Title: Time Trials versus Time to Exhaustion Tests: Effects on Critical Power, W′ and Oxygen Uptake Kinetics

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ABSTRACT

Purpose: To investigate single-day time-to-exhaustion (TTE) and time trial (TT) based laboratory tests values of critical power (CP), Wprime (W′) and respective oxygen kinetics responses. **Methods:** Twelve cyclists performed a maximal ramp test followed by three TTE and three TT efforts interspersed by a 60-min recovery between efforts. Oxygen uptake was measured during all trials. The mean response time (MRT) was calculated as a description of the overall $\dot{V}O_2$ kinetic response from the onset to 2 min of exercise. **Results:** TTE determined CP was 279 ± 52W and TT determined CP was 276 ± 50W (P = 0.237). Values of W′ were 14.3 ± 3.4 kJ (TTE W′) and 16.5± 4.2 kJ (TT W′) (P = 0.028). Whilst a high level of agreement (-12 to 17 W) and a low prediction error of 2.7% was established for CP, for W′ limits of agreements were markedly lower (-8 to 3.7 kJ) with a prediction error of 18.8%. The mean standard error for TTE CP values was significantly higher than that for TT CP values (2.4 ± 1.9% vs. 1.2 ± 0.7% W). The standard error for TTE W′ and TT W′ were 11.2 ± 8.1% and 5.6 ± 3.6%, respectively. The $\dot{V}O_2$ response was significantly faster during TT (~22 s) than TTE (~28 s). **Conclusions:** The time-trial protocol with a 60-min recovery period offers a valid, time-saving and less error containing alternative to conventional and more recent testing methods. Results however cannot be transferred to W′.

Key Words: $\dot{V}O_2$ response; anaerobic work capacity; power-duration relationship; severe-intensity exercise.

INTRODUCTION

Critical Power (CP) is defined as the highest sustainable rate of aerobic metabolism without a continuous loss of homeostasis.[1] It separates power output (PO) intensities for which exercise tolerance is predictable (PO > CP) from those of longer sustainable durations (PO < CP). The second parameter of the power-duration relationship, Wprime (W′) represents the amount of work that can be performed above CP. At a magnitude dependent rate, W′ is reduced when PO > CP. During severe-intensity exercise (i.e. > CP), W′ is predictably expended at a rate, which is related to the development of a $\dot{V}O_2$ slow component ($\dot{V}O_2SC$).[2] This provides an intrinsic link between the loss of muscular efficiency and the development of fatigue.[2,3]

In addition to a maximal ramp test, the conventional CP assessment requires athletes on repeated occasions to perform time to exhaustion trials (TTE), commonly applied after a 24 h recovery period. As this method is time consuming, alternative approaches, using shorter intra-exhaustive trial recovery period have been proposed. Galbraith et al.[4] observed a high level of agreements for Critical Speed but not for the anaerobic running distance (D′) (the mode equivalents of CP and W′) after using both, 30-min and 60-min recovery periods compared to the 24-h methods in runners. Additionally, using the 24-h and a 30-min recovery, Karsten et al. demonstrated interchangeable values between laboratory TTE determined CP values and ecological valid track[5] as well as road[6] time trial (TT) determined respective CP values. Both studies also identified a high prediction error for W′. Under laboratory conditions, Karsten et al.[7] observed similar results for CP and W′ when using the 30-min TTE recovery protocol. It might consequently be debatable whether the shortened recovery period is appropriate to return W′ to 'baseline' values.

Questions have to be raised over the ecological validity of commonly applied TTE trials. Laursen et al.[8] suggested TTE trials to be less reliable and not reflective of real-life performance. Moreover, at exercise onset power profiles between TT and TTE differ. During TT efforts PO cannot just project towards maximal values but may also fluctuate throughout, whilst PO for TTE efforts is driven up to a pre-determined fixed intensity in a square-wave fashion. Likewise a difference in cadence between TTE and TT efforts may produce different CP values.[9] However, given that both, TT and TTE effort intensities are located in the severe domain consequently develop a $\dot{V}O_2$ SC but also attain $\dot{V}O_{max}$, W′ in all trial types depletes towards zero independently of related power profiles.[10] Black et al.[11] recently demonstrated this by comparing TTE efforts with TT efforts.

