Does blood lactate predict the chronic adaptive response to training: A comparison of traditional and talk test prescription methods

Nicholas Preobrazenski, Jacob T. Bonafiglia, Matthew W. Nelms, Simo Lu, Lauren Robins, Camille LeBlanc, and Brendon J. Gurd

Abstract: The purpose of this study was to test the hypotheses (i) that interindividual variability in acute blood lactate responses during exercise at 65% of peak work rate (WRpeak, relative WRpeak protocol (REL)) will predict variability in the chronic responses to exercise training and (ii) that exercising at an intensity that causes uncomfortable speech production (negative talk test (TT) stage (NEG)) elicits high acute blood lactate responses and large adaptations to training. Twenty-eight participants completed 4 weeks of exercise training consisting of REL (n = 14) or NEG (TT, n = 14). Fifteen additional participants were assigned to a no-exercise control group (n = 15). In REL, acute blood lactate responses during the first training session significantly predicted changes in peak oxygen consumption (r = 0.69) after training. TT resulted in consistently high acute blood lactate responses. REL and TT improved (p < 0.05) peak oxygen consumption, WRpeak, and work rate at the onset of blood lactate accumulation (WROBLA). Despite nonsignificance, small to medium between-group effect sizes for changes in peak oxygen consumption, WRpeak, and WROBLA and a higher work rate, heart rate, rating of perceived exertion, and blood lactate during training at NEG support the potential superiority of TT over REL. When exercise is prescribed using a traditional method (a fixed percentage of WRpeak; REL), acute metabolic stress may partly explain the variance in the adaptations to training. In addition, TT elicited significant increases in peak oxygen consumption, WRpeak, and WROBLA, and although our small sample size limits our ability to confidently compare training adaptations between groups, our preliminary results suggest that future investigations with larger sample sizes should assess the potential superiority of TT over REL.

Key words: blood lactate, talk test, VO2peak, metabolic stress, exercise training.

Résumé : Cette étude a pour objectif de tester les hypothèses selon lesquelles : (i) la variation interindividuelle des réponses ponctuelles du lactate sanguin au cours d’un exercice sollicitant 65 % de l’intensité de travail (« WRpointe »; protocole de WRpointe relatif (« REL »)) est un prédicteur de la variation des réponses chroniques à l’entraînement physique, (ii) un exercice à une intensité rendant difficile (« NEG ») la parole (stade difficile du test de la parole (« TT »)) engendre de plus fortes réponses ponctuelles du lactate sanguin et des adaptations plus vastes à l’entraînement. Vingt-huit participants se sont soumis à 4 semaines d’entraînement physique consistant en REL (n = 14) et NEG (TT, n = 14). On assigne 15 autres participants dans le groupe de contrôle (n = 15). Dans la condition REL, les réponses ponctuelles du lactate sanguin au cours de la première séance d’entraînement prédissent significativement les modifications de la consommation du pointe d’oxygène (r = 0.69) observées après l’entraînement. La condition TT engendre systématiquement des réponses ponctuelles plus élevées du lactate sanguin. Les groupes REL et TT améliorent (p < 0.05) la consommation du pointe d’oxygène, la WRpointe et l’intensité de travail au début de l’accumulation sanguine du lactate (« WROBLA »). Nonobstant l’absence de différences significatives, les ampliures faibles à modérées de l’effet en ce qui concerne les modifications de la consommation du pointe d’oxygène, de la WRpointe, de la WROBLA et les plus hautes valeurs de l’intensité de travail, du rythme cardiaque, de la perception de l’intensité de l’effort et du lactate sanguin durant l’entraînement dans la condition NEG appuient la supériorité potentielle de TT par rapport à REL. Quand on prescrit de l’exercice selon la méthode traditionnelle [pourcentage donné de WRpointe; REL], le stress métabolique ponctuel pourrait expliquer partiellement la variance des adaptations à l’entraînement. En outre, la condition TT suscite des augmentations significatives de la consommation du pointe d’oxygène, de WRpointe; et de WROBLA; même si le petit échantillon limite la dimension comparative des adaptations à l’entraînement d’un groupe à l’autre, nos résultats préliminaires suggèrent qu’un plus grand échantillon dans des études ultérieures pourrait déterminer la supériorité potentielle de TT par rapport à REL. [Traduit par la Rédaction]

