Backward extrapolation technique: analysis of different criteria after supramaximal exercise in cycling



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**RESEARCH ARTICLE**

**TITLE:** BACKWARD EXTRAPOLATION TECNIQUE: ANALYSIS OF DIFFERENT CRITERIA AFTER SUPRAMAXIMAL EXERCISE IN CYCLING

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**RUNNING HEAD**

SUPRAMAXIMAL $\dot{V}O_2$ ESTIMATION IN CYCLING

**ABSTRACT**

BACKGROUND: Backward extrapolation technique (BE) is used to estimate $\dot{V}O_2$ from post-exercise measuring, eliminating oronasal mask (OM) during the efforts. Despite its advantage, literature presents discrepancy in applied methods. Thus, the aim of this study is to compare different mathematical criteria to estimate values of $\dot{V}O_2$ during a supramaximal effort. Secondly, we aim to verify the effects of OM on cycling performance. Twenty-four cyclists performed three days of tests, with at least 24 h of interval between each test. Firstly, a graded exercise test was applied to determine $\dot{V}O_{2MAX}$ and your correspondent intensity (i$\dot{V}O2_{MAX}$). The second and the third day were destined to supramaximal efforts at 120% of i$\dot{V}O2_{MAX}$, performed with ($Supra_{MASK}$) and without ($Supra_{BE}$) oronasal mask (OM) in a randomized order. After $Supra_{BE}$, OM was coupled and BE was applied. Sixty-six values of $\dot{V}O_2$ were obtained based on a linear regression fitting. We found that $\dot{V}O_{2PEAK}$

can be estimated using different curve lengths (i.e. 20 – 60 s) but $\dot{V}O_2$ values increase exponentially with the time used in the extrapolations (i.e. < -3 s). No significant differences, trivial effects sizes, high positive correlations and low systematic errors with consistent concordance were found in the selected criteria. Despite the inconvenient use of OM, the performance was not impaired and was similar in both condition ($p = 0.84$, $ES = 0.04$). We conclude that it was possible to accurately estimate $\dot{V}O_2$ values of a supramaximal effort without any respiratory apparatus with a time-efficient analysis.
**KEY-WORDS:** Bicycling, oxygen consumption, exercise test, cardiorespiratory fitness, regression analyses, linear models.

## Introduction

The maximal oxygen uptake ($\dot{V}O_{2MAX}$) is one of the most investigated physiological variables in exercise physiology since the early 20th century (Hale, 2008). $\dot{V}O_{2MAX}$ was usually defined as the maximum rate that the body can uptake the atmospheric oxygen in the lungs (i.e. alveolar diffusion capacity), transport through the bloodstream (i.e. by cardiovascular system) and utilize in the active tissues (i.e. mitochondrial respiration) (Green and Askew, 2018; Poole and Jones, 2017; Poole et al., 2008). In this context, $\dot{V}O_{2MAX}$ is a widely accepted method to discriminate maximal individual aerobic power (Degens et al., 2019; Gordon et al., 2011; Rodríguez et al., 2017), characterized as an important variable in sports science (e.g. evaluation, prescription and monitoring of training) (Basset and Howley, 2000; Bentley and McNaughton, 2003; Seiler and Kjerland, 2006; Stoggl and Sperlich, 2015) and in the clinical environment (e.g. cardiorespiratory fitness index and mortality predictor) (Green and Askew, 2018; Lavie et al., 2015; Schaun, 2017).

Despite the widespread use of $\dot{V}O_{2MAX}$, discussion was raised about this phenomenon, including different criteria for its occurrence (e.g. *plateau* or verification phase) (Green and Askew, 2018; Poole and Jones, 2017). When this ceiling limit of oxygen uptake ($\dot{V}O_2$) was not reached (e.g.

by innumerous factors, including mode of exercise and peripheral limitations) the maximal value obtained (e.g. in a single supramaximal effort) could be termed $\dot{V}O_{2PEAK}$, which is also an important measure of cardiorespiratory and neuromuscular function (Green and Askew, 2018).

