RESEARCH CONTRIBUTIONS

Ratings of Perceived Exertion to Determine Intensity During Outdoor Running

Dixie L. Thompson and Keith A. West

Catalogue Data

Key words: RPE, Borg Scale, exercise, lactate, training
Mots-clés: RPE, échelle de Borg, exercice, lactate, entraînement

Abstract/Résumé
A paucity of data exists related to the usefulness of Ratings of Perceived Exertion (RPE) to set exercise intensity in non-laboratory settings. The purpose of this study was to determine if RPE could be used on an outdoor track to generate blood lactate and heart rate (HR) responses similar to those obtained on a treadmill (tm) run. Nine experienced runners (6 males, 3 females; VO_2peak = 56.2 ± 6.7 ml kg\(^{-1}\) min\(^{-1}\) ) completed a horizontal, incremental tm test. HR, RPE, and lactate were measured for each stage. Subsequently, subjects ran for 30 min on an outdoor track at the RPE corresponding with 2.5 mM lactate during the tm run. Repeated measures ANOVA compared lactate and HR values at 2.5 mM lactate on the tm run and values obtained during the track run. Lactate during the track run was significantly higher (p < .05) than 2.5 mM throughout the 30 min (6.9 ± 2.9, 6.3 ± 2.9, and 5.8 ± 3.0 mM at 10, 20, and 30 min, respectively). HR at 2.5 mM lactate during the tm run (173 ± 6.1 bpm) was significantly lower (p < .05) than at min 10 and 20 of the track run (182.6 ± 9.3 and 182.9 ± 8.0 bpm, respectively) but not different from min 30 (181.3 ± 10.6 bpm). In summary, it is difficult to generate specific physiological responses using RPE.

Il y a peu d’études sur l’utilité de la cotation de la perception de la sensation de l’effort (RPE) pour déterminer l’intensité de l’exercice ailleurs qu’au laboratoire. Le but de l’étude est d’établir si le RPE peut être utilisé sur une piste extérieure pour obtenir des ajustements de fréquence cardiaque (HR) et du niveau de lactate similaires à ceux qui sont obtenus sur tapis roulant. Neuf coureurs d’expérience (6 hommes, 3 femmes; VO_2 de crête = 56.2 ± 6.7 ml ·}

D.L. Thompson and K.A. West: Exercise Science Unit, The University of Tennessee, Knoxville. Please send correspondence to: Dixie L. Thompson, Ph.D., 1914 Andy Holt Avenue, Exercise Science Unit, The University of Tennessee, Knoxville, TN 37996-2700.

56
kg⁻¹ · min⁻¹) complètent un test d’effort progressif sur tapis roulant. Les valeurs de HR, RPE, et de lactate sont obtenues à chaque palier. Les sujets sont appelés successivement à courir durant 30 min sur une piste extérieure à une intensité déterminée par la valeur du RPE correspondant à un niveau de lactate de 2,5 mM sur tapis roulant. Une ANOVA avec mesures répétées est utilisée pour comparer les valeurs de HR et de lactate sur tapis et sur piste. Tout au long des 30 min d’effort, les valeurs de lactate sur piste sont statistiquement supérieures (p < 0,05) aux 2,5 mM sur tapis (6,9 ± 2,9, 6,3 ± 2,9, et 5,8 ± 3,0 mM à la 10e, 20e, et 30e min respectivement). Les valeurs de HR pour un niveau de 2,5 mM de lactate sur piste (173 ± 6,1 bpm) sont statistiquement plus petites (p < 0,05) que sur piste à la 10e et à la 20e min respectivement (182,6 ± 9,3 et 182,9 ± 8,0 bpm). Bref, il est difficile d’obtenir des ajustements physiologiques spécifiques en se fiant au RPE.

Introduction

The Rating of Perceived Exertion (RPE) scale was developed to quantify subjective feelings of effort during exercise (Borg, 1970). RPE rises linearly with heart rate (HR) (Borg et al., 1987; Borg, 1970) and oxygen consumption (Demello et al., 1987) during a graded exercise test (GXT), and is strongly related to blood lactate accumulation (Demello et al., 1987; Seip et al., 1991; Steed et al., 1994). Also, RPE can be used to set exercise intensity during treadmill (tm) running to elicit HR and VO₂ values similar to those observed during a GXT (Dunbar et al., 1992; Glass et al., 1992; Stoudemire et al., 1996).