Mots-clés : lactate sanguin, test de la parole, VO2peak, stress métabolique, entraînement physique.
Introduction

When endurance training is prescribed as a percentage of peak oxygen consumption (\(\dot{V}O_2\text{peak}\)) or peak work rate (\(WR\text{peak}\)), individual variability in the observed responses for \(\dot{V}O_2\text{peak}\) (Bonafiglia et al. 2016; Gurd et al. 2016; Raleigh et al. 2016), \(WR\text{peak}\) (Montero and Lundby 2017) and the work rate at the onset of blood lactate accumulation (\(WR_{OBLA}\)) are observed (Bonafiglia et al. 2016, Gurd et al. 2016). Although recent work has suggested that interindividual variability in observed \(\dot{V}O_2\text{peak}\) responses to standardized endurance training may be explained partially by genetic differences (Timmons et al. 2010; Ghosh et al. 2013), hematological adaptations (Montero et al. 2015), or exercise-induced oxidative stress (Margaretis et al. 2017), the mechanism(s) underlying the variance in chronic adaptation to exercise training remain largely unexplored.

Acute exercise prescribed as a percentage of \(\dot{V}O_2\text{peak}\) or \(WR\text{peak}\) leads to considerable interindividual variability in blood lactate responses (Coyle et al. 1988; Orak et al. 1989; Weltman et al. 1990; Meyer et al. 1999; Scharhag-Rosenberger et al. 2010; Egger et al. 2016; Bonafiglia et al. 2017). Because blood lactate reflects muscle lactate (Tesch et al. 1982; Jacobs and Kaiser 1982), intramuscular stress (Sripreth et al. 2000), and potentially the induction of signaling pathways that trigger muscular remodeling (Hood 2001; Flück and Hoppeler 2003; Egan and Zierath 2013), the variability in metabolic stress associated with a fixed percentage of \(WR\text{peak}\) may contribute to interindividual variability in the adaptive response to exercise. Although it has been speculated that individuals who experience large increases in metabolic stress (and blood lactate) during training will experience a larger adaptive response than do individuals experiencing low metabolic stress (Mann et al. 2013, 2014), this theory has yet to be tested. Accordingly, the first purpose of this study was to test the hypothesis that differences in blood lactate responses during acute exercise at 65% of \(WR\text{peak}\) will predict, at least in part, the interindividual variability in observed responses to exercise training.

If, as speculated, in-training metabolic stress contributes to an individual’s adaptive response, then using an exercise prescription method that elicits consistently large increases in metabolic stress should also induce large adaptive responses. Although exercise can be prescribed to target the onset of blood lactate accumulation (OBLA) and lactate threshold (Chwalbinska-Moneta et al. 1989; Coen et al. 1991; Philp et al. 2008), repeatedly collecting blood lactate samples can be invasive, costly, and inaccessible outside of a laboratory setting. The talk test (TT) is a noninvasive, free, accessible exercise prescription method that estimates exercise intensity through self-evaluation of the perceived difficulty of reciting an approximately 30-word phrase (Webster and Aznar-Lain 2008; Reed and Pipe 2014, 2016). Importantly, exercise intensities characterized by uncomfortable speech (negative stage (NEG); Recalde et al. 2002) appear to produce consistently high blood lactate concentrations (Wolffmann et al. 2015). It is tempting to speculate that exercising at NEG should induce consistently large increases in metabolic stress and thus subsequently large adaptive responses to training. However, the metabolic stress/exercise intensity induced by repeated exercise at NEG has not been characterized, and the tolerability and efficacy of training at NEG is currently unknown. Thus, as a preliminary step toward developing an exercise prescription method that elicits consistently large increases in metabolic stress and large adaptive responses to training, the second purpose of this study was to characterize the in-training response to and tolerability of exercise at NEG and the efficacy of training at NEG for improving \(\dot{V}O_2\text{peak}\), \(WR\text{peak}\), and \(WR_{OBLA}\).