$\dot{V}O_2$ values were traditionally determined by a respiratory system coupled to volunteers during the efforts (da Silva et al., 2016; Ekblom-Bak et al., 2014). The available gas analyzers were connected with inconvenient apparatus (e.g. oronasal mask or snorkel in swimming), which could compromise the mechanical movement pattern in many modalities (e.g. running and swimming), cause discomfort to participants and hamper their communication with the researchers, restricting its application (da Silva et al., 2016; Léger et al., 1980).

In attempt to estimate $\dot{V}O_2$ without any disturbing instrumentation, Di Prampero et al. (1976) proposed the backward extrapolation technique (BE). In this procedure, $\dot{V}O_2$ values were estimated from post-exercise $O_2$ curve (i.e. excess post-exercise oxygen consumption; EPOC) based in different mathematical adjusts (Di Prampero et al., 1976; Léger et al., 1980). The use of BE allowed free sportive pattern in field context (i.e. sport specific) (Campos et al., 2017a; Campos et al., 2017b; Kalva-Filho et al., 2015a; Kalva-Filho et al., 2015b), presenting a valid practical application. Recently, our laboratory published a study comparing supramaximal running efforts (110% of i$\dot{V}O_{2MAX}$) using the traditional $\dot{V}O_2$ collection (i.e. oronasal mask; restricted bouts) and with unimpeded efforts by the BE (de Andrade et al., 2020). The authors found a 16% improvement in time to exhaustion for BE group and pointed out due to the unrestricted access to ambient air and attenuated sensation of fatigue.

Due to its advantages, BE was applied in different modalities, including running (de Andrade et al., 2020), cycling (Sleivert and Mackinnon, 1991), swimming (Campos et al., 2017a; Campos et al., 2017b; Costill et al., 1985; Kalva-Filho et al., 2015a; Kalva-Filho et al., 2015b; Montpetit et al., 1981), kayaking (Carré et al., 1994), speed skating (Di Prampero et al., 1976), in female soccer players (Mascarin et al., 2018) and in gymnasts (Marina and Rodriguez, 2014). However, the literature presents a widely discrepancy in the applied methods. Di Prampero et al. (1976) used an exponential least square fitting, while  Léger, Seliger e Brassard (1980) proposed different equations (linear and exponential fitting). Other different criteria can be found in literature, including equations that considered the time lag for connecting the participant to the breathing valve (about three seconds) (Léger et al., 1980) and with a wide range of efforts and periods of analysis (Costill et al., 1985; Jürimäe et al., 2007; Sleivert and Mackinnon, 1991). The log transformation of $\dot{V}O_2$ data is also commonly used (de Andrade et al., 2020; Kalva-Filho et al., 2015a; Kalva-Filho et al., 2015b; Léger et al., 1980; Rodríguez et al., 2017) in attempt to enhance the physiological response and avoid outliers or data collection error, however, there is no consensus about the advantage of this practice.

Another issue that may affect the existing data is the equipment that $\dot{V}O_2$ was measured, including different gas analyzers technologies. The firsts studies were conducted with the traditional open-circuit Douglas Bag, which only allows $\dot{V}O_2$ values after a period of sampling (e.g. values every 20-30 seconds) (Carter and Jeukendrup, 2002). In more recent years, the development of breath-by-breath (BxB) gas analyzers allows new approaches and can improve the existing criteria, enhancing physiological values with continuous data at each respiratory cycle (Carter and Jeukendrup, 2002; Keskinen et al., 2003) and could minimize the errors of this technique. Despite the advantages of recent technologies, the validation of BE could be modified.

In this context, the divergent existing criteria and technologies used for BE limit your application and do not allow consensus about which method is the most accurate. Thus, the aim of the present study was to compare the $\dot{V}O_2$ values obtained continuously during a supramaximal effort ($Supra_{MASK}$) and those obtained from BE after an unrestricted effort ($Supra_{BE}$). Additionally, we aim to propose an accurate criterion of analysis based on different mathematical assumptions for further investigations in cycling. The effect of the oronasal mask (OM) in exhaustive performance was also tested. We hypothesize that $\dot{V}O_2$ could be accurate estimated from $O_2$ recovery curve and the OM could compromise cycling performance.