Other important aspects to consider are that of 'priming' of the $\dot{V}O_2$ response,[12] when investigating shortened recovery durations and that of a fast-start pacing strategy[13] as used during the initial phases of TTs. Maintainable for up to 45 min,[2] priming has been described as a faster overall $\dot{V}O_2$ response together with a reduction of the $\dot{V}O_2$ SC.[14] Bailey et al.[12] showed an increase in exercise tolerance during two repeated bouts of severe intensity exercises separated by 20 min recovery. Moreover, a fast-start strategy can speed the $\dot{V}O_2$ kinetics, thereby preserving W′ during the initial phase of a subsequent exercise[15]. During repeated severe intensity TTE and TT efforts the aforementioned effects can impact on kinetic responses and W′, causing a predictable change in exercise tolerance.

There is a consistent need for ecologically enhanced, time saving CP/W′ laboratory testing. The present study aimed to compare CP and W′ values derived from TTE with those from TT efforts. Additionally, the presence of primed $\dot{V}O_2$ kinetics using a 60-min recovery period was investigated. Furthermore, the standard errors of CP and W’ parameter estimates were also analysed. As a final objective we aimed to analyse which method, TTE or TT efforts provide lower standard errors of CP and W′ estimates.

METHODOLOGY

Experimental Approach to the Problem

Participants and Design

Participants were 12 moderately trained cyclists (mean ± SD: age 39 ± 9 years, body mass 82 ± 13.4 kg, maximal aerobic power (MAP) 361 ± 55 W, peak oxygen consumption ($\dot{V}O_{2peak}$) 54.7 ± 9.6 $mL{\cdot}kg^{-1}{\cdot}min^{-1}$) with a minimum of two years racing experience. The study was approved by the University Ethics Committee of the host institution. Prior to providing written informed consent, cyclists were fully informed of the nature and risks of the research. Participants refrained from heavy exercise in the 24 h and from food and caffeine intake in the 3 h prior to testing. For all 3 visits participants were instructed to arrive at the laboratory in a fully rested and hydrated state. For all tests participants used their personal racing or TT bike, which was mounted to a Cyclus2 ergometer (RBM Electronics, Leipzig, Germany).

During visit one $\dot{V}O_{2peak}$, and MAP values were determined. In randomised order, participants performed either time-to-exhaustion based CP tests (CP_{TTE}) or time trial based CP tests (CP_{TT}). To avoid a possible priming effect,[2] a recovery period of 60-min between exhaustive tests was provided. During rest periods fluid intake was permitted ad libitum. PO and cadence were recorded continuously via the ergometer, and expired gases were continuously sampled through the gas analyser to ensure the attainment of individual $\dot{V}O_{2peak}$ values. All tests were performed at the same time of day (± 2h) in laboratory conditions with a controlled environment (18–22°C; 45–55% relative humidity).

Measurements

Peak oxygen uptake test

After a standardised warm-up at an intensity of 150 W and 120 W for 5 min (males and females respectively), cyclists completed a progressive incremental exercise test with an increase of 20 W·min^{-1} until volitional exhaustion. Cyclists were allowed to self-select their cadence. When cadence dropped by more than 10 rev·min^{-1} for more than 10 s despite strong verbal encouragement, tests were terminated. Expired gases were collected continuously throughout using a Cortex MetaLyzer 3B gas analyser (Cortex Biophysik, Leipzig, Germany). Heart rate (HR) was continuously monitored using the ergometer. If the last stage was not completed MAP was calculated using the following equation:

$$MAP=P_L+(t/60xP_I) \quad (1)$$

where P_L represents the last completed stage (W), t is the time for the incomplete stage (s) and P_I is the incremental work rate (W). The achievement of $\dot{V}O_{2peak}$ was taken as the highest 30 s interval during the incremental test.