Materials and methods

Forty-seven recreationally active (self-reported < 3 h of physical activity per week) and healthy young males volunteered to participate in the current study. We selected recreationally active participants because we have shown previously that prescribing exercise at 65% of \(WR\text{peak}\) in this population results in variability in acute and chronic responses (Bonafiglia et al. 2016, 2017). Volunteers were enrolled in the study only if they were between 18 and 30 years of age, were nonsmokers, were nonobese (body mass index < 30 kg/m²), were not taking any medication, and were free of cardiovascular and metabolic disease. Participants attended a preliminary screening session during which they were briefed on the study, they provided informed consent, and they had their height and mass recorded. Participants had not been trained previously in cycling and were not involved in a training program at the start of the study. Participants were instructed to maintain their regular physical activity and nutritional habits throughout the duration of the study. All experimental procedures performed on human participants were approved by the Health Sciences Human Research Ethics Board at Queen’s University. A verbal and written explanation of the experimental protocol and its associated risks was provided to all participants prior to obtaining written informed consent.

Experimental design

Participants who were to complete 4 weeks of training using the relative \(WR\text{peak}\) protocol (REL: \(n = 14\); see details later in the text) were part of a randomized control trial in which they were assigned either to REL or to a no-exercise control group (CTL: \(n = 15\)) via minimization. Briefly, the first participant was allocated randomly to REL or CTL, and every subsequent participant was allocated to REL or CTL in a manner that minimized the imbalance of baseline \(\dot{V}O_2\text{peak}\) between the groups (Treasure and MacRae 1998). The REL and CTL groups were part of a larger data collection that included muscle biopsy specimens (biopsy data not included). Participants who were to complete 4 weeks of training using the talk test (TT) training protocol (see details later in the text; \(n = 14\)) were recruited separately but concurrently. All participants were recruited from the same undergraduate population and met the same inclusion/exclusion criteria. All participants completed physiological testing in the week preceding the first week of training and 72 h after their last training session (or at the equivalent time for CTL). All physiological testing and training took place on a Monark Ergomedic 874 E stationary ergometer (Monark Exercise, Vansbro, Sweden). All participants were asked to refrain from ingesting nutritional supplements and exercising for the 24 h before, and from alcohol and caffeine for the 12 h before, all physiological testing. The study protocol is depicted in Fig. 1.

Physiological testing

In the week preceding (PRE) and the week following (POST) the 4-week interventions, participants reported to the laboratory on
2 separate occasions separated by at least 24 h. During the first visit to the laboratory at both PRE and POST, participants completed a \( \dot{V}O_2 \) \(_{\text{peak}} \) incremental step test to volitional exhaustion on a cycle ergometer in the fed state, as described previously (Edgett et al. 2013). Briefly, the \( \dot{V}O_2 \) \(_{\text{peak}} \) test consisted of a 5-min warm-up at 80 rpm, followed by a step increase to 80 W for 1 min, and then a progressive 24 W/min increase until volitional fatigue (1-min test). Gas exchange and heart rate (HR) measurements were collected throughout the test using a metabolic cart (Moxus, AEI Technologies, Pittsburgh, Pa., USA) and Polar HR monitors (Team2 Pro, Polar Electro Oy, Kempele, Finland), respectively. \( \dot{V}O_2 \) \(_{\text{peak}} \) and peak HR were calculated as the highest 30-s average oxygen uptake (\( \dot{V}O_2 \)) and HR observed, respectively, during the 1-min test. The rpm was collected continuously throughout the step test, and \( WR_{\text{peak}} \) was calculated as the highest 30-s average work rate (WR) from the 1-min test. Participants in the REL and CTL groups underwent a resting muscle biopsy approximately 30 min prior to their \( \dot{V}O_2 \) \(_{\text{peak}} \) test; however, biopsy data are not included in this manuscript.

During the second PRE and POST visit to the laboratory, participants completed an additional incremental step test following a protocol identical to that of the test described earlier, with the exception that the WR was increased by 24 W every 3 min (3-min test). Fingertip capillary blood was collected only during the 3-min test. WROBLA during the 3-min test, a submaximal measure in which a blood lactate concentration of at least 4.0 mmol·L\(^{-1} \) is reached (Sjödin and Jacobs 1981), was determined as the average WR in the final 30 s of the stage at which OBLA was reached. Gas exchange measurements were collected as described previously for the 1-min test (data not presented) for participants in the REL and CTL groups only. Gas exchange measurements were not collected for participants in the TT group during the 3-min test so that the TT could be administered during the final 30 s of each stage. The TT required participants to count aloud from 1 to 30 at a regular conversational pace and volume. Subsequently, participants were asked whether they could speak comfortably, and they chose one of the following 3 options: “Yes, I could speak comfortably” (positive stage; POS); “Yes, I could speak, but not entirely comfortably” (equivocal stage; EQ); or “No, I could not speak comfortably” (NEG; Recalde et al. 2002; Reed and Pipe 2014). The first stage at which participants in the TT group reported to be exercising at NEG was used to select the initial WR for the first training session.

