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AUTHOR

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THE INFLUENCE OF EVALUATION PROTOCOL ON TIME SPENT EXERCISING AT A HIGH LEVEL OF OXYGEN UPTAKE DURING CONTINUOUS CYCLING

K.L. Merry[1], M. Glaister[2], G. Howatson[3, 4], K. van Someren[5]

1. School of Science, University of Derby, Derby, United Kingdom
2. School of Sport, Health and Applied Science, St Mary's University College, Twickenham, United Kingdom
3. School of Life Sciences, Northumbria University, Newcastle upon Tyne, United Kingdom
4. Centre for Aquatic Research, University of Johannesburg, Johannesburg, South Africa
5. GlaxoSmithKline Human Performance Laboratory, Brentford , United Kingdom

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Corresponding Author:
K.L. Merry
School of Science
University of Derby,
Kedleston Road,
DE22 1GB, Derby
United Kingdom,
k.merry@derby.ac.uk;

ABSTRACT

Aim: This study evaluated the effects of protocol variation on the time spent exercising at ≥ 95% VO_{2max} during cycle ergometer trials performed at the exercise intensity associated with VO_{2max} (iVO_{2max}). **Methods:** Nine male triathletes (age: 32 ± 10 years; body mass: 73.3 ± 6.1 kg; stature: 1.79 ± 0.07 m; VO_{2max}: 3.58 ± 0.45 $L.min^{-1}$) performed four exercise tests. During tests 1 and 2, participants performed a maximal incremental cycle ergometer test using different stage durations (1 min and 3 min) for the determination of $iVO_{2max(1\ min)}$ and $iVO_{2max(3\ min)}$. During tests 3 and 4, participants performed a continuous bout of exhaustive cycling at $iVO_{2max(1\ min)}$ ($CONT_1$) and $iVO_{2max(3\ min)}$ ($CONT_3$). **Results:** $iVO_{2max(1\ min)}$ was significantly greater ($P < 0.001$) than $iVO_{2max(3\ min)}$ (340 ± 31 W vs. 299 ± 44 W). Time to exhaustion (TTE) measured during $CONT_3$ was significantly longer ($P < 0.001$) than $CONT_1$ (529 ± 140 s vs. 214 ± 65 s). Time spent at VO_{2max} was significantly longer ($P = 0.036$) during $CONT_3$ than $CONT_1$ (146 ± 158 s vs. 11 ± 20 s), and time spent at ≥ 95% VO_{2max} was significantly longer ($P = 0.005$) during $CONT_3$ than $CONT_1$ (326 ± 211 s vs. 57 ± 51 s). **Conclusion:** These results show that when exercising continuously at iVO_{2max}, time spent at ≥ 95% VO_{2max} is influenced by the initial measurement of iVO_{2max}.

Keywords: Continuous exercise, maximal oxygen uptake, time spent at maximal oxygen uptake, time to exhaustion

Introduction

Several researchers have suggested that it may be necessary for highly trained athletes to elicit VO_{2max} during training sessions in order to improve it.[1-4] Consequently, an interest has been developed in determining training protocols that allow athletes to spend the longest time exercising at VO_{2max} ($T@VO_{2max}$) or near to (≥ 95%) VO_{2max} ($T@95\%VO_{2max}$) during continuous and intermittent exercise.

The exercise intensity at VO_{2max} (iVO_{2max}) has been defined in several ways by various authors but generally represents the minimum exercise intensity associated with the attainment of VO_{2max} during a maximal incremental test.[5 6] Measurement of iVO_{2max} in this way has proved popular with coaches and researchers when setting interval training intensities for athletes. [7-9]

