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Abstract

Purpose: The aim of this study was to assess the dose-response relationships between different training load methods and aerobic fitness and performance in competitive road cyclists. *Method:* Training data from 15 well-trained competitive cyclists were collected during a 10-week (December – March) pre-season training period. Before and after the training period, participants underwent a laboratory incremental exercise test with gas exchange and lactate measures and a performance assessment using an 8-min time trial (8MT). Internal training load was calculated using Banister's TRIMP (bTRIMP), Edwards' TRIMP (eTRIMP), individualized TRIMP (iTRIMP), Lucia's TRIMP (luTRIMP) and session-RPE (sRPE). External load was measured using Training Stress Score™ (TSS). *Results:* Large to very large relationships (r = 0.54-0.81) between training load and changes in submaximal fitness variables (power at 2 and 4 $mmol \cdot L^{-1}$) were observed for all training load calculation methods. The strongest relationships with changes in aerobic fitness variables were observed for iTRIMP (r = 0.81 [95% CI: 0.51 to 0.93, r = 0.77 [95% CI 0.43 to 0.92]) and TSS (r = 0.75 [95% CI 0.31 to 0.93], r = 0.79 [95% CI: 0.40 to 0.94]). The highest dose-response relationships with changes in the 8MT performance test were observed for iTRIMP (r = 0.63 [95% CI 0.17 to 0.86]) and luTRIMP (r = 0.70 [95% CI: 0.29 to 0.89). *Conclusions:* The results show that training load quantification methods that integrate individual physiological characteristics have the strongest dose-response relationships, suggesting this to be an essential factor in the quantification of training load in cycling.

Introduction

Competitive road cycling is a sport that involves a large volume of training and competition.[1] As a consequence, cyclists experience a high physiological and psychological demand during training and competition. It is important that the training programme include a balance between training and rest to prevent both under- and overtraining to increase the chance of achieving the desired performance.[2] As such, it is important for coaches to monitor the cyclists training load to determine whether or not a training variable requires adjustment. Fortunately, the proliferation of mobile power meters and heart rate monitors, together with advanced training analysis software (e.g. TrainingPeaks), has made access to such monitoring data accessible.

However, while access to data is now easier than ever, there is still considerable uncertainty around the validity of this data for quantifying load, and particularly the dose-response validity. Although quantifying training load is an essential part of the training monitoring process[3], the best methods for describing the dose-response validity in cycling are unknown. Banister proposed a training load quantification method termed training impulse (TRIMP), which is an integration of training duration, mean heart rate (HR) of the training session and an exponential factor to weight the intensity of exercise. Since then the TRIMP method has been redefined, including two summated-zone TRIMP methods proposed by Edwards[4] and Lucia et al.[5], where the time spent in pre-defined HR zones are weighted using linear weighting factors. Manzi et al.[6] proposed the individualized TRIMP (iTRIMP) method, where the individual's HR – blood lactate relationship is used to calculate the exponential factor for weighting exercise intensity. In cycling, besides HR-based TRIMP methods, other methods of quantifying training load have been used based on session rating of perceived exertion (sRPE)[7] or power output ("Training Stress Score™")[8]. In order for a training load measure to be valid and have practical application, the method used must be related to an outcome of importance. In most sports these are fitness, fatigue or performance. Hence the chosen training load measure used should be selected on its ability to inform a dose-response relationship between the training load and the outcome of interest.[6] To have an impact on performance, coaches must have an idea of the nature of the relationship between the prescribed exercise dose and the expected training outcome or response. This information allows coaches to be more proactive when manipulating the training dose instead of reacting to a response (e.g. performance test).[9] Studies evaluating this dose-response relationship are valuable since a better understanding of the dose-response relationship between training load, performance, fitness, and/or fatigue, benefits applied practice.

The dose-response relationship can be evaluated by assessing changes in fitness and/or performance during a period of training monitoring. This has previously been shown in a study by Manzi et al.[6] with eight recreational long-distance runners. These authors reported that speed at 2 mmol·L^{-1} and 4 mmol·L^{-1} significantly increased after training and was very largely related to weekly iTRIMP (r = 0.87 [95%CI: 0.41 to 0.97], 0.74 [95%CI: 0.07 to 0.95]). Furthermore, there were very large inverse relationships between iTRIMP and both 5000 m (r = -0.77 [95%CI: -0.95 to -0.15]) and 10000 m (r = -0.82 [95%CI: -0.96 to -0.27]) running times.[6] Weaker relationships were observed between Banister's TRIMP (bTRIMP) and speed improvements at 2 mmol·L^{-1} and 4 mmol·L^{-1} (r = 0.61 [95%CI: -0.91 to -0.17], 0.59 [95%CI: -0.91 to -0.19]) or running performance (r = -0.41 [95%CI: -0.86 to -0.31], -0.54 [95%CI: -0.90 to -0.26]). Similar dose-response validity studies are lacking in cycling.