**Training protocols**

All groups were asked to maintain their habitual physical activity levels throughout the duration of the trial. Training for both exercise groups consisted of 15 training sessions over a 4-week period. During each training session, the REL group participants cycled for 30 min at 65% of \( WR_{\text{peak}} \), whereas the TT group performed the TT every 2.5–5 min to ensure that the intensity was sufficient to elicit a NEG response. On the basis of participant responses, WR was either increased or decreased or remained the same, to target a sustainable intensity within the NEG stage (see Fig. 2 for details on the TT training session protocol). All training sessions for both groups were fully supervised and were preceded by a 1-min loadless warm-up. During each 30-min training protocol, participants were instructed to maintain a cadence of 80 rpm, and they received verbal encouragement. Blood lactate concentrations were measured from fingertip capillary blood (~20 µL) at the 10- and 30-min points of the first training session.

![Flow chart used to guide exercise intensity to the NEG stage. EQ, equivocal TT stage; NEG, negative TT stage; POS, positive TT stage; TT, talk test; WR, work rate.](image-url)
session of each week. HR, rating of perceived exertion (RPE; 6–20 Borg Scale; Borg 1982), and WR were measured every 5 min during each training session.

Statistical analysis
A 1-way ANOVA was used to compare baseline characteristics across groups. A 2-way mixed ANOVA (group × time) was used to compare mean training blood lactate, HR, RPE, and WR between REL and TT. Additional 2-way mixed ANOVAs were used to compare changes in VO\(_2\)peak, WR\(_{\text{peak}}\), WROBLA, and body mass among groups following 4 weeks of training. Any significant interaction or main effects were analyzed subsequently using Bonferroni post hoc analyses. A linear regression was used to determine whether blood lactate concentrations during the first training session predicted changes in VO\(_2\)peak, WR\(_{\text{peak}}\), and WROBLA following training in the REL group. Statistical analysis was performed using SPSS (version 20.0, IBM Corp., Armonk, N.Y., USA).

A priori sample size calculations were made for the primary outcome, VO\(_2\)peak. Given that we have previously found a 1.69 ± 3.19 mL·kg\(^{-1}\)·min\(^{-1}\) increase in VO\(_2\)peak after 3 weeks of training at 65% of WR\(_{\text{peak}}\) (Bonafiglia et al. 2016), we expected a 2 mL·kg\(^{-1}\)·min\(^{-1}\) increase in VO\(_2\)peak after 4 weeks of training at 65% of WR\(_{\text{peak}}\) (REL). Using the sample size formula (Overall and Doyle 1994; eq. 13) relevant to repeated-measures ANOVA, we determined that a sample size of 13 was needed in each group (Z\(_92\) = 1.96, Z\(_92\) = 0.85, r = 0.85, \(\bar{X}_1 - \bar{X}_2 = 2\), SD = 3.19 mL·kg\(^{-1}\)·min\(^{-1}\)) to give 80% power to detect a difference in VO\(_2\)peak change scores (POST–PRE) of 2 mL·kg\(^{-1}\)·min\(^{-1}\) between REL/TT and CTL.

Although it was not a primary aim of this study, we completed a secondary exploratory analysis comparing changes in VO\(_2\)peak, WR\(_{\text{peak}}\), and WROBLA following REL and TT, despite not powering a priori to detect differences in change scores between the training groups. Differences in change scores between REL and TT were compared using \(t\) tests, and the corresponding effect sizes were calculated using Cohen’s \(d\) (small = 0.2; medium = 0.5; large = 0.8; Cohen 1992). Pooled (REL and TT) SDs of change scores were used for VO\(_2\)peak, WR\(_{\text{peak}}\), and WROBLA Cohen’s \(d\) calculations.