## Materials & Methods

### Participants

Twenty-four recreational male cyclists (De Pauw et al., 2013) who were regularly enrolled in national and regional competitions, voluntarily participated in this study (Mean ± SD; age 35 ± 6 years, body mass 81.3 ± 8.9 kg, height 180 ± 6 cm). Participants were informed about procedures and their potential risks and provided written informed consent about their participation, approved previously by the Human Research Ethics Committee. The experimental procedures were conducted in accordance with the Declaration of Helsinki.

### Experimental design

The experimental design lasted three days with at least 24h of recovery between the tests. On the first session, a graded exercise test (GXT) was performed to determine the maximal oxygen uptake ($\dot{V}O_{2MAX}$) and your correspondent intensity ($i\dot{V}O_{2MAX}$). Thereafter, two supramaximal exhaustive efforts at 120% of $i\dot{V}O_{2MAX}$ were applied in a randomized order. One effort was performed with OM ($Supra_{MASK}$) (i.e. traditional $\dot{V}O_2$ collection) and was used as a criterion for true $\dot{V}O_{2MAX}$ (i.e. verification phase) (Midgley et al., 2009; Schaun, 2017). Also, $\dot{V}O_2$ at exhaustion ($\dot{V}O_{2PEAK}$) in $Supra_{MASK}$ effort was used as standard protocol for further analysis. The other supramaximal effort was performed unimpeded, without the OM ($Supra_{BE}$) and was used for BE technique ($\dot{V}O_{2BE}$) analysis. During GXT and in supramaximal efforts, participants were verbally encouraged to perform maximally. **Fig. 1** shows the proposed design. All efforts were performed in participants own bicycles that were connected in an indoor cycling trainer (Powerbeam Pro Series, Cycle Ops, USA). This equipment has a resistance wheel with built-in strain gauges, enabling measurements of power in watts (W). The power was controlled online by computer software (Rouvy, VirtualTraining, Czech

Republic). Participants were allowed to maintain they preference cadence, which was monitored by telemetric dispositive sensor (Joule GPS, Powertap, EUA).

***Insert figure 1 next here***

### Graded exercise test

GXT was preceded of a seven minutes warm-up at 150W and therefore a progressive effort was performed with 50W increments every three minutes until voluntary exhaustion. $\dot{V}O_2$ was continually registered and $\dot{V}O_{2MAX}$ was attributed to the highest 30 s averages of the GXT (i.e. $\dot{V}O_2$ average over the final 30 s of each stage) only if a non-substantial increase was observed during Supra$_{MASK}$ (i.e. estimated value for $\dot{V}O_2$ at 120% of i$\dot{V}O_{2MAX}$ higher than $\dot{V}O_{2PEAK}$).The minimal exercise intensity at which the participant reached $\dot{V}O_{2MAX}$ was considered as i$\dot{V}O_{2MAX}$ (Billat et al., 1999) or was adjusted according Kuipers et al. (1985) when exhaustion occurred during the stages. Respiratory exchange ratio (RER) was continually monitored and maximal values were registered. Maximal heart rate ($HR_{MAX}$) was attributed to the highest 5 s averages during GXT (Midgley et al., 2009). The percentage of age-predicted maximal heart rate (HR/age[%]) were calculated according Tanaka et al. (2001).

### Supramaximal efforts

After a seven minutes warm-up at 150W, both Supra$_{MASK}$ and Supra$_{BE}$ were performed at 120% of i$\dot{V}O_{2MAX}$ until voluntary exhaustion. During Supra$_{MASK}$, ventilatory analysis was performed during all effort by connecting the participant to an OM, and $\dot{V}O_{2PEAK}$ was defined as the average $\dot{V}O_2$ over the last 30 s of the test. Supra$_{BE}$ follow the same general procedure, however, the effort was performed without the respiratory equipment and the OM were accoupled immediately at the end of the effort. Time-to-exhaustion ($T_{LIM}$) was recorded in these efforts as performance index.

