems to be a good option as an intensity parameter when BLC data are not available because individuals are able to adjust their intensity within a range during self-regulated exercise (10,20,21,24,34). Consequently, these RPE values (4.3 and 6.5) can be used to more effectively maintain amateur athletes within the established training zones.

Rating of perceived exertion has already been used to control training intensity (10,20,21,24,34), but a drift in relation to BLC can be a problem when controlling the training zones (12). A drift in metabolic demand can be present when a fixed mechanical workload (i.e., power output) corresponding to a determined RPE is used as the intensity parameter (12), but not when RPE is chosen as the anchor to control intensity (20,21,24,34), especially when RPE is used to reproduce fixed BLC (17,34). This is a strong evidence that favors the use of RPE to predict BLC response patterns to maintain adequate metabolic demand during training, and thus the prescribed zone.

Although the influence of physical fitness level on RPE values at determined intensity is already known (16), the values have been shown to be relatively stable in a specific modality for a homogeneous physical fitness group (16,29,32). Additionally, verbal anchors corresponding to our RPE values have achieved similar perceptions of exertion reported in other studies that used Borg's 15-graded scale for moderately trained samples (16,17,19,32). However, care should be taken as the RPE corresponding to the BLC training zone boundaries are predicted values, and individual variations need to be taken into account.

Our study has some limitations. We used fixed BLC of 2 and 4 $mmol \cdot L^{-1}$ to determine the training zone limits. Despite criticism on the use of fixed BLC values (2), we followed the same procedures as other studies to delimit the BLC training zones (13,30,31). Furthermore, these fixed BLC values are frequently used in practical settings and sports science laboratories and are known to be strongly related to aerobic fitness (2,22,23,33,35,37). Nevertheless, other criteria could have been used to determine the training zone boundaries. Additionally, our results refer specifically to runners, and they cannot be directly transferred to other activities.

In conclusion, the RPE values at the BLC training zone boundaries might be adequately determined by linear regression. These RPE values (4.3 and 6.5) could be suggested as affordable anchor scores for controlling training intensity across different training zones because RPE has been shown to be an adequate marker to maintain metabolic demand during exercise.

Practical Applications

This study provides evidence that coaches and athletes can use the 4.3 and 6.5 anchor values, using the CR-10 scale as markers for training zone boundaries. During a running session, maintaining the intensity at RPE $\leq$4.3 ensures that most of the exercise session is performed in the low lactate zone ($\leq$2 $mmol \cdot L^{-1}$). This corresponds to an intensity that is lower or the same at the aerobic threshold. Running exercise performed at RPE between 4.3 and 6.5 ensures that most of the exercise session is performed in the lactate accommodation zone ($\geq$2 and $\leq$4 $mmol \cdot L^{-1}$), in which the lactate steady state is achieved. Running exercise performed at RPE $\geq$6.5 ensures that most of the exercise session is performed in the lactate accumulation zone ($\geq$4 $mmol \cdot L^{-1}$) and can be used during the work stimulus of a high-intensity interval training session rather than a continuous training session.

Acknowledgments

The authors thank all the subjects who voluntarily participated in this study. The authors disclose professional relationships with companies or manufacturers who will benefit from the results of this study and state that the results do not constitute endorsement of the product by the authors or the National Strength and Conditioning Association. This research was supported by Gabriele Rosa and Giorgio Fanò-Illic grants. J. L. Dantas and C. Doria contributed equally to this study.

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