Results
A total of 75 individuals expressed an interest in participating in the current study, with 50 and 25 being screened for the REL/CTL arm and the TT arm, respectively (Fig. 3). Thirty participants completed baseline testing for the REL/CTL arm, and 17 completed baseline testing for the TT arm. One participant dropped out of the REL group (because of discomfort caused during the baseline muscle biopsy), and 2 participants dropped out of the TT group citing a lack of time and an unrelated sickness. Importantly, an additional TT participant dropped out during the second week of training because he was unable to complete the TT protocol. The remaining 43 participants completed the study, including all PRE and POST testing. Twenty-eight participants completed all 15 training sessions (REL: \(n = 14\), TT: \(n = 14\)). Data from 4 participants (CTL: \(n = 2\); REL: \(n = 1\); TT: \(n = 1\)) were excluded from the WROBLA analysis because blood lactate was unable to be collected.

Table 1. Participant baseline characteristics.

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>REL ((n = 14))</th>
<th>TT ((n = 14))</th>
<th>CTL ((n = 15))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)*</td>
<td>21.9±2.0</td>
<td>19.8±1.1</td>
<td>20.5±1.4</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>180.5±7.3</td>
<td>184.4±14.4</td>
<td>176.0±7.6</td>
</tr>
<tr>
<td>Mass (kg)</td>
<td>79.7±12.0</td>
<td>80.0±13.0</td>
<td>76.1±11.7</td>
</tr>
<tr>
<td>VO(_2)peak (mL·kg(^{-1})·min(^{-1}))</td>
<td>46.0±26.6</td>
<td>45.8±25.9</td>
<td>45.1±28.8</td>
</tr>
<tr>
<td>VO(_2)peak (mL·min(^{-1}))</td>
<td>3659±738</td>
<td>3640±629</td>
<td>3406±709.8</td>
</tr>
<tr>
<td>WROBLA (W)</td>
<td>155.4±54.3†</td>
<td>163.2±52.1†</td>
<td>161.0±41.3†</td>
</tr>
<tr>
<td>WR(_{\text{peak}}) (W)</td>
<td>281.8±55.5</td>
<td>286.1±56.1</td>
<td>259.1±50.1†</td>
</tr>
</tbody>
</table>

Note: Values are means ± SD. CTL, control; REL, 65% of peak work rate; TT, talk test; VO\(_2\)peak, peak oxygen uptake; WROBLA, work rate at the onset of blood lactate accumulation; WR\(_{\text{peak}}\), peak work rate.

*Significantly higher in REL (\(p < 0.05\)).
†\(n = 13\).
‡\(n = 14\).

Published by NRC Research Press
during their POST tests. In addition, data from 3 participants were excluded from the WRpeak analysis because the rpm recording software failed during data collection (CTL: n = 2; TT: n = 1). Sample sizes and baseline participant characteristics for the REL, TT, and CTL groups are presented in Table 1. Only age differed among the groups; the mean age was significantly (p < 0.05) higher in the REL group. Mass did not significantly change from baseline in any group (CTL: +0.02 ± 0.88 kg; REL: +0.35 ± 1.07 kg; TT: +0.30 ± 1.34 kg).

Figure 4 illustrates the mean weekly WR (Fig. 4A), blood lactate (Fig. 4B), HR (Fig. 4C), and RPE (Fig. 4D) from the first training session of each week for both the REL and the TT group. Significant interactions (group × time) were observed for each measure (p < 0.05 for all). Bonferroni post hoc analyses are presented in Fig. 4.

The mean blood lactate concentration of the first training session positively predicted changes in VO2peak in the REL group (Fig. 5; r2 = 0.5, r = 0.7, p < 0.01). No other significant linear regressions were observed between mean blood lactate responses and chronic responses to training in either the REL or the TT group. A significant (p < 0.001) main effect of time (POST–PRE) and a significant (p < 0.001) interaction effect (group × time) were observed for VO2peak (CTL: +0.17 ± 2.8 mL·kg−1·min−1; REL: +3.67 ± 3.1 mL·kg−1·min−1; and TT: +5.43 ± 3.0 mL·kg−1·min−1), WRpeak (CTL: +5.4 ± 19.6 W; REL: +33.1 ± 20.0 W; and TT: +46.5 ± 20.8 W), and WROBLA (CTL: +0.21 ± 17.2 W; REL: +34.2 ± 31.3 W; and TT: +42.4 ± 33.1 W). Bonferroni post hoc analyses are presented in Fig. 6.