### Data collection and processing

The OM (7450 Series Silicone V2™, Hans Rudolph Inc., USA) was connected to a gas analyzer (Quark CPET, Cosmed, Italy), allowing BxB $\dot{V}O_2$ data (i.e. every respiratory cycle). Before the beginning of each test the equipment was calibrated according to the specifications of the manufacturer. Briefly, it was used the ambient air, a gas of composition containing 16% $O_2$ and 5% of $CO_2$ (White Martins, Osasco, SP, Brazil) and a 3 L syringe for spirometer (Hans Rudolph Inc., USA), according to Quark CPET instruction manual. In all efforts, pulmonary gas exchange was recorded from five minutes in rest (i.e. baseline), during all effort in GXT and in $\text{Supra}_{\text{MASK}}$ and at recovery in $\text{Supra}_{\text{BE}}$. RER were directly measured as the product between carbon dioxide production ($\dot{V}CO_2$) and $\dot{V}O_2$. Heart rate (HR) was monitored beat-by-beat using a cardiac transmitter belt (H7, Polar Electro, Finland) integrated to gas analyzer system.

**Exploratory analysis and backward extrapolation technique**

To discriminate the best adjustment between length of $\dot{V}O_2$ recovery curve and time to the regression extrapolation, exploratory procedures were performed, and a sequence of criteria was applied. Four criteria have been selected in an attempt to choose the highest level of similarity between our standard ($\dot{V}O_{2PEAK}$) and the proposed criteria. Once they were based in statistical precepts, they were reported in **statistical analysis** section. The numbers of $\dot{V}O_2$ values analyzed were decreasing progressively, since the first procedure was requisite for the next. Backward extrapolation technique (BE) was based in a linear regression fitting (i.e. y = a + b * x) including curves at each 10 s (10 to 60 s; i.e. 6 curves) and negative extrapolations at each second (0 to -10 s; i.e. 11 seconds). All analyses of BE were performed in relation to standard $\dot{V}O_2$ value obtained in the end of $\text{Supra}_{\text{MASK}}$ (i.e.$\dot{V}O_{2PEAK}$) and sixty-six values of $\dot{V}O_2$ were obtained (i.e. 6 curves combined with 11 seconds).

**Statistical analysis**

Shapiro-Wilk's test was used to confirm the normality of data, allowing the use of parametric procedures and the presentation of data through mean and standard deviation. As mentioned in the previous section, the four criteria were: **i)** no significant difference between $\dot{V}O_{2PEAK}$ and the value obtained by different regression adjustments, which was tested using the *t-test* for dependent samples;

**ii)** trivial values of effect size (ES) between $\dot{V}O_2$ values (i.e., < 0.35, as proposed by Rhea (2004)); **iii)** high and positive relationship between $\dot{V}O_2$ values, evidenced using the Pearson's product moment correlation coefficient (*r*) (i.e., > 0.70, as proposed by Mukaka (2012)); **iv)** agreement between $\dot{V}O_2$ values and $\dot{V}O_{2PEAK}$, which was tested by Bland-Altman's analysis (Bland and Altman, 2010). Thus, to discriminate the best procedure for BE, a 1 $mL.kg^{-1}.min^{-1}$ cut-off value of the mean difference between procedures (i.e. systematic error; Bias) was assumed and, consequently, the smallest values of 95% limits of agreement (LoA) was considered for the conclusions. The coefficient *r* was also used to test the tendency between residuals and average values in the agreement analysis (i.e. heteroscedasticity). Comparison of $T_{LIM}$ for both supramaximal exercises were made with *t-test* for paired samples, accomplished with the ES and *r*, as described above. Statistical Package for Social Science software, version 17.0 (SPSS 17, International Business Machine, USA) was used, and the level of significance was set at *p*-value < 0.05.