The exercise intensity at VO_{2max} may allow the longest time to be spent exercising at or near to VO_{2max} during continuous exercise [10] and several studies have reported that iVO_{2max} and intensities very close to iVO_{2max} (95 – 105% iVO_{2max}) allow the longest time to be spent exercising at or near to VO_{2max} during intermittent exercise.[11-13] However, the protocol to measure iVO_{2max} has differed between studies. Some studies have measured iVO_{2max} using continuous incremental tests with stage durations ranging from 1 to 3 min[9 13-20] whilst others have measured iVO_{2max} using discontinuous protocols with stage durations ranging from 2 – 3 min.[11 21-23] The disparity between studies in terms of the method of iVO_{2max} determination makes comparison of iVO_{2max} values and indeed $T@VO_{2max}$ difficult. It has been demonstrated that an iVO_{2max} test protocol including 1 min stage durations did not produce significantly different values for iVO_{2max} or the exercise time to exhaustion (TTE) at iVO_{2max} than a separate protocol with 2 min stage durations. However, $T@VO_{2max}$ was not measured in the study. [15] It is clear that different protocols for iVO_{2max} determination can produce different iVO_{2max} values. A previous study compared a continuous incremental test protocol with stages of 1 min, with two discontinuous incremental test protocols with stages of 2 and 3 min respectively.[23] Significant differences in iVO_{2max} were reported between each of the three protocols. However, $T@VO_{2max}$ was also not measured.

It has been recommended that for running-based assessment, iVO_{2max} should be measured during a continuous incremental test with stage durations of one minute.[15] However, some researchers have argued that maximal incremental tests should utilise stages of at least 3 minutes to obtain a stabilisation of gas exchange parameters and an optimal relationship between VO_2 and exercise intensity.[5 24-26] If insufficient time is given for the elicitation of VO_{2max} during a given stage at the end of an incremental test, then iVO_{2max} may be reported as the intensity of the following stage and subsequently overestimated. Accuracy in determining iVO_{2max} is important, since an overestimation of iVO_{2max} may influence the total time spent exercising at VO_{2max}, compromising potential training adaptations. With this in mind, there is a need to clarify the impact of iVO_{2max} test protocol differences on $T@VO_{2max}$, since no common protocol for iVO_{2max} measurement currently exists. Therefore, the aim of this study is to assess the length of time spent exercising at a high level of VO_2 ($\geq$95% VO_{2max}) during continuous cycling to exhaustion at iVO_{2max} determined using two different protocols.

Materials and Methods

Subjects

Subjects were nine male triathletes. All had been training and competing in triathlon events for at least 3 years and had been engaged in $\geq$ 4 hours of training per week including running, cycling and swimming during the 6 months prior to testing. The subjects possessed the following characteristics (values are expressed as mean ± standard deviation); age: 32 ± 10 years, body mass: 73.3 ± 6.1 kg, stature: 1.79 ± 0.07 m, VO_{2max}: 3.58 ± 0.45 $L.min^{-1}$. All experimental procedures and potential discomforts associated with the study were explained to subjects before they gave written informed consent to participate. The study was approved by Loughborough College's Research Ethics Committee.

Experimental overview

Each subject reported to the laboratory on five separate occasions at approximately the same time of day. Each visit was separated by at least 48 hours and all visits were completed within two weeks. During visit one, participants performed a submaximal incremental test for the determination of the onset of blood lactate accumulation (OBLA). During each of visits two and three, a single maximal incremental test was performed to determine VO_{2max} and iVO_{2max}. Each of the maximal incremental tests incorporated different stage durations (1 and 3 min) and were performed in a randomised, counterbalanced order for the determination of $iVO_{2max(1\ min)}$ and $iVO_{2max(3\ min)}$. During visits four and five, participants performed two continuous cycle exercise to exhaustion tests at $iVO_{2max(1\ min)}$ ($CONT_1$) and $iVO_{2max(3\ min)}$ ($CONT_3$) for the determination of $T@VO_{2max}$. The $CONT_1$ and $CONT_3$ tests were performed in a randomised, counterbalanced order.