Although secondary analysis using independent-samples t tests of the change score differences between REL and TT for VO2peak (p = 0.14), WRpeak (p = 0.10), and WROBLA (p = 0.52) revealed no significant differences between groups, effect size calculations indicate a medium, medium, and small effect of TT increasing VO2peak (d = 0.58), WRpeak (d = 0.66), and WROBLA (d = 0.25) more than REL, respectively.
Acute blood lactate responses predict changes in VO2peak following training at 65% of WRpeak

Exercise prescribed as a percentage of VO2peak/WRpeak results in considerable variability in acute blood lactate responses (Coyle et al. 1988; Orak et al. 1989; Weltman et al. 1990; Meyer et al. 1999; Scharhag-Rosenberger et al. 2010; Egger et al. 2016; Bonafiglia et al. 2017) and changes in VO2peak (Bouchard and Rankinen 2001; Vollaard et al. 2009; Zelt et al. 2014; Bonafiglia et al. 2016), WRpeak (Montero and Lundby 2017), and WR0BLA (Bonafiglia et al. 2016; Gurd et al. 2016) following training. Consistent with the hypothesis that heterogeneity in acute exercise-induced metabolic stress may contribute to the variability in the adaptive responses to training (Mann et al. 2013, 2014), a positive relationship between acute blood lactate responses during the first training session and changes in VO2peak following training in the REL group was observed. Only the acute blood lactate responses in the first training session significantly correlated with changes in VO2peak. Unsurprisingly, there was no relationship between first-session blood lactate and any adaptive response in the TT group. It is possible that some participants in the TT group had a lower blood lactate concentration during week 1 compared with during the remaining 3 weeks because as training progressed, their WRs were increased on the basis of their TT responses (see Fig. 2). Thus, there would be no expectation of a relationship between first-session blood lactate and adaptations to training in TT, whereas the opposite would be true in REL. Furthermore, because the mean blood lactate responses in REL decreased over the training period (Fig. 4B), our data suggest that the ability to predict changes in VO2peak disappeared as participants in the REL group adapted to training.

Although the mechanisms underlying the relationship between acute blood lactate and VO2peak responses are unclear, it is possible that differences in acute blood lactate responses reflect the magnitude of exercise-induced perturbations and an associated induction of signaling pathways that ultimately underlie chronic improvements in VO2peak. For example, the concentration of blood lactate rises proportionately with plasma epinephrine levels (Lehmann et al. 1985), and epinephrine has been implicated as an important signaling molecule that initiates the induction of chronic cardiac and skeletal muscle adaptations (Williams and Barnes 1989). In addition to epinephrine-mediated signalling, blood lactate concentrations throughout training may reflect disturbances in intramuscular energetics (Spreit et al. 2000) and subsequent activation of the AMPK-PGC-1α pathway in exercising muscle (Jäger et al. 2007), which may affect VO2peak through the induction of mitochondrial biogenesis and angiogenesis (Jäger 1979; Calvo et al. 2008; Hawley et al. 2014). It is also possible that variability in acute blood lactate responses reflects interindividual differences in other determinants of VO2peak responses to endurance training, including (but potentially not limited to) acute oxidative stress (Margaretis et al. 2017) and hematological adaptations (Montero et al. 2015). Furthermore, it is possible that genetic factors may explain, at least in part, the significant relationship between acute blood lactate and VO2peak responses in REL. Specifically, the predictor genes that explain a portion of the variance in VO2peak response to exercise training (e.g., ACSL1, PRDM1, GRIN3A) (Bouchard et al. 2013) may also partially explain the variability in acute blood lactate responses. Although future work is needed to elucidate the mechanisms linking acute blood lactate responses and changes in VO2peak, our findings suggest that acute blood lactate responses to the first training session may partially explain the variability in VO2peak responses when training is prescribed as a fixed percentage of WRpeak.