Time to Exhaustion Critical Power

To determine CP_{TTE} and W'_{TTE} participants completed three TTE trials. Work rates were equivalent to ~85% (TTE1), ~100% (TTE2) and ~105% (TTE3) MAP, using a lowest to highest work rate order.[7] A 3-min unloaded cycling phase was followed by an immediate (square wave) increase in PO to the desired work rate intensity. Participants were instructed to adopt an even paced strategy, i.e. to maintain their preferred cadence for as long as possible. Tests were terminated as described above. Participants were allowed to continue unloaded cycling for 5 minutes before dismounting the bike. Whilst being blinded to elapsed time, cadence feedback was visible to participants. $\dot{V}O_{2peak}$ was determined as the highest 15-s rolling mean $\dot{V}O_2$ recorded during each trial.

Time Trial Critical Power

CP_{TT} and W'_{TT} were determined using maximal TT efforts of 12 min (TT1), 7 min (TT2) and 3 min (TT3) in that order. The protocol started with a 3 min unloaded cycling phase after which participants during the final 5 s were instructed to adopt a fast-start by acceleration of cadence. Using the TT mode, the resistance increased as a function of cadence and pedal force at the start of each TT. To replicate real-world TT cycling, participants consequently utilised a self-pacing strategy where gearing was adjusted throughout efforts using the virtual gear changer mounted to the handlebars. Feedback over elapsed time and strong encouragement was provided throughout. After completion of respective trials, tests terminated and participants were permitted to continue unloaded cycling for 5 minutes thereafter. Individual TT $\dot{V}O_{2peak}$ values were determined as described above.

Calculation of Critical Power and W′

Linear regression was used to determine CP and W′ using the power-1/time ($P = W'(1/t) + CP$) model. Results determined from TTE and TT trials were consequently termed CP_{TTE}/CP_{TT} and W'_{TTE}/W'_{TT}.

Oxygen uptake Kinetics

Before analysis, the breath-by-breath $\dot{V}O_2$ data were examined and breaths lying more than three standard deviations from a local mean of 5 data points were removed. The filtered data were linearly interpolated to 1 s and time aligned to the start of exercise.[16] A nonlinear least square algorithm was used to calculate the mean response time (MRT), with the fitting window constrained from the onset of exercise (t = 0) to 2 min of exercise (i.e. minimum completion time across the trials). The MRT was chosen as our study contained only one trial in each condition and therefore a higher order bi-exponential model would result in low statistical confidence. The overall $\dot{V}O_2$ kinetic response is described in the following equation:

$$\dot{V}O_2(t) = \dot{V}O_{2\ \mathrm{baseline}} + A\,(1 - e^{-t/\mathrm{MRT}}) \qquad (2)$$

where $\dot{V}O_2(t)$, $\dot{V}O_{2\ \mathrm{baseline}}$, A and MRT represent the $\dot{V}O_2$ at any given time, the $\dot{V}O_2$ over the final 60 s of baseline exercise, the amplitude from baseline to its asymptote and the mean response time, respectively. The total oxygen consumed up to 2 min was calculated and divided by the corresponding work to provide a measure of oxidative energy provision to PO.[17] The oxygen deficit at 2 min was calculated by multiplying the MRT and the $\dot{V}O_2$.

Statistical Analysis

Data were examined using the Shapiro–Wilk normality test. Pearson product moment correlation was used to provide an indication of the strength of any relationship between the derived values of CP and W′. Differences of statistical significance between CP_{TTE}/W'_{TTE} and CP_{TT}/W'_{TT} values were tested using paired samples t-tests. The agreement between CP and W′ values was assessed using Limits of Agreement (LOA). Linear regression was used to calculate values for the Standard Error of Estimate (SEE) in each experiment (as mean values). Paired sampled t-tests were also used to test for differences between TTE and TT trial durations and between individual SEE values. A 2-way ANOVA with time (i.e. 12, 7, 3 min vs. 85, 100, 105%) and method (i.e. TTE vs. TT) as model factors were used to analyse parameters of O_2 kinetics. Significant main effects were followed up employing the Bonferroni procedure for multiple testing.[18] Effect sizes are reported as Cohen's *d* (t-tests) and as partial Eta-squared (η_p^2) (ANOVAs) with 0.2, 0.5, 0.8 and 0.01, 0.1, 0.25 considered as small, moderate and large effects, respectively. Statistical significance was accepted at $P<0.05$. Results are reported as mean ± SD.

