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Jacqueline Tran\textsuperscript{a}, Anthony J. Rice\textsuperscript{b}, Luana C. Main\textsuperscript{c} & Paul B. Gastin\textsuperscript{a}

\textsuperscript{a} Centre for Exercise and Sports Science, Deakin University, Burwood, Australia
\textsuperscript{b} Physiology, Australian Institute of Sport, Belconnen, Australia
\textsuperscript{c} Centre for Physical Activity and Nutrition Research, Deakin University, Burwood, Australia

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Convergent validity of a novel method for quantifying rowing training loads

JACQUELINE TRAN¹, ANTHONY J. RICE², LUANA C. MAIN³ & PAUL B. GASTIN¹

¹Centre for Exercise and Sports Science, Deakin University, Burwood, Australia, ²Physiology, Australian Institute of Sport, Belconnen, Australia and ³Centre for Physical Activity and Nutrition Research, Deakin University, Burwood, Australia

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Abstract
Elite rowers complete rowing-specific and non-specific training, incorporating continuous and interval-like efforts spanning the intensity spectrum. However, established training load measures are unsuitable for use in some modes and intensities. Consequently, a new measure known as the T2minute method was created. The method quantifies load as the time spent in a range of training zones (time-in-zone), multiplied by intensity- and mode-specific weighting factors that scale the relative stress of different intensities and modes to the demands of on-water rowing. The purpose of this study was to examine the convergent validity of the T2minute method with Banister’s training impulse (TRIMP), Lucia’s TRIMP and Session-RPE when quantifying elite rowing training. Fourteen elite rowers (12 males, 2 females) were monitored during four weeks of routine training. Unadjusted T2minute loads (using coaches’ estimates of time-in-zone) demonstrated moderate-to-strong correlations with Banister’s TRIMP, Lucia’s TRIMP and Session-RPE (rho: 0.58, 0.55 and 0.42, respectively). Adjusting T2minute loads by using actual time-in-zone data resulted in stronger correlations between the T2minute method and Banister’s TRIMP and Lucia’s TRIMP (rho: 0.85 and 0.81, respectively). The T2minute method is an appropriate in-field measure of elite rowing training loads, particularly when actual time-in-zone values are used to quantify load.

Keywords: session rating of perceived exertion, Banister’s TRIMP, Lucia’s TRIMP, T2minute

1. Introduction
Coaches and sport scientists aim to prepare elite athletes for competitive success by maximising the influence of positive performance factors (e.g. sport-specific fitness characteristics, technical skill mastery) and minimising the influence of negative factors (e.g. illnesses, injuries, overtrained states). Periodised training plans provide a framework for this process, guiding the timing, sequencing and prescription of training in an effort to achieve a targeted performance level at a given point in time (e.g. World Championships, the Olympic Games) (Fry, Morton, & Keast, 1992). Central to periodisation is the accurate quantification of training load, which facilitates the effective implementation of planned training, monitoring of actual training undertaken and analysis of individual responses to training to ultimately inform subsequent changes to future practice (Borresen & Lambert, 2009).

Training load measures typically monitor acute physiological responses (e.g. heart rate (HR) monitoring) or athletes’ perceptions of training exertion (e.g. the session rating of perceived exertion (Session-RPE) method). HR monitoring is particularly favoured in endurance sports as it is a valid measure of exercise intensity during continuous and submaximal work (Achten & Jeukendrup, 2003) and is useful for quantifying load using methods such as Banister’s training impulse (TRIMP) (Banister, Calvert, Savage, & Bach, 1975) and Lucia’s TRIMP (Lucia, Hoyos, Santalla, Earnest, & Chicharro, 2003). Proponents of Banister’s TRIMP have cited its utility for modelling athletic performance as evidence of measurement validity (Banister et al., 1975; Morton, Fitz-Clarke, & Banister, 1990; Wallace, Slattery, & Coutts, 2014). However, the method has been criticised for scaling intensity using a weighting factor that is sex-specific but not individual-specific, which has subsequently led other researchers to develop more individualised approaches to training load quantification (Akubat, Patel, Barrett, & Abt, 2012; Borresen & Lambert, 2008). In comparison, Lucia’s TRIMP has drawn empirical support for its time-in-zone approach that...
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2. Methods

2.1. Participants

Ethics approval for this study was granted by the institutional ethics committees, and written informed consent was obtained from all participants prior to the commencement of data collection. Fourteen elite rowers training at the Australian Institute of Sport (AIS) participated in this study, which included 12 heavyweight male rowers (eight sweep rowers and four scullers) and two lightweight female rowers (both scullers). Descriptive data are presented in the “Results” section.