Procedures

All testing was performed on an electro-magnetically braked cycle ergometer (Lode Excalibur Sport, Groningen, The Netherlands) modified with cleat pedals and low-profile racing handlebars. The riding position, including saddle and handlebar positions was adjusted to resemble each subjects own bike and was replicated in subsequent trials. During all tests respiratory gas exchange was measured at the mouth using a breath by breath online gas analysis system (Cortex Metalyzer 3B, Leipzig, Germany). This system has been shown to have very good repeatability for measures of VO_2 (ICC = 0.964).[27] During measurement, subjects wore a rubber face mask (Hans Rudolph 8940, Hans Rudolph, Inc., Kansas City, USA) and breathed through a low resistance volume transducer (Triple V, Erich Jaeger GmbH, Hoechberg, Germany). Immediately before each test, the gas analyser was calibrated using ambient air which was assumed to contain 20.93% O_2 and 0.03% CO_2, and with a gas of known O_2 and CO_2 concentrations. Heart rate (HR) was recorded continuously throughout each test using a telemetric system which was interfaced with the gas analyser (Polar Electro Oy, Kempele, Finland). Ear lobe capillary blood samples were obtained in a 30 s pause between stages during the submaximal incremental test, and immediately after each subsequent maximal incremental test and $CONT_1$ and $CONT_3$ tests and analysed for lactate using an automated analyser (Biosen 5030, EKF Industrie, Germany). The repeatability of this analyser has previously been reported (R^2 = 0.99; CV = 1.4%).[28]

Submaximal Incremental Test

The submaximal incremental test commenced at a workload equal to 2 W.kg bm^{-1} and consisted of work rate increments of 20 W every 3 min. The test ended following attainment of OBLA which was considered to be equal to a blood lactate concentration of 4 mmol.L^{-1}.[29] Blood lactate was plotted against power output and the power output that corresponded to OBLA was identified using specific software.[30]

Determination of iVO_{2max}

For $iVO_{2max(1\ min)}$ and $iVO_{2max(3\ min)}$, testing commenced at a workload 80 W less than the workload associated with OBLA. Power output was increased by 20 W every 1 min thereafter until volitional fatigue during $iVO_{2max(1\ min)}$ and 20 W every 3 min for $iVO_{2max(3\ min)}$. $iVO_{2max(1\ min)}$ and $iVO_{2max(3\ min)}$ were taken as the lowest exercise intensities that elicited VO_{2max} as long as this intensity was held for 60 s. If VO_{2max} was elicited during a stage that wasn't maintained for 60 s then the intensity of the preceding stage was taken as iVO_{2max} in line with previous recommendations.[15] During all tests, subjects remained seated and cycled at their preferred cycling cadence which was held constant for all visits. For all subjects this ranged from 85 – 90 rpm. Testing was terminated if cycling cadence changed by more than 10 rpm. VO_{2max} was defined by the following criteria: 1) oxygen consumption stopped increasing linearly with exercise; 2) Heart rate reached within 10 beats.min^{-1} of age predicted maximum heart rate; 3) Respiratory exchange ratio (RER) was ≥ 1.15; 4) blood lactate concentration upon completion of the test was ≥ 8 mmol.L^{-1} (34). Following data collection, all VO_2 values were filtered and smoothed using rolling 30 s averages. VO_{2max} was taken as the highest 30 s VO_2 value obtained during each test.

Determination of Time at VO_{2max}

Immediately before the $CONT_1$ and $CONT_3$ tests, participants completed a standardised warm up consisting of 10 min of cycling at 150 W. Prior to the start of each test, the exercise intensity corresponding to $iVO_{2max(1\ min)}$ or $iVO_{2max(3\ min)}$ was manually imposed onto the flywheel of the cycle ergometer using the ergometer's external control unit. At the start of each $CONT_1$ and $CONT_3$ test, participants were encouraged to obtain their preferred cycling cadence as quickly as possible. Timing began when the ergometer's external control unit displayed the appropriate power output value corresponding to $iVO_{2max(1\ min)}$ or $iVO_{2max(3\ min)}$ (for all participants this occurred within 15 s). Participants were given strong verbal encouragement throughout the test to induce a maximal effort. Time to exhaustion (TTE) during each test was recorded. $T@VO_{2max}$ and $T@95\%VO_{2max}$ were calculated through the accumulation of VO_2 values superior or equal to 100% and 95% of the mean VO_{2max} calculated from the maximal incremental tests. Time to achieve VO_{2max} ($TTAVO_{2max}$) and time to achieve 95% VO_{2max} ($TTA95\%VO_{2max}$) were defined as the time taken to achieve 100% and 95% of the mean VO_{2max} calculated from the maximal incremental tests.