RESULTS

All data were normally distributed. There was no difference between $\dot{V}O_{2peak}$ reached during the incremental test (4.4 ± 0.59 $L \cdot min^{-1}$) and mean $\dot{V}O_{2peak}$TTE (4.4 ± 0.34 $L \cdot min^{-1}$, P = 0.153) and mean $\dot{V}O_{2peak}$TT (4.4 ± 0.36 $L \cdot min^{-1}$, P = 0.112) respectively. Table 1 represents results for CP and W′ estimates from the TT and TTE models, as well as LoA and SEE values. No differences were observed between CP_{TTE} and CP_{TT} (t(11) = 1.3, P = 0.237, *d* = 0.36) but between W'_{TTE} and W'_{TT} (t(11) = -2.5, P = 0.028, *d* = 0.73). The mean standard errors for CP_{TTE} and for CP_{TT} were 7 ± 5 W (2.4 ± 1.9%) and 3 ± 2 W (1.2 ± 0.7%), respectively resulting in a significant difference (t(11) = 2.6; P = 0.026; *d* =

1.1). For W'_{TTE} and W'_{TT} the standard errors were 1.6 ± 1.2 kJ (11.2 ± 8.1%) and 0.9 ± 0.5 kJ (5.6 ± 3.6%), respectively (t(11) = 2.2; P = 0.047; *d* = 0.80). TTE trial durations were 637 ± 165 s, 273 ± 72 s, and 180 ± 33 s at 85%, 100% and 105% MAP respectively (Table 2). There was a significant difference between the TTE2 and TT2 durations and PO ($P<0.001$). Bland-Altman plots and relationships are presented in Figure 1. The bias and 95% LoA between TTE vs. TT was 3 ± 8 W (-12 to 17) and 2.2 ± 6.7 kJ (-8.0 to 3.7) for CP and W', respectively. TTE and TT derived values of CP and W′ were significantly correlated ($P \leq 0.01$) and the SEEs were 2.7% (8 W) and 18.8% (2.5 kJ).

**Table 1 about here **

**Fig 1 about here **

The results of the O_2 uptake response are presented in Table 3 and illustrated in Figure 2. No main effects of time and method were found for baseline $\dot{V}O_2$ ($F_{2,22}$ = 1.7; P = 0.207; $\eta_p^2 = 0.13$ $F_{1,11}$ = 4.1; P = 0.063; $\eta_p^2 = 0.26$) and end-exercise $\dot{V}O_2$ ($F_{2,22}$ = 2.1; P = 0.149; $\eta_p^2 = 0.16$; $F_{1,11}$ = 1.2; P = 0.298; $\eta_p^2 = 0.01$). The O_2 uptake response was significantly faster (i.e. lower MRT) during all TTs compared with the respective TTE trials ($F_{1,11}$ = 7.7; P = 0.018; $\eta_p^2 = 0.41$). In addition, a significant main effect of time was observed ($F_{2,22}$ = 4.5; P = 0.023; $\eta_p^2 = 0.29$). The post-hoc test revealed that the 3-min TT MRT was significantly faster than the 7-min TT MRT (P = 0.046). The amplitude was not different between TT and TTE ($F_{1,11}$ = 0.4; P = 0.544; $\eta_p^2 = 0.03$). A significant main effect of time was observed ($F_{2,22}$ = 3.8; P = 0.039; $\eta_p^2 = 0.26$), with no significant post-hoc test results (P = 0.515 – 0.779). The total oxygen consumed and the total oxygen consumed by work completed over 2 min were significantly affected by time ($F_{2,22}$ = 8.2; P = 0.002; $\eta_p^2 = 0.43$ and $F_{2,22}$ = 5.1; P = 0.015; $\eta_p^2 = 0.32$) but not by method ($F_{1,11}$ = 3.3; P = 0.098; $\eta_p^2 = 0.23$