## Results

### Exploratory analysis

Seven participants did not reach the criteria for $\dot{V}O_{2MAX}$ and $\dot{V}O_2$ values did not drop in $Supra_{MASK}$. Thus, statistical analyses were carried out using 17 participants. The values obtained in GXT were summarized in **Table 1**. Performance in both supramaximal efforts were not statistically different (2.40 ± 0.61 and 2.43 ± 0.79 min for $Supra_{MASK}$ and $Supra_{BE}$, respectively; $p = 0.86$, ES = 0.04) with moderate correlations ($r = 0.572$, $p = 0.016$) (**Fig. 2**). Mean values of $\dot{V}O_2$ obtained through different adjustments between lengths of $\dot{V}O_2$ recovery curve and times to the regression extrapolation are exhibited in **Fig. 3**. $\dot{V}O_2$ values increase exponentially with the time used in the negative extrapolations, independently of the length of the $\dot{V}O_2$ recovery curve used. The different criteria used to discriminate the best procedure for backward extrapolation technique were demonstrated in **Fig. 4**. When the regression was negative extrapolated to five or greater times, significant differences from

$\dot{V}O_{2PEAK}$ were observed for all $\dot{V}O_2$ recovery curve used. The ES demonstrate values classified as small from the fortieth second of back extrapolation in the majority of the used VO2 recovery's curve (50, 40, 30 and 20 s). Small values of ES were also observed for the $\dot{V}O_2$ recovery's curve with 60 s of length, using negative extrapolations for zero and one second. The correlation criterion was observed for all times of extrapolation for 60, 50 and 40 s of $\dot{V}O_2$ recovery curve lengths. **Table 2** demonstrates the frequency of adjustments that met the different criteria. The curve length of 10 s do not satisfied our four statistical criteria for any extrapolated value and all curves above 20 s had at least one extrapolated time that met all statistical criteria.

***Insert figure 2 next here***

***Insert figure 3 next here***

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***Insert table 1 next here***

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**Selected adjustments**

The $\dot{V}O_2$ obtained of the eight adjustments that met all statistical criteria were presented in **Fig. 5**. In addition, the statistical results were specified in **Table 3**. Although all adjustments presented acceptable levels of similarity, correlation and agreement with $\dot{V}O_{2PEAK}$, values obtained through a curve length of 60 s using an extrapolation to -3 s demonstrated the lowest LoA (7.72 $ml.kg.min^{-1}$) with $\dot{V}O_{2PEAK}$. This curve (i.e. 60s and -3s) also have the highest correlation coefficient ($r$ = 0.824). The heteroscedasticity was confirmed for all selected criteria ($r$ < 0.478), and the residuals were spread without tendencies between the Bias and the upper and lower limit of LoA.

***Insert figure 4 next here***

***Insert table 3 next here***

## Discussion

In an attempt to compare the $\dot{V}O_2$ values obtained directly during a supramaximal effort and those obtained from BE, establishing the most accurate criteria for $\dot{V}O_2$ estimation, we conducted an exploratory analysis based on different mathematical estimation. Supporting our first hypothesis, the main findings of the present study were that $\dot{V}O_{2PEAK}$ can be estimated using different curve lengths but $\dot{V}O_2$ values increase exponentially with the time used in the extrapolations.

The select adjustments that satisfied all proposed criteria were essentially based in curves of 20 s or higher with extrapolation times of -3 s or lesser, showing similar values with $\dot{V}O_{2PEAK}$. In this context, we argue that the eight eligible criteria could be used with a satisfactory level of confidence, although, the curve of 60 s with extrapolation to -3 s is the most accurate criterion and should be used in further investigations. Our secondary hypothesis was that performance would be compromise with the OM, however, $T_{LIM}$ was similar in both condition (**Fig. 2**).

In the present study, we show consistent values from eight eligible criteria, presenting no significant differences ($p$-value > 0.417), trivial effects sizes (ES < 0.140), high positive correlations ($r$ > 0.736) with acceptable concordance (Bias < 0.94 mL.kg.min$^{-1}$; LoA < 11.73 mL.kg.min$^{-1}$). These systematic errors (i.e. Bias) are ranged between 0.7 and 1.9%. Rodríguez et al. (2017) demonstrated mean differences higher than 3.4% in their estimative from linear BE when the same intensity of effort was applied (i.e. 200 meters front crawl), which despite consistent, are higher than found in the present study. Other congruent methodological approach of this study was the use of BXB measurements, amplifying the real responses of each respiratory cycle, compared with the Douglas bag analysis (Carter and Jeukendrup, 2002; Keskinen et al., 2003).