Even though internal training load methods such as bTRIMP[10], Lucia's TRIMP (luTRIMP)[5] and session-RPE (sRPE)[11] and external training load methods such as Training

Stress Score™ (TSS)[12] are mentioned in the literature, there is little evidence of a dose-response relationship between these measures and training outcomes. Other measures of training load such as Edwards' TRIMP (eTRIMP) and iTRIMP have been applied in other sports but not in cycling. Accordingly, this study examined the dose-response relationships between different training load measures and changes in fitness and performance in well-trained competitive cyclists using a field-based approach.

Methods

Participants

      Fifteen male competitive road cyclists (mean (SD): aged 22 (2.5) y, height 187.7 (4.2) cm, body mass 74.2 (4.7) kg) volunteered to participate in the study. All participants were well-trained competitive cyclists, riding for Dutch club teams and Union Cycliste Internationale professional B teams, and active in national and international competitions. The participants were active as competitive cyclists for at least two years, with a mean of 10 (4) years of competitive experience (including youth competitions). Written consent was obtained prior to participation and institutional ethics approval was granted and in agreement with the Helsinki Declaration.

Research Design

      Training data were collected during a 10-week pre-season training period (December to February), where the training mainly consisted of low-intensity high-volume training. Before and after the training period, participants underwent a fitness and performance assessment. Riders were tracked and monitored throughout the training period using an online training diary (TrainingPeaks, Boulder, United States). No training prescription was provided to the participants - they adhered to their own training plan or a plan provided by their coach.

Fitness and performance assessment

      Before and after the training period, participants underwent a laboratory incremental cycling test with gas exchange and blood lactate measures for the identification of individual HR – blood lactate relationships, lactate thresholds and maximal oxygen uptake ($\dot{V}O_{2max}$). The incremental test started at 100 W and increased 40 W every 4 min until volitional exhaustion or when the pedalling cadence fell below 70 rev·min^{-1} and the cyclist was not able to increase cadence. Each cyclist performed the test on their own bicycle, which was placed on an ergometer (Cyclus2 ergometer, RBM Electronics, Leipzig, Germany). All tests were performed under similar environmental conditions (17-18° C, 45–55% relative humidity). Heart rate was recorded every 5 s using a portable HR monitor (Cyclus2; RBM Electronics, Leipzig, Germany). The highest 30 s mean HR obtained during the incremental test was used as a measure of maximal heart rate (HR$_{max}$). Capillary blood samples were taken from a fingertip at the end of every 4-min stage and directly analysed using a portable lactate analyser (Lactate Pro, Arkray KDK, Japan). As a measure of aerobic fitness, power output at 2 mmol·L^{-1} and 4 mmol·L^{-1} blood lactate were calculated using publicly available software.[13] The last completed stage was used as the measure of maximum aerobic power output (W$_{max}$). If the stage was not completed W$_{max}$ was calculated based on the fraction of the completed stage where volitional exhaustion occurred.[14] Gas exchange measures were obtained using an indirect calorimeter (Omnical, Maastricht Instruments, Maastricht, Netherlands) that was calibrated prior to testing according to the manufacturer's instructions. The test was

performed until complete exhaustion to estimate VO_{2max}. After the test, breath-by-breath values were visually inspected and $\dot{V}O_{2max}$ was defined as the highest 30 s mean obtained during the test.

As an assessment of performance the participants performed an 8-min all-out time trial (8MT) in the field before and after the training period. The 8MT was performed directly after a controlled warm-up (10-20 min at <60% power output at 4 mmol·L^{-1}, 5 min at 90% power output at 4 mmol·L^{-1}, 5 min at <60% power output at 4 mmol·L^{-1}) with the intensity for the warm-up based on the results of the pre-training laboratory test. Mean power output during the time trial was used as the performance measure.