and $F_{1,11} = 0.3$; $P = 0.592$; $\eta_p^2 = 0.03$). There was a significant main effect of the method for the oxygen deficit ($F_{1,11} = 5.6$; $P = 0.038$; $\eta_p^2 = 0.34$) with a significant post-hoc test between the 3-min TT and the 105% TTE ($P = 0.008$). No significant main effect of time was observed ($F_{2,22} = 2.3$; $P = 0.129$; $\eta_p^2 = 0.17$).

Subjects completed significantly more work over the initial 2 min during TTs trials ($F_{1,11} = 5.2$; $P = 0.044$; $\eta_p^2 = 0.32$). This was found for the 3-min TT (45.8 ± 7.4 kJ) vs. the 105% TTE (43.5 ± 7.1 kJ) ($P = 0.011$) and for the 12-min TT (41.6 ± 5.6 kJ) vs. the 85% TTE (36.7 ± 6.3 kJ) ($P < 0.0001$). No difference was observed between the 7-min TT (40.3 ± 6.4 kJ) and the 100% TTE (41.0 ± 6.9 kJ) ($P = 0.914$). In addition, the work completed over 2 min during the 3-min TT was significantly higher compared with the 7-min and the 12-min TT (both $P < 0.0001$).

**Fig 2 about here **

**Table 2 about here **

**Table 3 about here **

DISCUSSION

The main findings were that CP_{TTE} was not different from CP_{TT} despite significantly faster $\dot{V}O_2$ kinetics in the latter. Results demonstrate low mean differences between CP_{TTE} and CP_{TT} (3 ± 8 W) together with a high level of agreement (-12 – 18 W) and a low prediction error (2.7%; 8W). This is in keeping with other works that either compared TTE laboratory with TT field derived values[4–6,19] or which investigated shortened recovery durations.[4,7] Conversely, our findings are inconsistent with Black et al.[11] who used a self-paced TT strategy that matched the total work performed during respective TTE efforts resulted in 7% higher CP_{TT} values and no difference for W'_{TT}. Different from Black et al. who used a fixed resistance where PO was regulated via cadence variations, the ergometer used in the present study allowed the modification of both, the resistance and the cadence. Consequently, as occur during realistic TT efforts our participants used the virtual gear changer whilst self-selecting cadence throughout. Moreover, the predictive error inherent in the current testing protocol was notably below the 5% proposed as the upper level of acceptable error estimation[20] and can therefore be recommended as an ecological valid, time saving new method to determine CP.

To date, research directly comparing different modalities[5,6,21] or shortened recovery periods[4,6,7,22] do not comprise $\dot{V}O_2$ kinetics analysis. The faster MRT observed during the TTs is in accordance with studies using all-out or fast-start strategies compared with even-start or slow-start strategies.[23–25] Increasing the oxidative contribution at the onset of exercise could reduce the oxygen deficit, thereby sparing the W′ and improving performance.[24] The higher PO in the initial 2 min of the TT indicates a fast-start pacing strategy that promotes an increase in ATP turnover rates and consequently speeds $\dot{V}O_2$. While the total O_2 consumed to 2 min obviously increased from lowest to highest intensities in both, TT and TTE, no differences were observed between them. However, the 3-min TT was paced faster than all other trials as indicated by the highest work performed over the initial 2 min resulting in the fastest MRT, and the smallest O_2 deficit. This is consistent with Black et al.[11] where TT efforts also resulted in a faster MRT. Such a fast-start pacing improves performance in a final 60 s sprint after a 3-min but not a 6-min exercise bout.[23] The authors suggested that the initial sparing of W′ would leave a greater non-oxidative energy reserve towards the end of respective exercise bouts.

