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ORIGINAL ARTICLE

Agreement between Session RPE and individual training impulse across a range of running speeds

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ABSTRACT

BACKGROUND: The training impulse (TRIMP) provides a means of quantifying training dose during physical training; it is traditionally based on the heart rate response to exercise and involves establishing the heart rate – blood lactate relationship. A new approach is based on the individual's global rating of perceived exertion (RPE) for the training session. The current study was undertaken to examine agreement between individual TRIMP and session RPE.

METHODS: Nine healthy male volunteers completed three trials involving a 6 km treadmill run at speeds of 12 km×h^{-1}, 9 km×h^{-1} and 7.2 km×h^{-1} in random order. Individual training impulse and session rating of perceived exertion were calculated for each trial.

RESULTS: While both methods resulted in values increasing as the intensity of the trials increased there were no significant differences between the three trials for either method. There was a significant correlation between the two methods (N.=27) (r = 0.62, P<0.01) and the 95% limits of agreement lay between 27.34 and -107.42. Session rating of perceived exertion resulted in higher values for 24 of the 27 trials with the three giving higher individual training impulse all being during the lower training dose trials.

CONCLUSIONS: The findings indicate that while the two methods are related there is a progressive increase in the disagreement as the training dose increases. Which of the two methods gives the better relationship with physiological adaptation has yet to be determined.

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Key words: Heart rate - Exercise test - Running.

The aim of physical training is to disrupt homeostasis inducing physiological adaptation and thereby increasing physical capacity.[1] For athletic performance to be optimal the balance between training load or 'dose' and recovery is crucial [2] and the dose-response relationship needs to be closely monitored. The magnitude of the response to a single session is directly related to the dose, which is a product of the session duration and intensity.[3, 4] Endurance athletes have used training volume, such as daily or weekly distance covered, as a general indicator of training load, however, this method does not account for the disproportionate importance of high intensity work.[5] The training impulse (TRIMP) [5] quantifies training load and represents the exercise dose as a single value, which is the product of both duration and intensity, and provides a valuable tool to further the understanding of the exercise dose-response relationship.

Both objective (heart rate) [6-8] and subjective (RPE) [9, 10] measures of exercise intensity have been used in the calculation of training dose. Banister's original TRIMP was based on fractional elevation in exercise heart rate, which was weighted to reflect a typical blood lactate response in males and females to increasing exercise intensity.[5] This weighted heart rate value accounts for the disproportionate importance of high intensity work when examining physiological adaptation.[5] Manzi *et al.*[6] employed individual lactate response to track changes in performance over time and reported individual TRIMP (TRIMP$_i$) was a more valid tool than Banisters original TRIMP in tracking changes in fitness. Similarly, Stagno *et al.*,[7] who employed a group mean blood lactate response, reported that the modified TRIMP (TRIMP$_{MOD}$) was correlated with the change in both $\dot{V}O_{2max}$ and treadmill speed at a blood lactate concentration of 4 mmol×l^{-1}. While these methods have shown the value of TRIMP in understanding the dose-response nature of physical training they are time consuming and require laboratory access so are of limited value to athletes and coaches on a daily basis.

To address this issue Foster *et al.*[9] proposed a new approach to monitor exercise training employing a global session RPE, which was multiplied by the session duration to give an indication of the training dose. While the TRIMP and TRIMP$_i$ are calculated by multiplying the session duration by a weighting factor, based on the increase in blood lactate, the session RPE is based on a global rating of the entire session.[9] As such the two measures are not interchangeable. Session RPE has, however, been shown to be related to some of the more complex methods of quantifying training load in endurance athletes,[9] resistance trained athletes,[11] team sport athletes,[7, 10] swimmers[8, 12] and rowers.[13] It is yet to be established if the relationship between TRIMP$_i$ and session RPE is consistent across a range of exercise intensities. The current study was undertaken to examine the relationship between TRIMP$_i$ and session RPE while performing a 6 km treadmill run across a range of exercise intensities.

Materials and methods

Experimental approach to the problem

This study employed a within subjects repeated measures design in which nine male subjects attended the laboratory on four occasions. During the first visit the blood lactate – heart rate relationship was established and the resting and maximal heart rates determined. The remaining three visits involved completing a 6 km treadmill run and speed of 12 km×h^{-1}, 9 km×h^{-1} and 7.2 km×h^{-1} performed in randomised order. Individual training impulse and session RPE were calculated for each of the 6 km runs.