Training load

Training load was calculated using different methods based on either HR, power output or rating of perceived exertion (RPE). bTRIMP was calculated based on training duration, HR, and a weighting factor using the following formula:

$$bTRIMP = \text{duration training (minutes)} \times \Delta HR \times 0.64e^{1.92x}$$

where $\Delta HR = (HR_{ex} - HR_{rest}) / (HR_{max} - HR_{rest})$, e equals the base of the Napierian logarithms, 1.92 equals a generic constant for males and x equals ΔHR.[15] eTRIMP was calculated based on the time spent in five pre-defined HR zones multiplied by a zone-specific arbitrary weighting factor. HR zones were based on percentages of HR_{max} (zone 1: 50-59% HR_{max} − weighting factor = 1, zone 2: 60-69% HR_{max} − weighting factor = 2, zone 3: 70-79% HR_{max} − weighting factor = 3, zone 4: 80-89% HR_{max} − weighting factor = 4, zone 5: 90-100% HR_{max} − weighting factor = 5). Time spent in each zone is multiplied by the weighting factor and then summated to provide a total eTRIMP score.[4] luTRIMP was calculated based on the time spent in three pre-defined HR zones. Zones were defined using fixed blood lactate concentrations with zone 1 below LT_1 (2 mmol·L^{-1}), zone 2 between LT_1 and LT_2 (4 mmol·L^{-1}) and zone 3 above LT_2, a different approach compared to the original luTRIMP that used ventilatory thresholds to identify the zones.[5] Each zone is given a coefficient of 1, 2 and 3, respectively. Time spent in each zone is multiplied by the coefficient and then summated to provide a total luTRIMP score.[5] iTRIMP was calculated by weighting exercise intensity according to an individual's own HR-blood lactate relationship and then using this to weight every HR rather than creating zones. An accumulated iTRIMP can then be calculated by summating the iTRIMP value for each HR data point. The individual weighting factor (y_i) was calculated for each participant with the best-fitting method using exponential models as per the method of Manzi et al.[6]

As a subjective measure of internal training load, sRPE was calculated using the participants' RPE (CR-10 scale[16]) and session duration. The RPE was obtained 30 min after the training session based on the question: "How hard was your workout?" Training load for the session was then quantified by multiplying the RPE by the duration of the session (minutes).[7]

As a measure of external training load, TSS[8] was calculated using power output, derived from portable power meters during every training session on the bike. TSS is calculated using the following formula:

$$TSS = [(t \times NP^{TM} \times IF^{TM}) / (FTP \times 3600)] \times 100$$

where t is the time, NP™ is normalized power[8], IF™ is an intensity factor[8] and FTP is the individual's functional threshold power. The 8MT was used to estimate the participants' FTP,

where 90% of the mean 8MT power output was used as an estimation of FTP.[17,18] Power output data were collected using different power meter brands owned by the cyclists, which were calibrated according to the manufacturer's instructions prior to the training period: SRM system (SRM, Jülich, Welldorf, Germany), Power2max (Power2max, Chemnitz, Germany), PowerTap (CycleOps, Madison, USA), SRAM Quarq (SRAM, Chicago, USA), Rotor (Rotor bike components, Madrid, Spain), Stages powermeter (Stages Cycling, Saddleback LTd., UK) and Pioneer power meter (Pioneer, Kawasaki, Japan).

Statistical analysis

Descriptive results are presented as mean (standard deviation). Prior to analysis the assumption of normality was verified by using Shapiro-Wilk W test. Differences in (aerobic) fitness variables between the pre- and post-testing were assessed with paired samples T-tests. Standardised effect size is reported as Cohen's *d*, using the pooled standard deviation as the denominator. Qualitative interpretation of *d* was based on the guidelines provided by Hopkins[19]: 0 - 0.19 trivial; 0.20 – 0.59 small; 0.6 – 1.19 moderate; 1.20 – 1.99 large; ≥ 2.00 very large. Inferences about the true effect are based on the width of the confidence interval relative to the smallest important magnitude (SWC, 0.2 x standardized effect).[20] Dose-response relationships between measures of training load and aerobic fitness or performance were determined using Pearson's product moment correlation coefficients. Uncertainties in the correlation coefficients are presented as 95% confidence intervals. Interpretation of the strength of the correlation coefficients are based on guidelines provided by Hopkins[19]: 0-0.09 trivial; 0.1-0.29 small; 0.3-0.49 moderate; 0.50-0.69 large; 0.70-0.89 very large; 0.90-0.99 nearly perfect; 1.00 perfect.

Results

A total of 728 cycling training sessions were analysed for the 15 participants during the 10-week training period. Due to technological issues with some power meters, there is missing power output data for 3 participants. For these participants, training load was calculated using HR and sRPE data only. Mean weekly training load during the 10-week training period was measured at 1005 (229) AU for iTRIMP, 1090 (220) AU for bTRIMP, 891 (200) AU for luTRIMP, 2142 (432) AU for eTRIMP, 729 (193) AU for TSS, and 4086 (1460) AU for sRPE.