Despite the faster $\dot{V}O_2$ kinetics during the TTs observed in the present study, the estimates of CP are remarkably similar, which suggests that the initial higher performance through TT efforts does not alter CP results. Burnley et al.[26] showed that CP values are not influenced by prior constant-load severe intensity exercise, even though displaying a significant increase in primary $\dot{V}O_2$ amplitude together with a decrease in $\dot{V}O_2$ slow-component and elevated $\dot{V}O_{2peak}$ values. The similarity in PO and consequently CP between TT and TTE also suggests that the 60-min recovery protocol, whilst demonstrating overall faster $\dot{V}O_2$ kinetics, was sufficiently long enough to minimize subsequent performance enhancements due to priming effects. In fact it has been shown that severe prior exercise improve muscle perfusion and O_2 availability in a subsequent exercise[12,27] which maintains for up to 45 minutes[2]. Moreover, Bailey et al.[12] stated that faster overall $\dot{V}O_2$ kinetics do not necessarily enhance subsequent severe intensity exercise performance. The same authors just recently reported that $\dot{V}O_2$ kinetics and performance were similar during high-intensity cycling initiated with a self-paced or all-out pacing strategy but a bout of priming exercise enhanced these variables in both cases.[17]

Values for W′ provided notably larger differences between the TTE and the TT testing method (mean difference 2.2 ± 3.0 kJ, LoA -8.0 to 3.7 kJ) with a high prediction error of 18.8% (2.5 kJ). These findings are in accordance with previous studies reporting prediction errors between 25 to 40%.[4–7,19] For example, compared to the 24-h recovery protocol Karsten et al.[7] identified prediction errors of 25.6% (3.9 kJ) and 32.9% for the 3-h and 30-min inter-trial recovery method, respectively. While 4 out of 9 participants were found with larger W′ values using the 3-h protocol, 3 out of these 4 also produced larger W′ values using the 30-min recovery protocol. Conversely, Galbraith et al.[4] found consistently larger D′ values using the 24 h protocol. There seems to be an inherent error in predicting W′ as all the aforementioned studies commonly identify high prediction errors for W′/D′. Part of this error could be explained by the standard error associated with the model to estimate CP and W′. Compared to previous studies[11,28] the observed standard error for CP_{TTE} was 2.4% and for CP_{TT} it was 1.2%, whilst for W'_{TTE} and W'_{TT} it was 11.2% and 5.6%, respectively. It seems that the TT protocol produced significantly lower errors in the parameter estimates and thus increases the quality of the model. In fact, as criteria for the quality of the model, Black et al.[11] used standard errors < 5% and 10% associated with CP and W', respectively, and had their subjects perform a fourth prediction trial if these criteria were exceeded after three trials. As a consequence of the improved fitting of the model the authors found W′ to be similar between TTE and TT. In addition, large inter-individual variability in TTE durations.[29] and lower reliability for TTE tests[30] have been reported, which could further explain differences in W′ between TTE vs. TT tests.

Practical application

Without the requirement of a MAP test, the present study has identified an ecologically enhanced shortened laboratory method to test CP from TT efforts. Moreover TT $\dot{V}O_{2\ peak}$ values equalled those measured in the incremental test and consequently they can be used as an alternative evaluation of cardio-respiratory fitness. Results furthermore extend to ergometers, which allow a real-world replication of TT efforts. Finally, real-world laboratory TT testing should also open up a greater acceptability of field testing and utilisation of training data. Nonetheless, furthers analysis are needed to clarify whether an iso-duration approach, i.e. TT and TTE efforts of same durations would reduce the error as evident for W′ results.

Conclusions

Real-world TT efforts offer an ecological and time saving novel testing method to determine CP. Moreover, a lower error inherent in TT-derived CP values provides an accurate and valid assessment for cyclists. However, caution has to be taken when considering W′ as results suggest that this parameter cannot be used inter-changeably between TTE and TT protocols.