Although relationships exist between RPE and physiological variables, less is understood about the responses elicited when using RPE in a field setting to determine exercise intensity. Ceci and Hassmen (1991) asked subjects to complete two tests, one on the tm and another on the track, in which RPE was used to set exercise intensity. Using this production method, subjects ran on the tm and track at RPEs of 11, 13, and 15. HR, lactate, and velocity were significantly higher on the track than those measured at the same RPE on the tm. These findings suggest that an exercise prescription based on RPEs observed on the tm are too intense for a field setting. However, the longest production period used was 11 min; therefore, these data cannot be used to draw conclusions about using RPE during extended aerobic exercise (Ceci & Hassmen, 1991). Steed et al. (1994) studied RPE and blood lactate during 30 min of submaximal tm running. Subjects completed an incremental tm test followed by 30 min tm running bouts at velocities associated with the lactate threshold (LT) and blood lactate concentrations (BLC) of 2.5 and 4.0 mM. Although Steed et al. (1994) found that RPE and BLC are closely related over a 30 min run, the issues of extended running in a field setting and of using RPE as the method of setting intensity were not investigated. Stoudemire et al. (1996) compared incremental and extended tm running during which RPE was used to determine intensity. Using RPE as a guide to exercise intensity yielded lactate values similar to those observed during the GXT.

Performance enhancement is addressed in venues ranging from popular running magazines to professional journals. Although a variety of training methods result in improved performance, using knowledge of lactate accumulation has become a common training technique (Weltman, 1995). An individual who trains above his/her LT achieves a greater physiological adaptation than one who exercises at or below the LT (Henritze et al., 1985; Weltman et al., 1992). Because of
the strong association between lactate levels and RPE (Demello et al., 1987; Seip et al., 1991; Steed et al., 1994), RPE could potentially be used to set exercise intensities resulting in an individual training at specific BLCs; however, the efficacy of using this method of exercise prescription in an outdoor setting has not been documented.

The purpose of this study was to determine if the physiological responses observed at a BLC of 2.5 mM during an incremental tm test were comparable to those measured when subjects ran on an outdoor track for 30 min at the RPE corresponding to a BLC of 2.5 mM. Based on earlier findings (Ceci & Hassmen, 1991), it was hypothesized that HR and lactate obtained at a given RPE on the tm would be lower than those seen at that same RPE during outdoor track running.

Methods

SUBJECTS

Three females and 6 males ranging in age from 19-24 years served as subjects. All subjects had been running regularly (a minimum of 3 days per week for at least 30 min per session) for no less than 1 year. Informed consent was obtained prior to the start of the study according to the guidelines issued by the Institutional Review Board of the University of Tennessee, Knoxville.

GENERAL TESTING PROTOCOL

Subjects completed an incremental tm test and, on a subsequent day, a 30 min run test on an outdoor track. Each test was performed 3-4 hr after the subject's last meal and at least 24 hr after the subject's last exercise session. Timing was standardized so that both tests were performed at approximately the same time of day (± 3 hr). Subjects were instructed to consume 3 meals in the time between their last workout and testing. Subjects were also asked to refrain from alcohol consumption for at least 24 hr prior to the tests. Immediately before each test, subjects were read the following instructions for use of the 6-20 RPE scale:

During the exercise test we want you to pay close attention to how hard you feel the exercise work rate is. This feeling should be your total amount of exertion and fatigue, combining all sensations and feelings of physical stress, effort, and fatigue. Don’t concern yourself with any one factor such as leg pain, shortness of breath or exercise intensity, but try to concentrate on your total, inner feeling of exertion. Try not to underestimate or overestimate your feeling of exertion; be as accurate as you can (ACSM, 1995).

LACTATE THRESHOLD TEST

Each subject underwent an initial LT test to determine blood lactate, HR, and RPE at various velocities. Subjects completed a horizontal, discontinuous, incremental tm protocol with the initial velocity set at 134 m min⁻¹. RPE and HR were obtained during the last 30 s of each 3 min stage. Each stage was followed by a 1 min blood sampling period during which blood was collected from a fingertip. After blood collection, tm velocity was increased by 13.4 m min⁻¹. The test was terminated when subjects reached volitional exhaustion. Oxygen uptake was assessed
continuously using standard open circuit spirometric techniques. Heart rate was monitored throughout the test using a Heart Watch (Computer Instruments Corp.; Hempstead, NY). The average HR during the last 30 s of each stage was used for comparison with measurements made on the outdoor track.