Subjects

Nine healthy male volunteers, who were recruited via email from a range of university sports teams and a local sports centre, participated as subjects in the current study. All subjects reported routinely taking part in vigorous activity on a minimum of 3 occasions per week for at least 12 months prior to involvement in the current study but were not considered highly trained. Physical characteristics (mean ± SD); age 31.4 ± 13.8 years, body mass 73.9±4.2 kg and stature 175 ± 7.5 cm. All subjects give written informed consent and completed a Pre-screening Physical Activity Readiness Questionnaire (PARQ) before participation in any aspect of the study which was granted ethical approval by Aberystwyth University Ethics Committee. All procedures conformed to the Declaration of Helsinki.

Procedures

All testing was performed on a motorised treadmill (ELG 70 Weiss, Woodway GmbH, Weil am Rhein, Germany) in a well ventilated laboratory at a temperature of 21-23° C. Subjects attended the laboratory on four separate occasions in a well rested state having completed no strenuous exercise in the preceding 24 h and having refrained from large meals, alcohol and caffeine during the previous 3 h. All trials were separated by a minimum of 24 h with all four completed in a maximum of 12 days; the three experimental trials were completed in random order.

On arrival at the laboratory and following measurement of statue (Harpenden stadiometer, Holtain Ltd, Crymych, UK) and body mass (Seca 714, Seca gmb & co, Hamburg, Germany) subjects sat in a quiet room for 10 min during which time heart rate was recorded continuously using short-wave telemetry (Polar S610i, Polar Electro, Kempele, Finland). Resting heart rate was defined as the lowest 5 s average during the 10 min period; subjects were then introduced to the Category-Ratio 0-10 (CR10) RPE Scale [14] and standard anchoring terms explained. Individual heart rate — blood lactate relationships were then establish via an incremental treadmill protocol. The initial speed was set at 4 $km\times h^{-1}$ and was increased by 1 $km\times h^{-1}$ every 3 min; heart rate was recorded continuously throughout the trial and averaged over the last 60 s of each stage. On completion of each stage a capillary blood sample was taken from a fingertip and analysed for lactate (2300 Stat Plus, YSI, Yellow Springs, USA); the trial was terminated when blood lactate concentrations reached 4 $mmol\times l^{-1}$. The 4 $mmol\times l^{-1}$ cut-off provided sufficient data points (minimum of 11) for each subject to establish the lactate — heart rate relationship, see below. Following the incremental treadmill protocol subjects were given a 15 min recovery before completing a ramped test, starting at 4 $km\times h^{-1}$ and increasing at a rate of 1 $km\times h^{-1}\times min^{-1}$ (0.1 $km\times h^{-1}$ every 6 s) to volitional fatigue, maximal heart rate was defined at the highest 5 s average. Fractional elevation in heart rate was then calculated for each stage during the incremental treadmill protocol and plotted against lactate. An exponential line of best fit was applied to the data and an equation produced where y was the weighing factor, e was the Napierian logarithm having a value of 2.712 and x was the fractional elevation in heart rate, Equation 1:

$$y = Ae^{Bx}$$

During each of the three experimental trials subjects completed a 6 km treadmill run. Prior to each trial a 5 min standardised warm-up was completed at 7 $km\times h^{-1}$ followed by a 3 min recovery during which static stretches of the calf, hamstring, quadriceps and hip flexors were completed. The three trials involved running for 30 min at 12 $km\times h^{-1}$ (high intensity trial [HIT]), 40 min at 9 $km\times h^{-1}$ (moderate intensity trial [MIT]) and 50 min at 7.2 $km\times h^{-1}$ (low intensity trial [LIT]). Heart rate was recorded throughout each trial and a mean value for the duration of each run calculated. On completion of the 6 km distance subjects rested for 30 min, with the final 5 min being seated, before being shown the CR10 RPE Scale [14] and asked 'with a single value please rate your training session'. A value of 0 on the scale represents complete rest with effort only just noticeable rated at 0.5; 10 is almost maximum effort. This method to establish a global session RPE has been used previously,[9-11] but differs from the conventional approach, which uses the scale to give a rating of instantaneous effort during physical activity.