2.2. Procedures

Prior to the commencement of the training period of interest, the elite male and female rowers completed laboratory-based performance testing in accordance with the pre-existing NRCE testing schedule. From these tests, individual-specific physiological parameters were identified as required for calculating training loads using Banister’s TRIMP and Lucia’s TRIMP methods. The rowers were then monitored over four weeks of routine training as prescribed by their coaches, during the specific preparation phase that immediately preceded the national team’s departure to Europe for the 2011 World Rowing Championships (see the “Results” section for training details). All measures were familiar to coaches, athletes and sports scientists, having been routinely used in the AIS rowing programme for several years preceding this study.

2.3. Performance testing

The athletes completed one incremental step test using a rowing ergometer on slides (Concept2 Model D, Morrisville, VT, USA), in accordance with national performance testing guidelines (Rice & Osborne, 2013). The protocol consisted of seven 4-min steps (six submaximal steps and one maximal step), with 1 min of rest between each.
step. The drag factor was set at 95 for lightweight females and 115 for heavyweight males. Workloads for the submaximal steps were individualised to each athlete’s best 2000-m rowing ergometer time trial performance from the preceding 12 months. Respiratory variables (i.e. ventilation, volume of oxygen consumption (\(\text{VO}_2\)), volume of carbon dioxide production (\(\text{VCO}_2\))) and HR were measured continuously throughout the test using a first-principles indirect calorimetry system, as described in the previous research conducted in the AIS physiology laboratory (Russell, Gore, Ashenden, Parisotto, & Hahn, 2002; Vogler, Rice, & Withers, 2007). From these tests, maximal and resting HR were identified to enable load calculation using Banister’s TRIMP, and the aforementioned expired gas variables were used to identify the ventilatory threshold (VT) and respiratory compensation point (RCP) for each athlete using the V-slope method (Beaver, Wasserman, & Whipp, 1986). Heart rate values at VT and RCP were then extrapolated to identify individual-specific training zone limits as per Lucia’s TRIMP.

2.4. Training load measures

2.4.1. T2minute method. The T2minute method takes a time-in-zone approach to quantifying load, similar to the intensity-weighted methods proposed by Foster, Florhaug, et al. (2001) and Lucia et al. (2003). Training intensity zones (T zones) are defined by the standardised physiology nomenclature that was established at the AIS to ensure consistency in training intensity prescription across sports (Table I) (Bourdon, 2013). The load within each T zone is the product of the duration of training spent in that T zone, an intensity-specific weighting factor for that T zone and a mode-specific weighting factor for the training mode, as shown by equations (1) and (2). Session load is the sum of loads in all T zones and provides a single index of load in a unit of measure known as a T2minute. One T2minute reflects the training demand equivalent to 1 min of single scull on-water rowing at T2 intensity (moderate aerobic, 75–84% HR\(_\text{max}\), 60–72\% VO\(_2\)\(_\text{max}\)) (Bourdon, 2013; Tran et al., 2014).

\[
T2\text{minute load} = L_{T1} + L_{T1.5} + L_{T2} + L_{T2.5} + L_T3 + L_{T3.5} + L_{T4} + L_{T4.5} + L_{T5} + L_{T6}
\]

where

\[
L_{Tx} = D_x \times F_m \times F_{i(x)}
\]

\(L_{Tx}\) = load at intensity zone \(x\) (T2minutes);
\(D_x\) = duration of training at intensity zone \(x\) (min);
\(F_m\) = weighting factor for training mode (unitless);
\(F_{i(x)}\) = weighting factor for intensity at zone \(x\) (unitless).