Statistical Analysis

Statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS for Windows, SPSS Inc., Chicago, IL). Prior to statistical analysis, all measures were assessed for normality using the Shapiro-Wilk (W) test.[32] Mean values for $iVO_{2max(1\ min)}$ and $iVO_{2max(3\ min)}$ were compared using a paired samples t-test. Values for VO_{2max} measured during $iVO_{2max(1\ min)}$ and $iVO_{2max(3\ min)}$ were also compared using a paired samples t-test. Since it was found that the data for $T@VO_{2max}$ was not normally distributed, mean values for $T@VO_{2max}$ measured during $CONT_1$ and $CONT_3$ were compared using a Wilcoxon matched pairs test. Mean values for TTE, $T@95\%VO_{2max}$, $TTAVO_{2max}$ $TTA\%95VO_{2max}$ and blood lactate concentration (BLa) measured during $CONT_1$ and $CONT_3$ were compared using paired samples t-tests. Mean values for $TTAVO_{2max}$ and $TTA95\%VO_{2max}$ expressed as a percentage of TTE were compared using paired t-tests. The above analyses provided 95% confidence limits for all estimates. For all analyses, results were considered significant at $P < 0.05$. All results and descriptive statistics are reported as means ± standard deviations.

Results

Maximal incremental tests

Mean values for $iVO_{2max(1\ min)}$, $iVO_{2max(3\ min)}$ and their corresponding VO_{2max} values are summarised in Table 1. iVO_{2max} was significantly greater ($P < 0.001$) (mean difference 41 W; 95% likely range: 29 – 54 W) during $iVO_{2max(1\ min)}$ than $iVO_{2max(3\ min)}$. Mean VO_{2max} values obtained during the incremental tests were not significantly different ($P > 0.05$).

Continuous cycling to exhaustion

The mean values for each of the parameters measured during $CONT_1$ and $CONT_3$ tests are presented in Table 2. The mean TTE measured during $CONT_3$ was significantly longer ($P < 0.001$) (mean difference 315 s; 95% likely range: 209 – 424 s) than the TTE measured during $CONT_1$. Six participants elicited a $VO_2 \geq VO_{2max}$ during $CONT_1$. Seven participants elicited a

$VO_2 \geq VO_{2max}$ during $CONT_3$. $T@VO_{2max}$ measured during $CONT_3$ was significantly longer (*P* = 0.036) (mean difference 134 s; 95% likely range: 8 – 260 s) than $T@VO_{2max}$ measured during $CONT_1$. Six participants elicited a $VO_2 \geq 95\%$ of VO_{2max} during $CONT_1$. All participants elicited a $VO_2 \geq 95\%$ of VO_{2max} during $CONT_3$. Subsequently, $T@95\%VO_{2max}$ was significantly longer (*P* = 0.005) (mean difference 269 s; 95% likely range: 110 – 428 s) during $CONT_3$ than $CONT_1$. $TTAVO_{2max}$ and $TTA95\%VO_{2max}$ were both significantly shorter ($P < 0.001$ and $P = 0.029$) (mean difference 222 s; 95% likely range: 144 – 299 s) (mean difference 76 s; 95% likely range: 10 – 142 s) during $CONT_1$ than during $CONT_3$. Mean BLa measured upon termination of $CONT_1$ was significantly greater than the BLa measured upon termination of $CONT_3$ ($P < 0.001$) (mean difference 1.8 $mMol.L^{-1}$; 95% likely range: 1.0 – 2.5 $mMol.L^{-1}$). When expressed as a percentage of TTE, $TTAVO_{2max}$ (91 ± 27 *vs*. 77 ± 17%) and $TTA95\%VO_{2max}$ (46 ± 11 *vs*. 34 ± 16%) were not significantly different ($P > 0.05$) between $CONT_1$ and $CONT_3$.