There was a moderate increase in $\dot{V}O_{2max}$ (+5%, *P* = 0.002, ES = 0.73) and power output at 2 mmol·L^{-1} (+7%, *P* < 0.001, ES = 0.72) after the training period. Small increases in power output at 4 mmol·L^{-1} (+4%, *P* < 0.001, ES = 0.56), W_{max} (+3%, *P* = 0.009, ES = 0.38), mean power output (+1%, *P* = 0.490, ES = 0.25) and mean relative power output (W·kg^{-1}) (+3%, *P* = 0.124, ES = 0.46) during the 8MT performance test were observed after the training period (Table 1).

Dose-response relationships between the different training load measures and percentage changes in aerobic fitness and performance variables are presented in Table 2. There were very large relationships observed between iTRIMP (Figure 1A) and TSS and percentage changes in power output at 2 mmol·L^{-1}. Large relationships were observed for sRPE, bTRIMP, eTRIMP and luTRIMP and changes in power output at 2 mmol·L^{-1} (Figure 2). Percentage changes in power output at 4 mmol·L^{-1} was very largely related to iTRIMP (Figure 1B), luTRIMP, eTRIMP and TSS. Large relationships were observed for sRPE and bTRIMP. Large and very large relationships were observed for iTRIMP and luTRIMP and changes in power output during the 8MT performance test (Figure 3). When examining the

dose-response relationship of improvement in relative power output (W·kg^{-1}) during the 8MT and training load there were very large relationships for luTRIMP and large relationships for eTRIMP, iTRIMP, bTRIMP and TSS, and sRPE.

Discussion

The aim of this study was to assess the dose-response relationships between different training load measures and aerobic fitness and performance in well-trained competitive cyclists. Since the strongest dose-response relationships were observed with individualized training load measures, the results of this study support the use of a training load method that integrates individual physiological characteristics (i.e. HR – blood lactate relationship, functional threshold power) rather than mean exercise intensity values or arbitrary weighting factors.

We also observed considerable variation in the dose-response validity of the various methods examined. sRPE and bTRIMP showed the weakest relationships between training load and changes in power output at 2 and 4 mmol·L^{-1} compared to the other measures of training load. The limitations of both methods could explain why they may be less suited for road cycling. bTRIMP uses mean HR of the training session or competition which may not be applicable for the stochastic nature of (competitive) road cycling, where there are specific moments where the exercise intensity can be very high or very low depending on terrain, tactical factors and weather conditions.[1] Even though this stochastic nature may be less during training sessions, these fluctuations in exercise intensity limits the use of bTRIMP as a training load measure in road cyclists. Furthermore, bTRIMP uses a generic equation for the blood lactate response to exercise which doesn't integrate individual physiological characteristics.[21] The complex interaction of many factors (e.g. hormone concentrations, personality traits, environmental conditions)[3] that contribute to the RPE may explain the weaker dose-response relationships compared to other training load methods (e.g. HR-based TRIMP methods).[22] Nevertheless, the current study observed a stronger dose-response relationship for sRPE compared to previous research by Foster et al.[7] (r = 0.29) in a population of 56 athletes. Pinot and Grappe[11] reported very large correlations (r = 0.83 – 0.94) between increases in training load quantified by sRPE and mean maximal power outputs (5 - 240 min) achieved during training and competition each year. However, the study by Pinot and Grappe[11] was a case-study conducted over an extended period of time, and so it is hard to compare their results directly with ours. Wallace et al.[23] reported that correlations between total V̇O$_2$ and training load were higher for bTRIMP (r = 0.85) and luTRIMP (r = 0.83) compared to sRPE (r = 0.75) suggesting that HR-based methods correlate better with V̇O$_2$ kinetics during exercise compared to RPE-based methods. Therefore, even though sRPE is an easy-to-use simple method, HR-based internal training load quantification appears to demonstrate higher dose-response validity when related to fitness or performance changes in cycling.[22,23] However, in situations where the pattern of HR can be affected by accumulated fatigue, the combination of sRPE together with HR-based training load methods may be useful in providing information about the fatigue state of cyclists.[22,24] Since this study evaluated the dose-response validity in a pre-season preparatory training period, future research should evaluate this in competitive periods where the nature of training differs (i.e. more high-intensity training, increased training load) and the athletes are more prone to states of fatigue to see if these relationships are maintained.