Distinct weighting factors corresponding to each T zone were determined from the curvilinear relationship between power output, training intensity and blood lactate (Green, Hughson, Orr, & Ranney, 1983). The mode-specific weighting factors were developed by a working group of experienced sport scientists and national coaches within the AIS rowing programme, to reflect the relative stresses imposed upon rowers when training in a variety of modes. A detailed outline of the T2minute method’s development has been presented (Tran et al., 2014). See Table II for all intensity- and mode-specific weighting factors.

For the purposes of this study, two forms of T2minute training loads were calculated. First, unadjusted T2minute loads were quantified using coaches’ estimates of training time spent in each T zone, in accordance with the current use of the T2minute method in the field (Tran et al., 2014). In order to objectively verify coaches’ estimates, adjusted T2minute loads were then calculated using actual time-in-zone data as determined from HR data.

2.4.2. Banister’s TRIMP. Heart rate was continuously recorded during rowing, cycling, running and

<table>
<thead>
<tr>
<th>T zone</th>
<th>Blood lactate threshold relationship</th>
<th>%HR(_\text{max})</th>
<th>%VO(<em>2)(</em>\text{max})</th>
<th>RPE</th>
</tr>
</thead>
<tbody>
<tr>
<td>T1</td>
<td>Below LT1</td>
<td>60–75</td>
<td>&lt;60</td>
<td>Very light</td>
</tr>
<tr>
<td>T2</td>
<td>Lower half between LT1 and LT2</td>
<td>75–84</td>
<td>60–72</td>
<td>Light</td>
</tr>
<tr>
<td>T3</td>
<td>Upper half between LT1 and LT2</td>
<td>82–89</td>
<td>70–82</td>
<td>Somewhat hard</td>
</tr>
<tr>
<td>T4</td>
<td>LT2</td>
<td>88–93</td>
<td>80–85</td>
<td>Hard</td>
</tr>
<tr>
<td>T5</td>
<td>Above LT2</td>
<td>92–100</td>
<td>85–100</td>
<td>Very hard</td>
</tr>
</tbody>
</table>

Note: %HR\(_\text{max}\) = relative maximal heart rate (%); %VO\(_2\)\(_\text{max}\) = relative maximal oxygen consumption (%); RPE = rating of perceived exertion (arbitrary units); LT1 = lactate threshold 1, “a sustained increase in blood lactate concentration above resting levels”; LT2 = lactate threshold 2, “the upper limit of equilibrium between lactate production and lactate clearance” (Bourdon, 2013).
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2.4. General conditioning training sessions using HR monitors (Forerunner 110 and 310XT, Garmin, Olathe, KS, USA). Data were stored on each athlete’s training watch and uploaded to a central network drive on a daily basis. Banister’s TRIMP loads were then calculated, as per equations (3)–(5) (Banister et al., 1975; Morton et al., 1990):

Banister’s TRIMP = $D \times \frac{HR_{ratio}}{Y}$

where

$HR_{ratio} = \frac{HR_{ex} - HR_{rest}}{HR_{max} - HR_{rest}}$ (4)

$Y = e^{bx}$ (5)

$D =$ exercise duration (min); $HR_{ex} =$ average HR during exercise (beats·min$^{-1}$); $HR_{rest} =$ resting HR (beats·min$^{-1}$); $HR_{max} =$ maximal HR (beats·min$^{-1}$); $Y =$ intensity weighting factor (arbitrary units); $e =$ the mathematical constant known as Euler’s number, 2.718 when approximated to three decimal places (unitless); $b =$ sex-specific value, 1.92 for men and 1.67 for women (unitless); $x =$ change in HR ratio (unitless).

2.4.3. Lucia’s TRIMP. Lucia’s TRIMP loads were calculated from HR values on 5 s time points, with individualised intensity zones based on HR at VT and RCP as per equation (6) (Lucia et al., 2003):

Lucia’s TRIMP = $(1 \times D_{Zone\ 1}) + (2 \times D_{Zone\ 2}) + (3 \times D_{Zone\ 3})$ (6)

$D =$ exercise duration (min) in zone 1, 2 or 3; Zone 1 = below VT; Zone 2 = between VT and RCP; Zone 3 = above RCP.