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Figure and table captions

Fig. 1. Bland-Altman plots of CP_{TTE}/CP_{TT} and W'_{TTE}/W'_{TT} values (panel A and B). The horizontal line represents the mean difference between values and the dashed line represents 95% LoA. Panel C and D represent the relationship between CP_{TTE}/CP_{TT} and W'_{TTE}/W'_{TT} values.

Fig. 2. Oxygen uptake responses from baseline to 2 min during (A) high-intensity (3-min TT vs. 105% TTE), (B) medium-intensity (7-min TT vs. 100% TTE) and (C) low-intensity (12-min TT vs. 85% TTE) trials. Data are presented as group means; error bars are omitted for clarity. The dashed vertical lines indicate the start of the trials.

Table 1. Mean values, mean differences, limits of agreement and standard error of estimate of CP and W'.

Table 2. Mean durations (s) and mean PO (W) for TTE trials and TTs

Table 3. Oxygen uptake responses during TT and TTE conditions (mean ± SD)

Table 1. Mean values, mean differences, limits of agreement and standard error of estimate of CP and W'.

CP_{TTE} (W)	279 ± 52	**W'_{TTE} (kJ)**	14.8 ± 3.4
CP_{TT} (W)	276 ± 50	**W'_{TT} (kJ)**	16.3 ± 4.3
Mean diff. (W)	3 ± 8	**Mean diff. (kJ)**	-0 ± 6.7
95% CI	-2.1 – 7.6	**95% CI**	-4.1 – 0.3
LoA (W)	-12 to 17	**LoA (kJ)**	-8 – 3.7
SEE (%)	2.7	**SEE (%)**	18.8
SEE (W)	8	**SEE (kJ)**	2.5

Table 2. Comparison of mean durations (s) and mean PO (W) for TTE trials and TTs

	TTE1 vs TT1	**TTE2 vs TT2**	**TTE3 vs TT3**
Duration (s)	637±165 *vs.* 720	273±72 *vs.* 420*	180±30 *vs.* 180
	TTE1 vs TT1	**TTE2 vs TT2**	**TTE3 vs TT3**
PO (W)	302±53 *vs.* 300±52	338±58 *vs.* 317±57**	359±60 *vs.* 369±63

*Significantly different from TTE2 duration ($P < 0.01$)

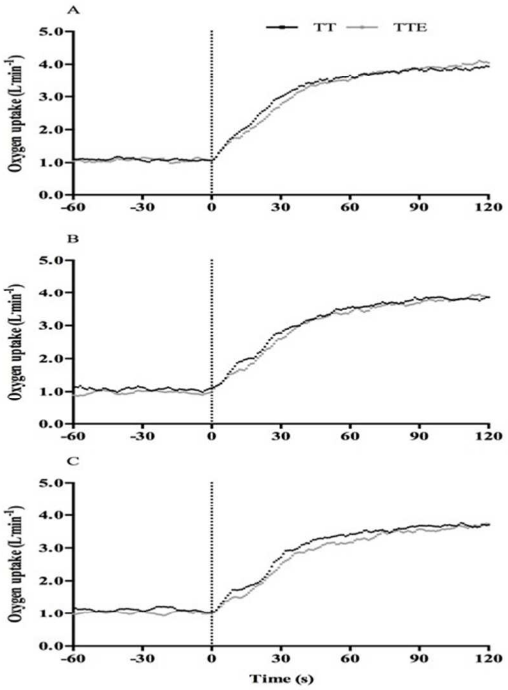
**Significantly different from TTE2 PO ($P< 0.01$)

Table 3. Oxygen uptake responses during TT and TTE conditions (mean ± SD)

TT	**TT1**	**TT2**	**TT3**
Baseline (L·min^{-1})	1.12 ± 0.26	1.09 ± 0.30	1.10 ± 0.21
Primary Amplitude (L·min^{-1})	3.75 ± 0.68	3.91 ± 0.67	3.89 ± 0.84
MRT (s)	23 ± 6	24 ± 6	21 ± 5#
End-Exercise $\dot{V}O_2$ (L·min^{-1})	4.25 ± 0.44	4.54 ± 0.26	4.04 ± 0.46
O_2 deficit at 2 min (L)	0.75 ± 0.26	0.80 ± 0.27	0.69 ± 0.25
Total O_2 consumed to 2 min (L)	3.08 ± 0.51	3.17 ± 0.52	3.29 ± 0.65*
Total O_2 consumed/work to 2 min (mL·kJ^{-1})	74 ± 9	79 ± 8	72 ± 10#