There was a moderate relationship between TSS and the changes in mean power output during the 8MT performance test. Wallace et al.[25] reported higher correlations

between a running-based version of TSS and changes in performance (r = 0.70) compared to bTRIMP (r = 0.60) and sRPE (r = 0.65). Overall, the dose-response relationships between training load methods and changes in performance weren't as strong compared to those between training load and aerobic fitness variables. The high variability (ES = 0.25 [95% CI: -0.51 to 1.01]) observed in the improvement of the 8MT may provide explanations for these mixed results. Post-race fatigue and motivational factors could contribute to this variability in the results as the post-training 8MT tests were performed when the competitive season had started. Furthermore, the relative short duration of the performance test may contribute to these results. Time trials of longer duration (20-90 min) have shown to have strong relationships with incremental exercise test variables.[26-28] However, shorter tests are easier to integrate in to the busy training plan of these athletes and are less physically and mentally demanding. Taking these factors into account, the dose-response relationships with performance in this study should be interpreted with caution.

As highlighted by the mixed results of the performance test, studies in the field with well-trained athletes makes collecting training data less controlled compared to laboratory-based research designs. However, using a field-based approach provides higher external validity and provides valuable information for coaches and practitioners working in the field, which may outweigh some of the limitations resulting from such an approach. Additionally, different power meters were used in this study for the collection of HR and power data, leading to increased power output data variability. Even though there is research validating some of the power meter systems used in this study[29,30], not all power meters are tested for validity and accuracy. Furthermore, confounding factors with regards to the interpretation and accuracy of blood lactate concentration measurement to track changes in training status must be taken in to account.[3] However, despite some of the limitations of blood lactate measurements, the dose-response relationships were shown using widely used methods of assessing endurance performance variables in cycling.

Practical applications

An improved understanding of the dose-response relationships between training load and fitness/performance is valuable for coaches and practitioners. To have an impact on performance we must be sure of the nature of the relationship between the prescribed exercise dose and the expected training outcome or response. Practically valuable information can be derived from the dose-response relationships presented. For example, the dose-response relationships between iTRIMP and aerobic fitness suggest that to maintain improvements in aerobic fitness (i.e. power output at 2 mmol·L^{-1}) the cyclists should accumulate a mean weekly iTRIMP of ~ 650 AU (Figure 1A). Furthermore, improvements in aerobic fitness will most likely occur when mean weekly iTRIMP of >650 AU is implemented in the training plan. Even though this is only indicative data for this specific group of well-trained cyclists, providing coaches with such an evidence-based framework may contribute to optimized training monitoring and design of training programmes. Future research should asses the relationships over more prolonged training periods and possibly with more frequent performance tests.

Conclusions

In conclusion, this study is the first to show the dose-response relationships between different training load measures and changes in fitness and performance in well-trained cyclists. The strongest dose-response relationships between training load and changes in submaximal aerobic fitness variables were observed for iTRIMP and TSS, where 56-65% of the variance was explained. The dose-response relationships with performance changes were not as strong compared to the aerobic fitness variables with the results showing iTRIMP and luTRIMP to have the strongest relationships. Overall, the results show that training load quantification methods that integrate individual physiological characteristics have the strongest dose-response relationships, suggesting this to be an essential factor in the quantification of training load in cycling.