Discussion

The purpose of this study was to assess the influence of iVO_{2max} test protocol differences on the time spent exercising at a high percentage of VO_{2max} during continuous cycling to exhaustion at iVO_{2max}. The main finding was that a significantly longer time was spent exercising at a high percentage of VO_{2max} when iVO_{2max} was determined using a protocol involving stage durations of 3 min, compared to a protocol involving stage durations of 1 min.

As expected, $iVO_{2max(1\ min)}$ represented a significantly greater exercise intensity than $iVO_{2max(3\ min)}$. This is consistent with other studies that have measured iVO_{2max} using several protocols with different stage durations.[23] Although $iVO_{2max(1\ min)}$ and $iVO_{2max(3\ min)}$ could both be characterised as 100% iVO_{2max}, it is clear that $iVO_{2max(1\ min)}$ is not the minimal exercise intensity associated with VO_{2max} since it produced intensities 12% greater than $iVO_{2max(3\ min)}$.

The mean TTE when cycling continuously at $iVO_{2max(3\ min)}$ ($CONT_3$) was over twice as long as that recorded during the continuous cycling to exhaustion at $iVO_{2max(1\ min)}$ ($CONT_1$) and reflects the substantial effect that small differences in iVO_{2max} determinations can have on TTE at iVO_{2max} during continuous exercise. Previous research has demonstrated an inverse relationship between iVO_{2max} and TTE in homogenous samples of athletes.[6 14 33] Since $iVO_{2max(1\ min)}$ represented a higher exercise intensity than $iVO_{2max(3\ min)}$, it is anticipated that the depletion of the anaerobic energy reserves would have been greater during $CONT_1$ than during $CONT_3$ increasing the rate at which metabolites associated with fatigue (P_i, H^+, K^+) accumulate.[34 35] The significantly greater BLa values recorded following $CONT_1$ support this premise.

TTE values reported for $CONT_3$ are higher than mean values previously reported for elite cyclists (222 – 245 s),[14 36] triathletes (390 s),[37] and competitive cyclists (224 - 239 s).[38] Since the subjects used in the present study can be considered less well trained than those used in previous studies, the longer TTE values reported for $CONT_3$ are likely due to differences in the protocols used to determine iVO_{2max}. Previous studies have employed shorter stage durations (15 – 120 s),[14 36 38] larger increments (35 – 50 W)[14 37] or a combination of shorter stage durations and larger increments[14] than those used during $iVO_{2max(3\ min)}$. Therefore, it is likely that $iVO_{2max(3\ min)}$ represents a lower relative exercise intensity than the iVO_{2max} utilised in other studies and likely accounts for the longer TTE values.

The mean $TTAVO_{2max}$ during $CONT_3$ was significantly longer than that recorded during $CONT_1$. The accelerated VO_2 kinetics during $CONT_1$ is consistent with the higher exercise intensity utilised during $CONT_1$. Several studies that have compared continuous exercise at intensities $\leq iVO_{2max}$ with continuous exercise at intensities $> iVO_{2max}$ have reported faster

$TTAVO_{2max}$ values for intensities > iVO_{2max}.[33 39] Hence, it was expected that $TTAVO_{2max}$ would be faster during exercise at $iVO_{2max(1\ min)}$ than during exercise at $iVO_{2max(3\ min)}$. Oxidative energy production and the speed of the rise in oxidative metabolism at the onset of exercise appear to be increased as exercise intensity is increased.[40 41] Oxidative phosphorylation may be stimulated by an increase in the intracellular concentrations of ADP, Pi and Ca^{2+}.[40 42 43] Since the rate of ATP hydrolysis and its subsequent resynthesis from PCr is proportional to exercise intensity, it is hypothesised that exercise during $CONT_1$ may have elevated those stimuli responsible for an increase in oxidative phosphorylation in comparison to $CONT_3$.