2.4.4. Session rating of perceived exertion. The Athlete Training System (ATS) was used to capture self-reported Session-RPE training load data. The ATS is an online, questionnaire-style athlete diary created at the AIS, which includes items for athletes to log their training and report their perceptions of wellness (e.g. confidence, sleep quality, etc.) on a 10-point Likert scale. Within the training section of the ATS, athletes provided RPE values and estimates of session duration (in minutes) for each session completed in a given day. Session-RPE load was then calculated as RPE × session duration (Foster, Florhaug, et al., 2001). Consistent with AIS guidelines, athletes typically completed their ATS entries each evening to document each day’s training.

2.5. Data analysis

T2minute loads and Session-RPE loads were calculated in Excel (Microsoft, Redmond, WA, USA). All HR data were initially processed in SportTracks (Zone Five Software, Raleigh, NC, USA), then exported to Excel for further calculation of Banister’s TRIMP and Lucia’s TRIMP loads. Individual sessions were excluded from the analysis if an athlete did not complete the prescribed training due to injury or illness, or if no measure of load was recorded using an established measure. For example, HR data were not recorded for five athletes due to equipment malfunction, resulting in fewer participants being represented in the T2minute vs. HR-based methods data ($n = 9$), compared to the T2minute vs. Session-RPE data ($n = 13$). No Session-RPE data were available when athletes failed to record their training activities within the ATS, which explains the fewer paired observations represented in the T2minute vs. Session-RPE data set. Given these exclusion criteria, the T2minute vs. Banister’s TRIMP and T2minute vs. Lucia’s TRIMP analyses were conducted using 248 paired observations (i.e. 248 training sessions) from nine participants, and the T2minute vs. Session-RPE analysis was conducted using 225 paired observations (i.e. 225 training sessions) from 13 participants.
Statistical analyses were conducted using Statistical Analysis Software (SAS, Version 9.3, SAS Institute Inc., Cary, NC, USA). The alpha level was set at $P < 0.05$. Descriptive data are reported as means $\pm$ standard deviation. Exploratory data analysis revealed that the data sets were non-normally distributed and heteroscedastic. Non-parametric Spearman’s rank correlation coefficients ($\rho$) were calculated to examine the relationship between the T2minute measure and each established measure. Correlation coefficients are discussed as very strong ($\rho \geq 0.7$), strong (0.70 > $\rho \geq 0.5$), moderate ($0.5 > \rho \geq 0.3$) and small ($0.3 > \rho \geq 0.1$) (Hopkins, Marshall, Batterham, & Hanin, 2009). In addition, a Kruskal–Wallis test was conducted to compare unadjusted T2minute loads to adjusted T2minute loads, to assess whether using actual time-in-zone data produced significantly different loads compared to using coaches’ estimated time-in-zone values. A customised spreadsheet was used to convert correlation coefficients into effect sizes (Hopkins, 2007). To draw magnitude-based mechanistic inferences about true (population) values of an effect (i.e. the correlations), the uncertainty in the effect is reported as approximate 90% confidence limits (CLs), and as likelihoods that the true value of the correlation would demonstrate a relationship between an established measure and the T2minute method (Batterham & Hopkins, 2006). An effect was deemed unclear if the effect could be substantially positive and negative, as determined by examining the 90% CL in relation to Cohen’s effect thresholds (Batterham & Hopkins, 2006). All other effects were deemed to be clear.

3. Results

3.1. Participant and training programme descriptive data

Descriptive data for the participants are presented in Table III. On average, the rowers completed 17.4 $\pm$ 2.3 sessions, in rowing-specific (on-water rowing and ergometer rowing) and non-specific modes (road cycling, stationary cycling, resistance training, running and swimming). Weekly total training time was 17.7 $\pm$ 0.6 h per week, of which 63% of training time was dedicated to rowing-specific training. Based on total training duration within a week, the predominant training modes were: (1) on-water rowing (8.9 $\pm$ 1.1 h per week); (2) road cycling (3.4 $\pm$ 2.0 h per week); (3) resistance training (2.8 $\pm$ 0.5 h per week) and (4) ergometer rowing (2.3 $\pm$ 0.6 h per week).