Blood samples (150 μl) were preserved using YSI 2315 Blood Lactate Preservative Kits (Yellow Springs Instrument Co., Inc.; Yellow Springs, OH). Immediately after each test, the samples were analyzed using a YSI Model 27 automated lactate analyzer (Yellow Springs Instrument Co., Inc.; Yellow Springs, OH).

LT and BLC were determined by visual inspection of the blood lactate/running velocity relationship as validated by Weltman et al. (1990). The fastest running velocity achieved prior to an elevation in blood lactate above baseline levels was used to define LT. The running velocity associated with a BLC of 2.5 mM (V @ 2.5) was determined from the exponential rise in blood lactate observed from the blood lactate/running velocity relationship. The RPE corresponding to the V @ 2.5 was used during the track run to set the exercise intensity.

**TRACK PROTOCOL**

Each subject completed a 30 min track run 24-96 hr after the LT test. Upon arrival, resting HR and blood lactate were obtained as described above, and subjects were read the RPE instructions. Subjects were then instructed to run at an individualized RPE corresponding to V @ 2.5 on the tm test. Subjects were blind to time and HR during the track run. Two RPE charts were posted around the track to assist the subject in maintaining RPE. Every 5 min during the test, the distance covered was assessed, and velocity was calculated by dividing distance by time. Every 10 min during the 30 min run, subjects stopped for 1 min while blood was collected using the methods described above. The average HR during the last 30 s of each 10 min of running was measured using a Heart Watch (Computer Instruments Corp.; Hempstead, NY). To minimize the impact of environmental temperature, tests were conducted when temperatures ranged from 13 to 21°C (Maw et al., 1993; Potteiger and Weber, 1994).

**STATISTICAL ANALYSIS**

One-way ANOVA with repeated measures was utilized to determine if the HR or lactate measured at V @ 2.5 during the tm test differed from the values measured at min 10, 20, and 30 on the outdoor track. Velocity during the track run was measured at 5 min intervals and compared using repeated measures ANOVA with the V @ 2.5 of the incremental test. When indicated, Sheffe’s post hoc procedure was used to indicate which values were different. A significance level of $p < .05$ was chosen a priori for all tests.

**Results**

Nine volunteers (6 males, 3 females) with a mean age of 21.2 ± 1.9 years served as subjects. Height, weight, and VO2 peak averaged 175.4 ± 7.0 cm, 64.5 ± 6.6 kg, and 56.2 ± 6.7 ml kg⁻¹ min⁻¹, respectively. The subjects ran an average 32.8 ± 14.2 km per week and had been running for a mean of 6.3 ± 2.9 years. During the tm test, V @ 2.5 mM averaged 224.8 ± 34.7 m/min⁻¹ and corresponded to 83.7 ± 5.4%
of VO$_2$peak. The mean HR and RPE at V @ 2.5 were 175.1 ± 6.9 bpm and 14.1 ± 2.7, respectively.

Lactate and HR results from the tm and field runs are presented in Figures 1 and 2, respectively. Statistical analyses revealed a significant difference (p < .05) in lactate values between the tm run (2.5 mM) and min 10 (6.9 ± 2.9 mM), min 20 (6.3 ± 2.9 mM), and min 30 (5.8 ± 3.0 mM) of the track run. There were no statistical differences in the 10, 20, and 30 min lactate values during the field test. A significant difference (p < .05) was observed between the HR @ 2.5 mM (174 ± 6.1 bpm) and min 10 (182.6 ± 9.3 bpm) and min 20 (182.9 ± 8.0 bpm) during the field test (Figure 2). No significant difference was observed between the tm HR @ 2.5 mM and min 30 (181.3 ± 10.6 bpm) of the field test. No significant differences were found among the HR values at minutes 10, 20, and 30.

**Figure 1.** Comparison of track lactate values to 2.5 mM obtained on the treadmill test (TM). * – Significantly different from lactate during tm test (p < .05).

**Figure 2.** Comparison of track heart rates to heart rate at 2.5 mM of lactate on the incremental treadmill test (TM). * – Significantly different from heart rate during tm test (p < .05).
Figure 3. Comparison of track velocities to velocity at 2.5 mM of lactate on the incremental treadmill test (TM). * = Significantly different from velocity at min 10, 20, and 30 \( (p < .05) \).