The fact that $T@VO_{2max}$ and $T@95\%VO_{2max}$ were both significantly longer during $CONT_3$ than $CONT_1$ likely reflect the longer TTE values recorded during $CONT_3$ compared to $CONT_1$ and are supported by previous research which has reported significant correlations between TTE and $T@VO_{2max}$ ($r = 0.89$, $P < 0.05$).[19] Furthermore, several studies have reported longer TTE and subsequently longer $T@VO_{2max}$ values for continuous exercises performed at intensities slightly less than iVO_{2max} (92 – 95% iVO_{2max}) than those performed at iVO_{2max}.[7 39] $T@VO_{2max}$ appears to be influenced by $TTAVO_{2max}$ and TTE.[19] Hence, $T@VO_{2max}$ can be increased by reducing the $TTAVO_{2max}$ or increasing the TTE. The present results indicate that increasing the TTE may be more important for extending $T@VO_{2max}$, since the faster $TTAVO_{2max}$ during $CONT_1$ did not result in a longer mean $T@VO_{2max}$.

Comparison of $T@VO_{2max}$ between studies is limited due to differences in the method used to calculate $T@VO_{2max}$. Several studies calculated $T@VO_{2max}$ by subtracting $TTAVO_{2max}$ from TTE.[7 21 39] This assumes that all VO_2 values from the time VO_{2max} is elicited until exercise is terminated are $\geq VO_{2max}$. It is believed that this method overestimates $T@VO_{2max}$ because as can be seen in figures 1 and 2, during exercise at iVO_{2max}, individual VO_2 values can fall below

VO_{2max} when VO_{2max} has already been attained. Some studies have accepted data as being at VO_{2max} when ≥ 95% VO_{2max}[16 44]. It has been established that T@VO_{2max} is significantly longer when calculated using VO_2 data points that are ≥ 95% VO_{2max} in comparison to VO_2 data points that are ≥ VO_{2max}.[23] Therefore, it may be more appropriate to compare T@VO_{2max} recorded in these studies with T@95%VO_{2max} values reported in the present study. Only one study by Hill *et al* [39] reported longer T@95%VO_{2max} values (388 ± 161) than the present study, achieved during continuous exercise at 92% iVO_{2max}.[39] The longer T@95%VO_{2max} values resulted from a longer TTE (621 ± 184) than reported in the present study, since TTA95%VO_{2max} was slower (233 ± 92) owing to the lower exercise intensity that was utilised. The results of Hill *et al* [39] and those of the present study further highlight the importance of prolonging TTE to maximise T@VO_{2max} and T@95%VO_{2max} during continuous exercise.

Conclusions

In conclusion, the time spent exercising at a high level of VO_2 was increased when i$VO_{2max(3\ min)}$ was utilised as the exercise intensity. TTE was longer during exercise at i$VO_{2max(3\ min)}$ and this probably accounted for the longer T@VO_{2max} and T@95%VO_{2max} values derived during $CONT_3$. Hence, if the goal is to maintain VO_{2max}, i$VO_{2max(3\ min)}$ is a more appropriate exercise intensity than i$VO_{2max(1\ min)}$.

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Table 1. Responses to a maximal incremental cycle test for the determination of iVO_{2max} and VO_{2max}.Values are means ± standard deviations.

	$i\dot{V}O_{2max}$ (W)	$\dot{V}O_{2max}$ (L.min^{-1})	$\dot{V}O_{2max}$ (ml.kg^{-1}.min^{-1})	$\dot{V}O_{2max(DAY)}$ (L.min^{-1})	$\dot{V}O_{2max(DAY)}$ (ml.kg^{-1}.min^{-1})
$i\dot{V}O_{2max(1\ min)}$	337 ± 36*	3.59 ±	49.06 ±	3.54 ±	48.35 ±
$i\dot{V}O_{2max(3\ min)}$	292 ± 43	3.53 ±	48.20 ±	3.46 ±	47.20 ±

$\dot{V}O_{2max}$ = maximal oxygen uptake; $i\dot{V}O_{2max(1\ min)}$ = minimal exercise intensity to elicit $\dot{V}O_{2max}$ during an incremental test with 1 min stages; $i\dot{V}O_{2max(3\ min)}$ = minimal exercise intensity to elicit $\dot{V}O_{2max}$ during an incremental test with 3 min stages; $\dot{V}O_{2max(DAY)}$ = $\dot{V}O_{2max}$ of the day. $\dot{V}O_{2max}$ determined during $i\dot{V}O_{2max(1\ min)}$ and $i\dot{V}O_{2max(3\ min)}$ tests. $\dot{V}O_{2max(Day)}$ determined during the $i\dot{V}O_{2max(1\ min)}$ + 20 W and $i\dot{V}O_{2max(3\ min)}$ + 20 W tests.*Indicates significant differences.