3.2. Unadjusted T2minute training loads vs. established measures

All correlations between the T2minute method and the established measures are presented in Table IV. Banister’s TRIMP, Lucia’s TRIMP and Session-RPE were used to measure training load. All correlations between the T2minute method and each established measure are provided. Strong correlations were observed between the unadjusted T2minute and both HR-based measures, while a moderate correlation was observed between the unadjusted T2minute and Session-RPE loads.

### Table III. Participants’ descriptive data, presented as means $\pm$ standard deviation.

<table>
<thead>
<tr>
<th></th>
<th>$n$</th>
<th>Age (years)</th>
<th>Height (m)</th>
<th>Mass (kg)</th>
<th>VO$_2$max (ml·kg$^{-1}$·min$^{-1}$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>All</td>
<td>14</td>
<td>25.9 $\pm$ 3.4</td>
<td>1.9 $\pm$ 0.1</td>
<td>89.5 $\pm$ 13.0</td>
<td>65.1 $\pm$ 2.7</td>
</tr>
<tr>
<td>Heavyweight males</td>
<td>12</td>
<td>25.4 $\pm$ 3.0</td>
<td>1.9 $\pm$ 0.0</td>
<td>94.4 $\pm$ 4.5</td>
<td>65.7 $\pm$ 2.3</td>
</tr>
<tr>
<td>Lightweight females</td>
<td>2</td>
<td>29.0 $\pm$ 5.7</td>
<td>1.7 $\pm$ 0.0</td>
<td>60.6 $\pm$ 3.0</td>
<td>61.5 $\pm$ 1.3</td>
</tr>
</tbody>
</table>

### Table IV. Measures of association between the T2minute method and the established measures Banister’s TRIMP, Lucia’s TRIMP and session rating of perceived exertion (Session-RPE).

<table>
<thead>
<tr>
<th></th>
<th>Banister’s TRIMP</th>
<th>Lucia’s TRIMP</th>
<th>Session-RPE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Unadjusted T2minutes</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>rho $\pm$ approximately 90% CL</td>
<td>0.58* $\pm$ 0.44</td>
<td>0.55* $\pm$ 0.46</td>
<td>0.42* $\pm$ 0.41</td>
</tr>
<tr>
<td>Qualitative inference</td>
<td>Likely positive</td>
<td>Likely positive</td>
<td>Likely positive</td>
</tr>
<tr>
<td><strong>Adjusted T2minutes</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>rho $\pm$ approximately 90% CL</td>
<td>0.85* $\pm$ 0.22</td>
<td>0.81* $\pm$ 0.26</td>
<td>0.46* $\pm$ 0.54</td>
</tr>
<tr>
<td>Qualitative inference</td>
<td>Most likely positive</td>
<td>Very likely positive</td>
<td>Unclear</td>
</tr>
</tbody>
</table>

*Note: *$P < 0.05$; rho = Spearman’s correlation coefficient; 90%CL = 90% confidence limits.*
3.3. Adjusted T2minute training loads vs. established measures

Very strong correlations were observed between adjusted T2minute loads and both HR-based methods, although the correlation with Session-RPE remained moderate after time-in-zone values were adjusted. A significant Chi-Square value ($H$) was obtained from the Kruskal–Wallis test, indicating that unadjusted T2minute training loads were significantly greater than adjusted T2minute training loads ($H(1) = 46.7, P < 0.05$), with a mean rank of 292.5 for unadjusted T2minute loads and 204.5 for adjusted T2minute loads.

4. Discussion

This study is the first to examine the convergent validity of the T2minute method, a novel measure for quantifying elite rowing training loads. Both unadjusted and adjusted T2minute loads compared favourably with the established measures, as evidenced by moderate-to-strong correlations with Banister’s TRIMP, Lucia’s TRIMP and Session-RPE (rho range = 0.42–0.85). The strongest correlations were observed between adjusted T2minute loads and the HR-based Banister’s TRIMP and Lucia’s TRIMP methods (rho = 0.85 and 0.81, respectively). Together, these correlations demonstrate that the T2minute method achieved very good convergence with established measures. Furthermore, quantifying T2minute loads using actual time-in-zone values provided a more accurate assessment of load, compared to using coaches’ estimates of time-in-zone.