Figure 3 shows the comparison of V @ 2.5 on the tm with velocity during the field experiment. No significant differences were observed between the V @ 2.5 on the tm test and values obtained in the field test. The velocity during the first 5 min of the track run \( (252.5 \pm 34.7 \text{ m.min}^{-1}) \) was significantly higher than the velocity at min 10 \( (222.5 \pm 38.9 \text{ m.min}^{-1}) \), 20 \( (218.5 \pm 32.4 \text{ m.min}^{-1}) \), and 30 \( (220.4 \pm 35.3 \text{ m.min}^{-1}) \).

**Discussion**

The major finding of this study was that the use of RPE to set endurance exercise intensity on an outdoor track resulted in HR and lactate values significantly higher than those observed at the same RPE during incremental tm running. These findings are similar to previously published data (Ceci and Hassmen, 1991; Van den Burg and Ceci, 1986) indicating that, when using RPE to prescribe exercise intensity (production method), HR in an outdoor setting is higher than HR on a tm. The unique contribution of the present study is the comparison of GXT responses (lactate, HR, and velocity) with values measured during an extended outdoor running bout in which RPE was used to determine intensity. This has important implications for designing training programs. Based on the present findings, a training program using RPEs from a GXT will result in higher lactate and HR values than those observed during the laboratory session. The potential for higher physiological responses leads to the possibility of overtraining.

Ceci and Hassmen (1991) showed that the RPE production method resulted in significantly higher HR, lactate, and velocity values on an outdoor track compared to a tm. In the present study, even though there were increases in HR and lactate, there was no significant difference between V @ 2.5 mM during the tm test and the velocity during the track run. However, the velocity during the first 5 min of the field test was significantly faster \( (p < .05) \) than min 10, 20, and 30 of the track run. This initial increase in velocity may have contributed to a rapid accumulation of lactate in the blood, causing subjects to slow as the exercise continued. Although not statistically significant, the velocity during the first 5 min of each 10
min bout was faster than the last 5 min even though RPE was held constant. This finding agrees with data of Van Den Burg and Ceci (1986), who reported that production trials on an outdoor track led to higher HRs but similar overall velocities when compared to tm running.

The oxygen demand of horizontal running is similar for tm and outside running (Bassett et al., 1985; McMiken & Daniels, 1976). Because the mean velocity of the 30 min field trial (230.3 ± 34.5 m min⁻¹) was not different than the V @ 2.5 mM (224.8 ± 34.7 m min⁻¹) on the GXT, one would not expect lactate values to be different. As suggested above, it appears that the initial higher velocity led to an accumulation of lactate so that even after the subjects slowed their pace, the buffering system was not sufficient to decrease blood lactate concentration to the 2.5 mM level.

When running overground, the work performed propels the body forward. In contrast, energy is used in tm running to maintain body position as the belt moves. In an analysis of the biomechanics of overground and tm running, Ingen Schenau (1980) indicated that there are no fundamental mechanical differences. The primary difference between the two modes is that during overground running one must overcome air resistance. For an Olympic caliber sprinter running at top speed, approximately 13-16% of the energy expended is used to overcome air resistance; however, this percentage declines dramatically at slower speeds (Noakes, 1991). Based on calculations by Pugh (1970), the energy cost of overcoming air resistance in the current study would be less than 3%. Unfortunately, wind velocity, which can also affect the energy demands of running, was not measured in the present study. Because subjects ran on an oval track, they ran both with the wind and against the wind; however, the benefit of running with a tail wind is considerably less than the extra energy cost of a head wind (Noakes, 1991). Even if air and wind resistance did increase the energy cost of outdoor running in the present study, it does not fully explain the dissociation between RPE and lactate in the two trials.

The requirement that field trials be conducted when the temperature was between 13 and 21°C makes it unlikely that temperature affected the findings of the present study. Earlier studies (Maw et al., 1993; Potteiger and Weber, 1994) have reported varied effects of different environmental temperatures on RPE and physiological variables. In the present study, the mean environmental temperature for the tm test was 20.1 ± 0.9°C and the mean relative humidity was 54.9 ± 4.3%. During the field tests, the mean temperature and humidity were 18.1 ± 3.6°C and 60.5 ± 23.5%, respectively. The similarity (p > .05) in temperature and humidity between the two trials makes it unlikely that these factors affected the results. Other factors that may alter one’s perception of effort when running outside (e.g., visual or proprioceptive input) remain to be elucidated.