Acknowledgments

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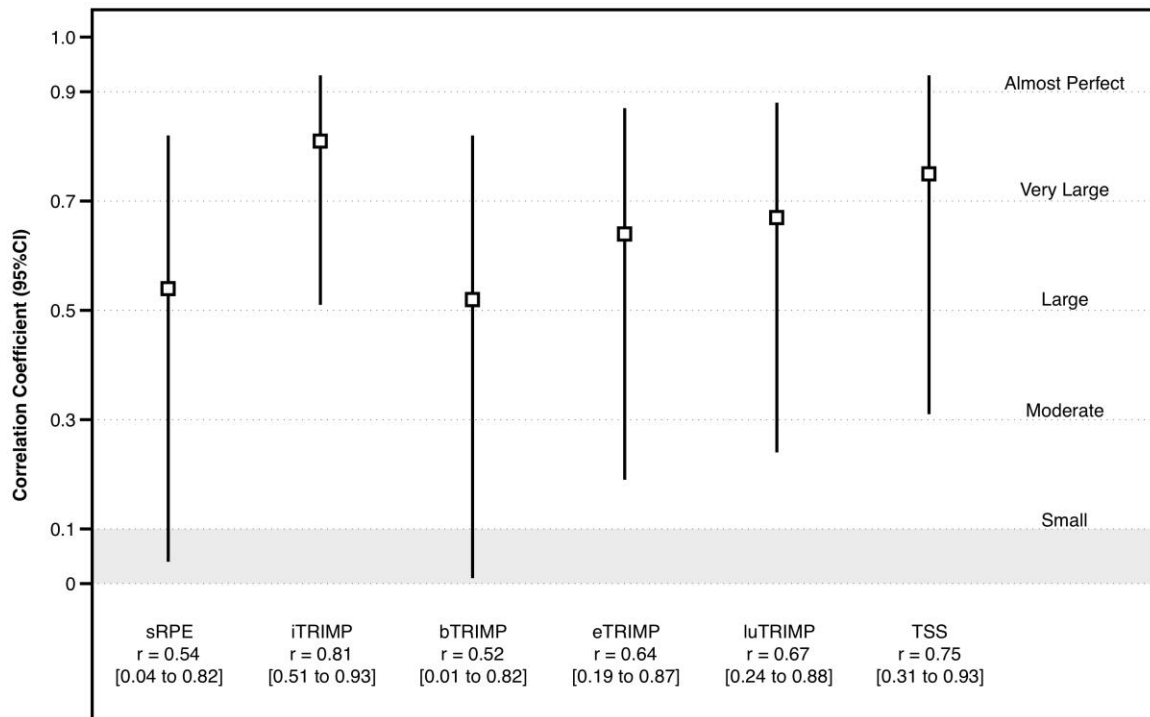
Figures and tables
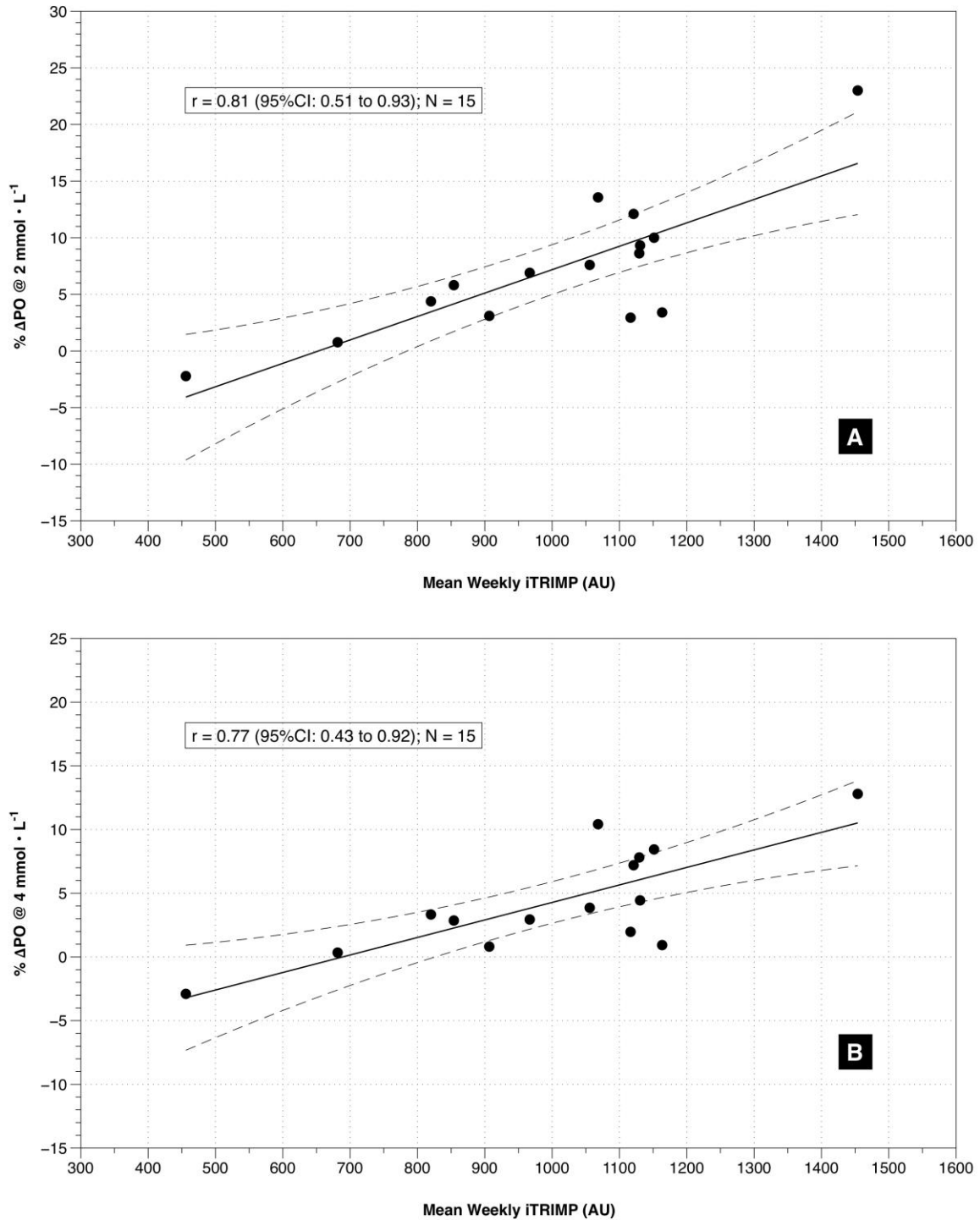