Although no studies have previously examined the validity of the T2minute method or indeed any training load measure in rowing, these findings are consistent with comparisons of training load measures in other sports. Significant correlations (Pearson’s $r$ range = 0.73–0.84) have been reported between Session-RPE and HR-based measures (Banister’s TRIMP and Lucia’s TRIMP), particularly when continuous, submaximal exercise has been quantified in cycling, swimming, soccer and taekwondo (Alexiou & Coutts, 2008; Haddad, Chaouachi, Castagna, Wong, & Chamari, 2012; Rodriguez-Marroyo, Villa, García-López, & Foster, 2012; Scott et al., 2013; Wallace, Slattery, & Coutts, 2009). However, lower mean correlations (Pearson’s $r$ range = 0.32–0.60) have been observed in relation to intermittent or stochastic work in taekwondo and soccer (Haddad et al., 2012; Impellizzeri et al., 2004). In the present study, correlations were relatively stronger between the T2minute method (unadjusted and adjusted forms) and the HR-based measures (rho range = 0.55–0.85), compared to the moderate correlations observed between the T2minute method (unadjusted and adjusted forms) and Session-RPE (rho = 0.42 and 0.46, respectively). Consistent with previous research (Akubat et al., 2012; Borresen & Lambert, 2008; Impellizzeri et al., 2004), substantial between-individual variability in Session-RPE values seems to explain the relatively weaker correlations between T2minute and Session-RPE loads, given the wide CLs observed (rho ± approximate 90% CL: unadjusted T2minute vs. Session-RPE = 0.42 ± 0.41; adjusted T2minute vs. Session-RPE = 0.46 ± 0.54).

The lower accuracy of HR monitoring for measuring the demands of high-intensity and intermittent training must be taken into account (Impellizzeri et al., 2004). The design of this study deliberately incorporated routine training in order to investigate training load measurement in the applied context. As such, the observed period included sessions of high intensity and discontinuous or interval-type efforts, which may have diminished the strength of the correlations between the T2minute method and the HR-based measures. Nevertheless, associations between these measures were strong, indicating that the T2minute method demonstrates an acceptable level of accuracy when compared to concurrently measured loads using HR-based methods.

Comparing the practical measure of interest (in this case, the T2minute method) to HR-based methods is a limitation of previous validity studies and the present investigation. However, there is no accepted gold standard in training load measurement. More importantly, there is a lack of consensus as to what constitutes the construct of “training load” (Borresen & Lambert, 2008; Lambert & Borresen, 2010) and limited knowledge regarding the most effective prescription of load for inducing specific cell signalling and gene expression processes (Baar, 2006; Jones & Carter, 2000). In the absence of a gold standard measure of training load, assessing convergent validity is valuable for determining whether a new measure provides any new information beyond that which could be quantified using existing measures.

In this investigation, the very strong correlations observed indicate that adjusted T2minute loads compared favourably with the HR-based methods, but there remains some degree of unexplained variance between these measures. This finding appears to have two reasonable interpretations. First, we cannot discount the possible presence of measurement errors. For example, HR monitors have demonstrated excellent validity (correlation coefficients above 0.90) compared to electrocardiograph readings during exercise (Laukkanen & Virtanen, 1998). However, minor inaccuracies may be amplified when incorporated with other factors, such as
training duration, to calculate load. If we assume that all of the unexplained variance is attributable to measurement error, full convergence would be achieved with the HR-based methods when error is discounted. Based on this assumption, the T2minute method would capture no different information about training load than those existing measures. Conversely, the unexplained variance may comprise some error and some additional training information that is uniquely captured by the T2minute method but not by the HR-based methods. The precise content of this additional training information cannot be determined from this study, and similarly, these interpretations cannot be confirmed or refuted based on these results. However, we contend that these promising results provide support for the T2minute method as a novel load quantification tool in rowing. The method is sport specific and customised to the unique practicalities of rowing training, which occurs in varied modes and environments (indoor and outdoor) and comprises continuous and discontinuous bouts of work (Tran et al., 2014). In addition, the three-component structure of the T2minute method equation includes a novel weighting factor for training mode (duration × intensity × mode) and by definition captures more information about training than the two-component structure used by established measures (combining duration and intensity, but not mode).