Table 2. Physiological responses to a continuous bout of cycling to exhaustion at $iVO_{2max(1\ min)}$ ($CONT_1$) and a second continuous bout of cycling to exhaustion at $iVO_{2max(3\ min)}$ ($CONT_3$). Values are means ± standard deviations.

	TTE (s)	T@$\dot{V}O_{2max}$ (s)	T@95%$\dot{V}O_{2max}$ (s)	TTA$\dot{V}O_{2max}$ (s)	TTA95%$\dot{V}O_{2max}$ (s)	BLa (mMol.L^{-1})	HR_{max} (beats.min^{-1})
$CONT_1$	214 ± 65	11 ± 20	57 ± 51	185 ± 54	97 ± 34	10.8 ± 1.5	188 ±10
$CONT_3$	529 ± 140*	146 ± 158*	326 ± 211*	407 ± 118*	173 ± 76*	9.0 ± 1.2*	189 ±10
Mean diff [95% CL]	315 [209-424]	134 [8-260]	269 [110-428]	222 [144-299]	76 [10-142]	1.8 [1.1-2.5]	1 [0-1]

$CONT_1$ = continuous cycling to exhaustion at $i\dot{V}O_{2max(1\ min)}$; $CONT_3$ = continuous cycling to exhaustion at $i\dot{V}O_{2max(3\ min)}$; TTE = time to exhaustion; T@$\dot{V}O_{2max}$ = time at $\dot{V}O_{2max}$; T@95%$\dot{V}O_{2max}$ = time at 95% $\dot{V}O_{2max}$; TTA$\dot{V}O_{2max}$ = time to achieve $\dot{V}O_{2max}$; TTA95%$\dot{V}O_{2max}$ = time to achieve 95% $\dot{V}O_{2max}$; BLa = blood lactate concentration; HR_{max} = maximum heart rate; Mean diff = mean difference between $CONT_1$ and $CONT_3$; 95% CL = 95% confidence limits;*Indicates significant differences between mean values.