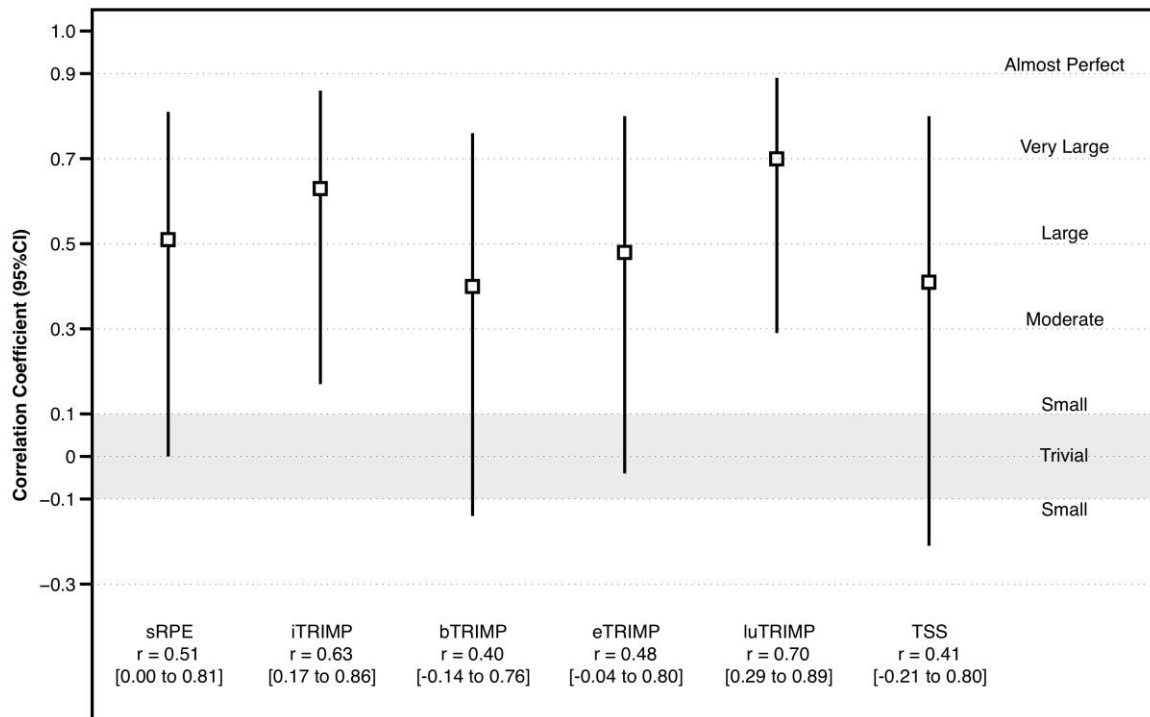**Figure 1:** Relationship between percentage changes in power output at 2 (A) and 4 (B) mmol·L^{-1} lactate and mean weekly iTRIMP (n= 15).