$TRIMP_i$ was calculated by first solving Equation 1 for each trial by substituting in the fractional elevation in heart rate calculated from the mean trial heart rate; the duration of the trial in minutes was then multiplied by the resultant weighting factor. Similarly, Session RPE was calculated by multiplying the duration of the trial in minutes by the global session RPE as described by Foster *et al*.[9]

Statistical analysis

All statistical analyses were performed using SPSS (version 18.0 for windows, SPSS Inc, Chicago, IL). Comparisons between trials for each method ($TRIMP_i$ and session RPE) were made using one way repeated measures ANOVA, with *post-hoc* analysis performed by paired samples *t*-test with Bonferroni correction where appropriate. Relationships between variables were evaluated using Pearson's product moment correlation coefficient. Where significant correlations were observed systematic variation between the $TRIMP_i$ and session RPE across the range of values were explored using the Bland-Altman limits of agreement analyses.[15] All data are represented as means ± standard deviation; significance was set at $P<0.05$.

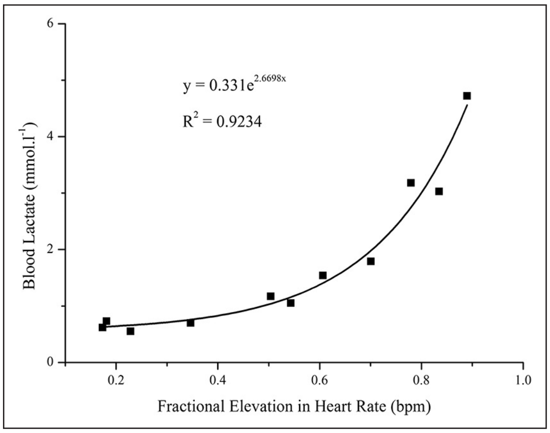

Figure 1.—Typical response in blood lactate and heart rate, showing exponential line of best fit and equation, during the incremental treadmill protocol.

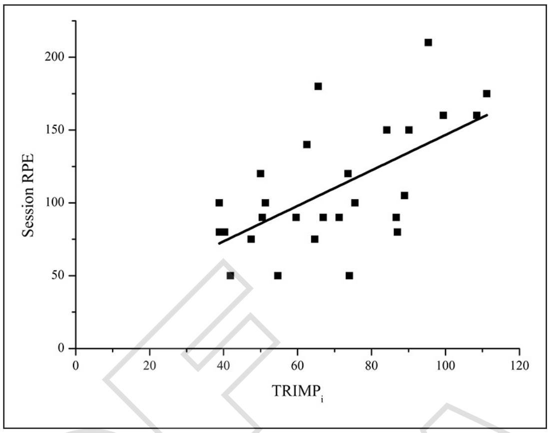

Figure 2.—Relationship between training dose calculated by $TRIMP_i$ and session RPE during the three experimental trials.

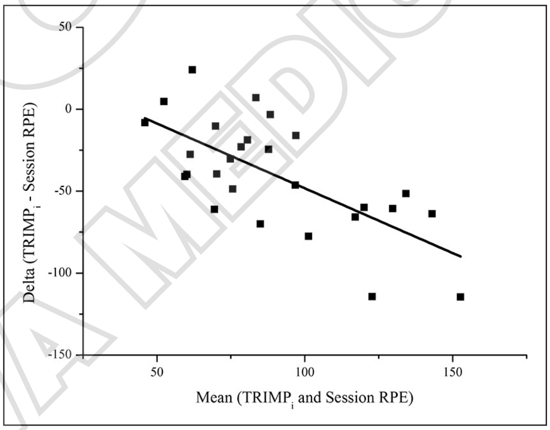

Figure 3.—Bland-Altman plot of differences in training dose calculated by $TRIMP_i$ and session RPE during the three experimental trials.

Results

A typical response in blood lactate and heart rate to the incremental treadmill protocol can be seen in Figure 1, the mean coefficient of determination for the relationship was 0.775 ± 0.113. Both $TRIMP_i$ and session RPE values increased as the intensity of the experimental trials increased even though work done in each of the trials was kept constant at 6 km (Table I). However, there were no significant differences in either $TRIMP_i$ values ($P>0.05$) or the session RPE values ($P>0.05$) between the three experimental trials.

There was a significant correlation between training dose calculated by $TRIMP_i$ and session RPE when all three experimental trials were included (N.=27) ($r=0.62$, $P<0.01$) (Figure 2). When each experimental trial was considered individually the correlation remained significant during LIT (N.=9) ($r=0.67$, $P<0.05$) and MIT (N.=9) ($r=0.71$, $P<0.05$). However, during HIT there was no significant relationship (N.=9) ($r=0.46$, $P>0.05$) between $TRIMP_i$ and session RPE values.