TTE	**TTE1**	**TTE2**	**TTE3**
Baseline (L·min^{-1})	1.03 ± 0.26	0.98 ± 0.27	1.06 ± 0.29
Primary Amplitude (L·min^{-1})	3.78 ± 0.59	3.92 ± 0.75	4.03 ± 0.59
MRT (s)	28 ± 5†	28 ± 7†	26 ± 6†
End-Exercise $\dot{V}O_2$ (L·min^{-1})	4.40 ± 0.22	4.38 ± 0.49	4.41 ± 0.42
O_2 deficit at 2 min (L)	0.87 ± 0.18	0.93 ± 0.32	0.89 ± 0.23†
Total O_2 consumed to 2 min (L)	2.93 ± 0.53	3.10 ± 0.62$	3.23 ± 0.56$
Total O_2 consumed/work to 2 min (mL·kJ^{-1})	80 ± 6	75 ± 7$	74 ± 6$

TT = time trial; TTE = time to exhaustion; MRT = mean response time; * = significantly different from 12 min at $P < 0.05$; # = significantly different from 7 min at $P < 0.05$; $ = significantly different from 85% at $P < 0.05$; † = significantly different from TT at $P < 0.05$



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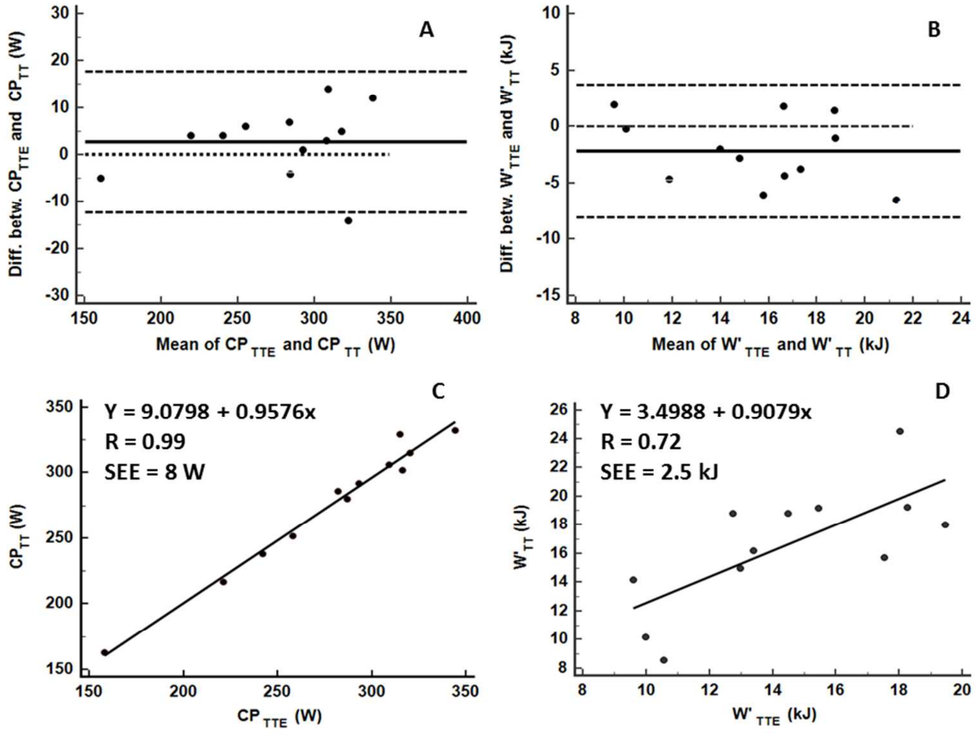
254x190mm (96 x 96 DPI)



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