Figure 2: Relationship between all the measures of training load and percentage changes in power output at 2 mmol·L^{-1} lactate. Correlation coefficients (r) are presented with 95% confidence intervals. Interpretation of the strength of the correlation coefficient was based on guidelines provided by Hopkins[19].

Figure 3: Relationship between measures of training load and percentage changes in mean power output during an 8-min performance test. Correlation coefficients (r) are presented with 95% confidence intervals. Interpretation of the strength of the correlation coefficient was based on guidelines provided by Hopkins[19].

Table 1. Physiological and performance measures before and after the 10-wk training period

	Pre-testing	Post-testing	Mean difference	Effect size	Qualitative outcome[a]
	mean (SD)	mean (SD)	[95%CI]	[95% CI]	
$\dot{V}O_{2max}$ (mL·kg^{-1}·min^{-1})	62 (4)	65 (4)	3.2** [1.4 to 4.9]	0.73 [0.31 to 1.14]	Very likely moderate effect
PO at 2 mmol·L^{-1} (W)	282 (28)	303 (32)	22** [12 to 31]	0.72 [0.40 to 1.04]	Most likely moderate effect
PO at 4 mmol·L^{-1} (W)	324 (26)	339 (30)	16** [9 to 22]	0.56 [0.31 to 0.91]	Most likely small effect
W_{max} (W)	384 (31)	397 (34)	12** [4 to 21]	0.38 [0.11 to 0.65]	Likely small effect
8MT PO (W)	382 (40)	393 (35)	4 [-8 to 16]	0.25 [-0.51 to 1.01]	Unclear small effect
8MT PO (W·kg^{-1})	5.15 (0.37)	5.35 (0.49)	0.14 [-0,43 to 0.32]	0.46 [-0.14 to 1.06]	Likely small effect

Abbreviations: $\dot{V}O_{2max}$; maximal oxygen uptake, PO; power output, W_{max}; maximal power output, 8MT; 8-min time trial.

a. With reference to a smallest worthwhile change of 0.2 x standardized effect.

*. Difference is significant at the 0.05 level (2-tailed)

**. Difference is significant at the 0.01 level (2-tailed)

Table 2. Relationship between training load measures and percentage changes in fitness variables and performance. Pearson's product-moment correlation coefficients are presented with 95% confidence intervals.

	sRPE	iTRIMP	bTRIMP	eTRIMP	luTRIMP	TSS
% ΔPO 2 mmol·L^{-1}	0.54[*] [0.04 to 0.82]	0.81[**] [0.51 to 0.93]	0.52[*] [0.01 to 0.82]	0.64[*] [0.19 to 0.87]	0.67[**] [0.24 to 0.88]	0.75[**] [0.31 to 0.93]
% ΔPO 4 mmol·L^{-1}	0.60[*] [0.13 to 0.85]	0.77[**] [0.43 to 0.92]	0.67[**] [0.24 to 0.88]	0.73[**] [0.35 to 0.90]	0.72[**] [0.33 to 0.90]	0.79[**] [0.40 to 0.94]
% Δ $\dot{V}O_{2max}$	0.36 [-0.19 to 0.74]	0.08 [-0.45 to 0.57]	0.37 [-0.18 to 0.74]	0.39 [-0.15 to 0.75]	0.20 [0.35 to 0.65]	0.25 [-0.38 to 0.72]
% ΔW$_{max}$	0.30 [-0.25 to 0.70]	0.11 [-0.43 to 0.59]	0.44 [-0.09 to 0.78]	0.43 [-0.11 to 0.77]	0.28 [-0.27 to 0.69]	0.01 [-0.57 to 0.58]
% ΔPO 8MT	0.51 [0 to 0.81]	0.63[*] [0.17 to 0.86]	0.40 [-0.14 to 0.76]	0.48 [-0.04 to 0.80]	0.70[**] [0.29 to 0.89]	0.41 [-0.21 to 0.80]
% ΔPO·kg^{-1} 8MT	0.51 [0 to 0.81]	0.62[*] [0.16 to 0.86]	0.63* [0.17 to 0.86]	0.66* [0.22 to 0.88]	0.76[**] [0.41 to 0.92]	0.61* [0.06 to 0.88]

Abbreviations: sRPE; session rating of perceived exertion, iTRIMP; individualised training impulse, bTRIMP; Banister's training impulse, eTRIMP; Edwards' training impulse, luTRIMP; Lucia's training impulse, TSS; Training Stress Score. % ΔPO 2 mmol·L^{-1}; percentage change in power output at 2 mmol·L^{-1} pre *vs.* post, % ΔPO 4 mmol·L^{-1}; percentage change in power output at 4 mmol·L^{-1} pre *vs.* post, % Δ $\dot{V}O_{2max}$; percentage change in $\dot{V}O_{2max}$ pre *vs.* post, % ΔPO 8MT percentage change in power output during the 8MT pre *vs.* post; % ΔPO·kg^{-1} 8MT percentage change in relative power output (W·kg^{-1}) during the 8MT pre *vs.* post.

*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).