The 95% limits of agreement between $TRIMP_i$ and session RPE lay between 27.34 and -107.42 with a mean of -40.04. When the mean value of the two methods was plotted against the difference between the two methods (Figure 3) there was a significant correlation ($r=-0.682$, $P<0.001$) indicating a systematic variation across the range of values. Session RPE resulted in higher values for 24 of the 27 trials, the three which give higher $TRIMP_i$ were all during the lower training dose trials with a mean value of less than 80.

TABLE I.—*Heart Rate (HR), $TRIMP_i$ and session RPE during the three experimental trials (Mean±SD).*

	LIT	MIT	HIT
HR	117±17	137±18	162±13
$TRIMP_i$	64.4±23.0	69.4±25.7	75.0±15.7
Session RPE	96.1±47.9	111.1±31.8	121.7±46.5

Discussion

The current study was undertaken to determine if $TRIMP_i$ and session RPE would differ consistently across a range of exercise intensities and could therefore be considered as comparable measures, albeit having different scales, for training dose. As the mean value of $TRIMP_i$ and session RPE increased the session RPE resulted in a progressively higher value compared to the $TRIMP_i$.

Both methods resulted in progressively greater values as the intensity of the exercise performed increased. Since all trials involved completion of the same amount of work, and in spite of the non-significant difference between the intensities, this trend in the data would support the suggestion that both methods take into account the disproportionate importance of high intensity work.[5] Furthermore, the significant correlation between the two methods supports previous research, which has reported relationships between $TRIMP_i$ and Session RPE.[9, 10, 11, 16] The proportionally higher values for session RPE during the higher mean training dose trials (Figure 3) indicate that session RPE gives a greater weighting to higher intensity training than $TRIMP_i$. It is not possible to state from the current study if session RPE over values, or $TRIMP_i$ under values, the importance of high intensity work. The global session RPE may be prone to elevation during endurance exercise due to a recency effect. Kilpatrick *et al.* [16] reported that a session RPE taken 15 minutes post exercise matched the reported exertion during the final minute of a 30-min exercise trial but did not match the majority of the session. In order to minimise any effect the rating for the session followed a 30 min recovery period.[9] While the conventional use of the RPE scale is to give a rating of instantaneous effort previous research has employed the scale to give a global rating to an entire exercise session [9-11] these studies support the current data and have shown the scale to be sensitive to changes in training dose across a range of activities and exercise intensities.

The $TRIMP_i$ is calculated from the heart rate response to the exercise bout, weighted by a corresponding lactate value. Since the relationship between lactate and incremental exercise is one of accelerating growth; the method will result in a greater increase in training dose for the same absolute increase in exercise intensity at higher, when compared to lower, intensities of activity. Similarly, the relationship between the CR10 scale for perceived exertion and incremental exercise is also one of positively accelerating growth.[17] The similar nature of the relationship between exercise intensity and both CR10 and lactate underpins the relationship between the two measures. The exact nature of those relationships does, however, differ with the CR10 scale ranging from 0-10 while the weighting factor derived from lactate concentration rarely increases above 5 during exercise lasting longer than 15 min. While this explains why there is a progressive increase in disagreement between the two measures is does not give any indication in to which of the methods has the greater agreement with adaptation to training.

This is the first study to compare $TRIMP_i$ and session RPE during steady state exercise across a range of exercise intensities to examine systematic variation. The findings indicate that while the two methods are related there is a progressive increase in disagreement as the training intensity increases. This disagreement would result in a different relationship between each of the methods of measuring dose and training adaptation (the dose-response relationship). Since the current study did not monitor adaptation it is yet to be determined which method has the greater validity. Specific studies are needed which examine test characteristics of the measure such as reliability and validity in a range of settings.

Conclusions

While Session RPE and $TRIMP_i$ are related there is a systematic disagreement and it is not clear which method best reflects training adaptation. The session RPE method provides an easy to use tool for both coaches and athletes to monitor and prescribe physical training. In addition to the sporting applications, due to its ease of use, Session RPE has potential application when examining the dose response relationship between physical activity and health outcomes.

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Conflicts of interest.—The authors certify that there is no conflict of interest with any financial organization regarding the material discussed in the manuscript.

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