The TT can be used as an exercise training prescription tool

To our knowledge, this is the first study to demonstrate that training at the NEG TT stage improves VO2peak, WRpeak, and WR0BLA in young healthy males. Recently, Porcarci and colleagues (2018) demonstrated that 10 weeks of cycling at the last positive TT stage (i.e., the highest intensity that allows for comfortable speech) improves maximal oxygen consumption, peak power output, and VO2 at the ventilatory threshold. Taken together, these results
suggest that the TT can be used to prescribe exercise when access to the facilities and resources required to prescribe exercise as a percentage of a given physiological variable (e.g., $WR_{peak}$, $V\dot{O}_2peak$, lactate threshold, etc.) is limited.

The difference in change scores between REL and TT for $V\dot{O}_2peak$ (TT – REL = 1.76 mL·kg⁻¹·min⁻¹), $WR_{peak}$ (TT – REL = 13.42 W), and $WR_{OBLA}$ (TT – REL = 8.13 W) may suggest that TT elicits superior adaptations to training than does REL. The larger adaptations in TT are likely attributable to the higher in-training metabolic stress (Fig. 4), which is probably a result of adjusting the exercise intensity consistently during each exercise session (Fig. 2). Conversely, because exercise intensity remained unchanged during REL, the in-training metabolic stress decreased throughout training (Fig. 4), which may have contributed to the relatively smaller REL, the in-training metabolic stress decreased throughout training, inversely, because exercise intensity remained unchanged during REL exercised at the NEG TT stage improves training adaptations and improves chronic responses when training is prescribed as a percentage of the current study, our findings suggest that the TT may be more effective at improving $V\dot{O}_2peak$, $WR_{peak}$, and $WR_{OBLA}$ than pre-scribing exercise intensity at 65% of $WR_{peak}$; however, future work is needed to confirm these preliminary results.

Conflict of interest statement

The authors have no conflicts of interest to report.

Acknowledgements

The authors thank the volunteers and students who participated in this study.

References


Calvo, J.A., Daniels, T.G., Wang, X., Paul, A., Lin, J., Spiegelman, B.M., et al. 2008. Muscle-specific exercise training increases in each group to detect an expected difference in $V\dot{O}_2peak$ change scores be-

Conflict of interest statement

The authors have no conflicts of interest to report.

Acknowledgements

The authors thank the volunteers and students who participated in this study.

References


Calvo, J.A., Daniels, T.G., Wang, X., Paul, A., Lin, J., Spiegelman, B.M., et al. 2008. Muscle-specific exercise training increases in each group to detect an expected difference in $V\dot{O}_2peak$ change scores between REL and TT. Accordingly, we were unable to perform an a priori sample size calculation for our secondary analysis (i.e., comparing $V\dot{O}_2peak$ change scores between REL and TT). Given our small sample size, the observed power for our secondary analysis was only approximately 30%, suggesting that the nonsignificant difference in $V\dot{O}_2peak$ change scores between REL and TT may reflect a type II error. Using eq. 8 from Overall and Doyle (1994) and a statistical power of 80%, we calculate that future studies would need a total sample size of 96 (TT = 48, REL = 48) to detect our observed effect size (d = 0.58) for the difference in $V\dot{O}_2peak$ change scores between REL and TT as significant. In addition, REL and CTL participants received their group assignment following the completion of baseline testing, whereas participants were recruited separately for TT. Therefore, we were unable to blind TT participants to their group assignment during baseline testing. Considering these limitations, there is a need for future work that is designed to test the hypothesis that exercising at the NEG TT stage improves training adaptations more than does REL.

Conclusion

Acute blood lactate responses partially explain the variability in chronic responses when training is prescribed as a percentage of $WR_{peak}$. These results suggest that acute metabolic stress may underlie interindividual differences in observed changes in $V\dot{O}_2peak$. We demonstrated, we believe for the first time, that exercising at the NEG TT stage is a simple and accessible exercise prescription tool that leads to consistently high in-training responses and improves $V\dot{O}_2peak$, $WR_{peak}$, and $WR_{OBLA}$ in recreationally active young men. Studies in other populations, including sedentary, elderly, and obese individuals, are needed before generalizing these findings. In addition, although not a primary aim of the current study, our findings suggest that the TT may be more effective at improving $V\dot{O}_2peak$, $WR_{peak}$, and $WR_{OBLA}$ than pre-scribing exercise intensity at 65% of $WR_{peak}$; however, future work is needed to confirm these preliminary results.

Conflict of interest statement

The authors have no conflicts of interest to report.