Steed et al. (1994) revealed that running on a tm at a constant velocity associated with LT and BLC of 2.5 and 4.0 mM resulted in a close relationship between BLC and RPE over a 30 min run; however, the data suggested the existence of a “lag time” in RPE when subjects exercise for extended periods at LT or higher intensities. Steed et al. (1994) reported that after the first 5 to 10 min of exercise, RPE leveled out for the duration of the 30 min run. The elevation in velocity during the first 5 min in the present study could be related to the “lag time” in RPE and may have resulted in rapidly rising lactate levels that necessitated a subsequently slower running velocity. The use of RPE to set exercise intensity for
endurance running may be difficult because of a delayed response of RPE during extended exercise. The category-ratio scale of Borg (1982) was developed to examine perceptual changes during constant load exercise, and the increase in RPE over time is further described by Borg and Johansson (1986).

The recent data of Stoudemire et al. (1996) contrast with the present findings. Stoudemire and colleagues utilized a GXT comparable to that used in the present study and followed that test with a 30 min tm run in which RPE was used to set exercise intensity. During the extended run, subjects were instructed to run at the RPE corresponding to a lactate of 2.5 mM measured during the GXT. Lactate was not significantly different from 2.5 mM except at min 30 when an elevation was noted. Additionally, velocity and oxygen uptake throughout the extended run were similar to those observed during the GXT. HR was significantly lower during the first 20 min of exercise compared to that measured during the GXT. The Stoudemire et al. (1996) study and the present study tested males and females with similar physical characteristics, so it is unlikely that subject differences can explain the discrepancy in results. In contrast to the present study, Stoudemire et al. allowed a 5 min aerobic warm-up prior to the run. This may have helped overcome the “lag time” mentioned above. It is unclear why the production method of using RPE to set exercise intensity appears to work better on the treadmill than on an outdoor track.

It might also be argued that the use of both male and female subjects in this study biased the findings; however, several studies have reported no significant gender effect on the RPE/HR, RPE/VO, and/or RPE/lactate relationship (Demello et al., 1987; Eston et al., 1987; Eston & Williams, 1988; Ueda & Kurokawa, 1995).

Based on data indicating that lactate steady state is not reached until more than 5 min after beginning constant load exercise at 74-79% of VO,max (Nagle et al., 1970), it could be argued that the 3 min stages during the GXT did not allow enough time for the subjects to attain a steady state in lactate production and removal. Additionally, Foxdal et al. (1996) suggest that an incremental test with 8 min stages is better than protocols utilizing 4 or 6 min stages for reproducing lactate values corresponding to the onset of blood lactate accumulation (OBLA — a lactate concentration of 4 mM) during constant velocity tm running. However, several studies have demonstrated that the lactate values measured at a given work rate during constant load exercise is comparable to the lactate concentrations at the same workload during incremental tests, given that the subject is below maximal lactate steady state (Weltman, 1995). The present study utilized a slightly modified version (increments of 13.4 rather than 10 m/min) of the Weltman protocol (1990) which, by using 3 min stages and beginning well below LT, yields lactate values similar to those observed with 10 min discontinuous stages. Also, Steed et al. (1994) demonstrated that velocities associated with LT and BLC of 2.5 and 4.0 mM during the Weltman incremental protocol (1990) can be used to reproduce a given lactate level during 30 min of constant tm running. In comparison to the Weltman incremental protocol (1990) used by Steed et al. (1994) and in the current study, Foxdal et al. (1996) utilized a protocol in which subjects began running at a faster velocity and used larger increments during the later stages of exercise. It appears that for a GXT to be used successfully for prescribing velocities during constant load running, the protocol must start well below LT, use stages of 3 min or longer, and use small increments between stages. Even with these considerations, it is more likely that inaccuracies will occur at higher (above OBLA)
rather than lower velocities due to the time necessary to achieve lactate steady state when running near VO_{2}max.

In conclusion, the use of RPE to prescribe exercise intensity during 30 min of running in a field setting resulted in higher lactate and HR values than those obtained on a GXT. While RPE can be used to guide exercise prescription, it is difficult to elicit a specific physiological response through the use of RPE. Additional research investigating the use of RPE in a field setting should include a gradual increase in RPE to serve as a warm-up period. It is possible that, with training, subjects could be taught to pace themselves to avoid initially faster velocities and resultant high levels of lactate accumulation.

References


Received February 4, 1997; accepted in final form July 21, 1997.