We acknowledge that this study has its limitations, including a relatively small sample of elite athletes (n = 14). Further investigations are required to confirm whether these findings hold true in a larger sample, and to determine whether the method might be appropriate for use in other populations (e.g. sub-elite, junior and recreational rowers). In addition, ergometer performance tests were used to determine HR values corresponding to the intensity zones for each training load measure, yet the primary mode of training was on-water rowing. Discrepancies are known to exist in the demands imposed by these rowing modes. For example, during 2000-m time trial protocols, average speed has been found to be lower (Nevill, Beech, Holder, & Wynon, 2010) and energy expenditure higher during on-water rowing compared to ergometer rowing (De Campos Mello, De Moraes Bertuzzi, Grangeiro, & Franchini, 2009). Conversely, Vogler, Rice, and Gore (2010) found no differences in power output, HR, VO₂ and blood lactate concentration during ergometer versus on-water rowing at submaximal intensities, using a 6 × 4 min protocol similar to the performance test employed in our study. The researchers also reported good agreement between modes for mean HR at anaerobic threshold (Pearson’s r = 0.81), although substantial individual variation was apparent (standard error of the estimate = 9 beats-min⁻¹). While the aforementioned differences between rowing modes may have contributed to some measurement inaccuracy in the present study, the work of Vogler et al. (2010) suggests that an ergometer test can provide appropriate training intensity prescription to on-water work for most rowers.

Furthermore, the T2minute method is not without its drawbacks. Although unadjusted T2minute training loads were significantly associated with the established measures, the strength of the correlations was considerably weaker than for adjusted T2minute loads. This is likely due to the fact that coaches’ estimates of time-in-zone reflected the training prescribed to a crew or squad, whereas HR monitoring provided precise, individual-specific time-in-zone values. Similarly, previous research has reported discordance between the subjective assessments of training provided by coaches compared to athletes (Foster, Heimann, Esten, Brice, & Porcari, 2001; Murphy, Duffield, Kellett, & Reid, in press). Based on these findings, it is recommended that objective time-in-zone data are used to calculate loads, to ensure that T2minute training loads closely represent the actual work completed by individual athletes. Finally, the current form of the T2minute method does not include weighting factors for resistance training; thus resistance training session loads could not be included in this analysis. Further development of the T2minute method should focus on creating weighting factors for resistance training, to permit the quantification of these training stimuli and allow their inclusion into an assessment of the loads accumulated from all training formats.

5. Conclusion

The T2minute method is a novel measure of training load that was designed to have practical utility for quantifying elite rowing training loads across the different modes and intensities in which rowers typically train. The results of this study indicate that the T2minute method is a valid measure of rowers’ training loads compared to established measures, demonstrating very good convergence with HR- and RPE-based methods of quantifying training load. Moreover, adjusting coaches’ estimates of time-in-zone to actual time-in-zone values improved the T2minute method’s convergence with Banister’s TRIMP and Lucia’s TRIMP. The convergent validity demonstrated in the present study, and the pre-existing adoption and acceptability of the method for end-users, provides preliminary evidence to support the ongoing in-field use of the T2minute method as a practical measure of load in high-performance rowing. Where possible, it is recommended that coaches and sports scientists use objectively recorded
time-in-zone values in the T2minute equation to improve measurement accuracy.

In addition to accounting for intensity and duration, the T2minute method is novel in its inclusion of a weighting factor for training mode, which is intended to scale the relative demands of training in different modes to an on-water rowing equivalent. The very good convergence observed may indicate that this novel component of the T2minute equation provides useful and unique information about training that is not captured by established training load measures. The promising results of this study justify further investigations to assess the content and construct validity of the T2minute method, particularly to examine the internal validity of the weighting factors for intensity and mode. The theoretical concept that underpins the T2minute method has potential applications in other sports, particularly those that incorporate substantial proportions of training in a variety of modes (e.g. triathlon, cross-country skiing). The structure of the T2minute method described here was specifically designed for use in elite rowing, but the mode-specific weighting factors could be adapted as appropriate for athletes training in other sports.

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