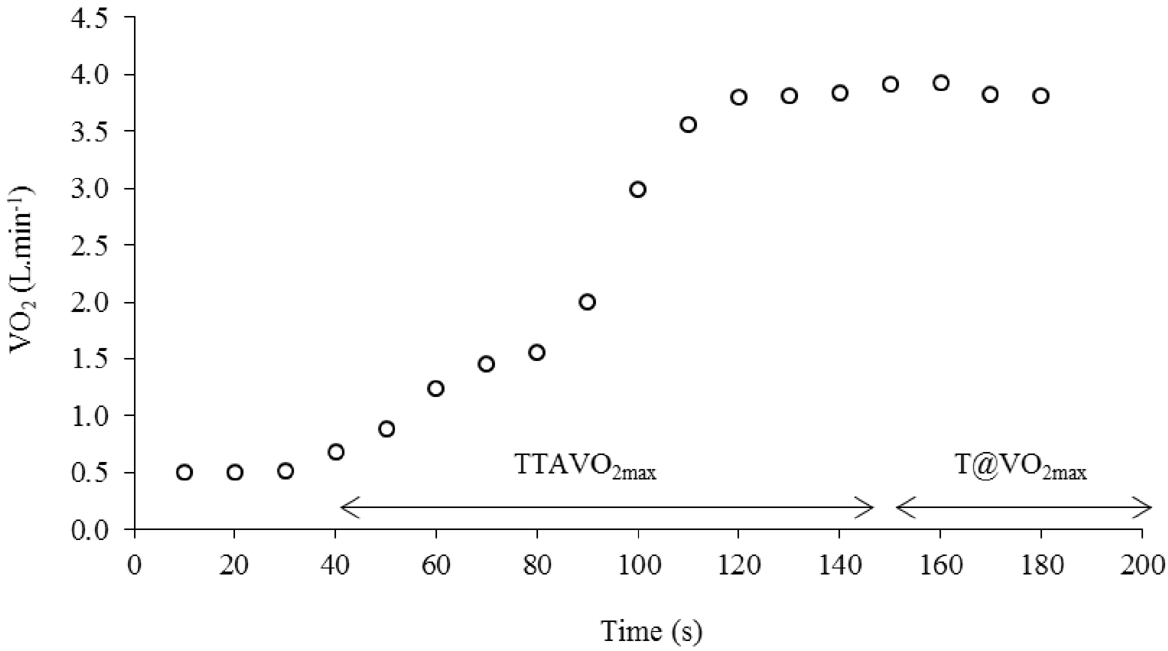

Figure 1. Example of the oxygen uptake response observed in a single participant during a continuous bout of cycling to exhaustion at the lowest exercise intensity associated with VO_{2max} during an incremental test with one minute stages (20 W increments). Individual data points are 10 s average values. $TTAVO_{2max}$ = time to achieve VO_{2max}; $T@VO_{2max}$ = time at VO_{2max}.

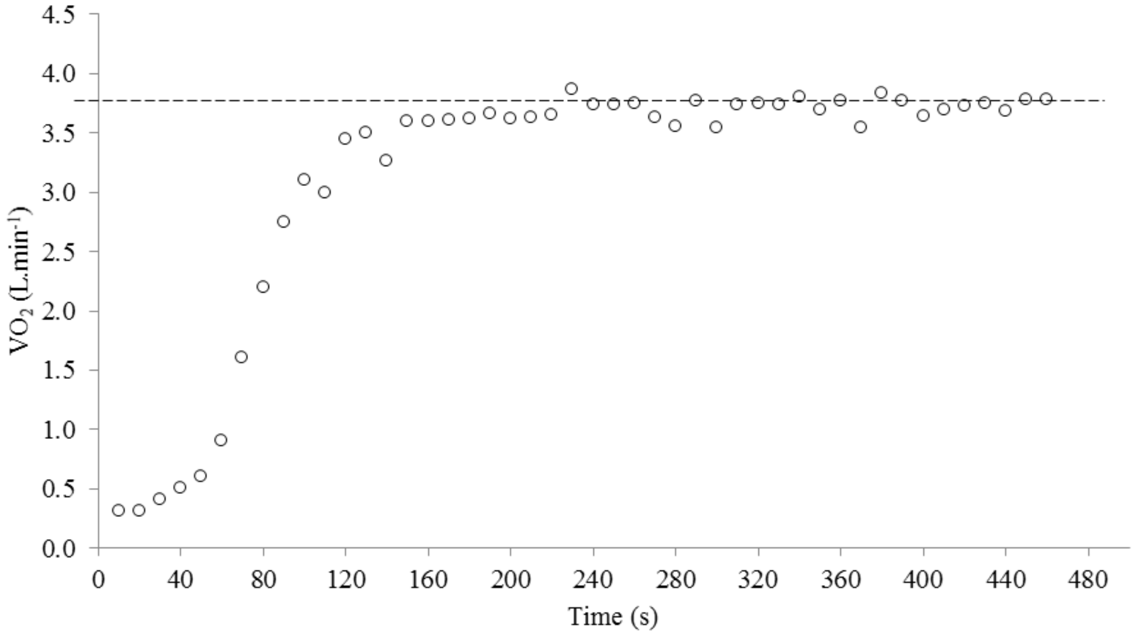

Figure 2. Example of the oxygen uptake response observed in a single participant during a continuous bout of cycling to exhaustion at the lowest exercise intensity associated with VO_{2max} measured during an incremental test with three minute stages (20 W increments). Individual data points are 10 s average values. $TTAVO_{2max}$ = time to achieve VO_{2max}; $T@VO_{2max}$ = time at VO_{2max}.