The selected values for proposed exploratory analysis were based in the several previous studies, which presents different criteria (Campos et al., 2017a; Campos et al., 2017b; Costill et al., 1985; de Andrade et al., 2020; Di Prampero et al., 1976; Jürimäe et al., 2007; Kalva-Filho et al., 2015a; Kalva-Filho et al., 2015b; Léger et al., 1980; Sleivert and Mackinnon, 1991). These studies include curves ranged from one minute or higher (Di Prampero et al., 1976; Léger et al., 1980) to 20 s (Chaverri et al., 2016; Montpetit et al., 1981; Rodríguez et al., 2017), with extrapolation at time zero (i.e. y-intercept) (Léger et al., 1980) to -20 s (Rodríguez et al., 2017). Besides that, log transformation data are common. However, we found in earlier pilot study that this strategy did not improve the accuracy of our data (unpublished data). Therefore, we use the raw data, excluding only extreme outliers.

The results of the selected curves are in accordance with the most previous finds, and this interval probably is in absence of the slow component of $\dot{V}O_2$ recovery curve ($EPOC_{SLOW}$) (i.e. < 2 minutes) (Di Prampero et al., 1973; Green and Askew, 2018; Léger et al., 1980; Margaria et al., 1933), which could modify the characteristic of our fitting and consequently the prediction equation. In addition, the selected extrapolation times could be explained by time lag between the end of exercise and the coupling of the participants to the OM, which has shown to be around 3 seconds (Carré et al., 1994; Léger et al., 1980). Thus, values lesser than -3 s are undesirable and overestimate $\dot{V}O_{2PEAK}$. This affirmation is valid especially in our setting, which was conducted in laboratory environment, facilitating the coupling of the OM at the end of exercise.

Different of the most available literature (Chaverri et al., 2016; Di Prampero et al., 1976), our results present some advantages since we used separated efforts to compare estimated ($\dot{V}O_2BE$) and the actual values of $\dot{V}O_2$ ($\dot{V}O_{2PEAK}$) (**Fig. 1**). Rodríguez et al. (2017) utilized separate efforts and analyzed several criteria for BE, however, this study was conducted with swimmers. In swimming, the kinetics of $\dot{V}O_2$ was different from other modalities because the prone position (i.e. horizontal plane) and the simultaneous activation of upper and lower limbs could modify the fast and slow phases of EPOC (Koga et al., 1999; Sousa et al., 2015). Rodríguez et al (2017) also used maximal efforts in fixed distances (i.e. 200 m and 400 m). Despite these distances known to be elicited close to $\dot{V}O_{2MAX}$ values and very dependent on aerobic power (Correia et al., 2020; Rodríguez, 2000), they were influenced by pace strategies. To eliminate this bias, we used fixed intensities during all effort (i.e. 120% of $i\dot{V}O_{2MAX}$). Considering these methodological differences, their result must be interpreted with caution.

Contrary to our second hypothesis, performance was not influenced by the use of OM ($p$ = 0.86) (**Fig. 2**) with almost null effects sizes (ES = 0.04). Thus, the theoretical discomfort and sensation of fatigue caused by OM was not detrimental in our settings. Recently, our laboratory demonstrated that performance was impaired by OM in running, compromising $T_{LIM}$ in supramaximal efforts (unimpeded effort 16% higher) (de Andrade et al., 2020). There are several factors that separated these two modalities, however, we speculated that at least in cycling, mechanical factors are less compromised with the use of OM than in running. We found significant ($p$ = 0.016) but only moderate correlations ($r$ = 0.572) between performance in these efforts. This could be an indicative that participants respond different with the use of OM, increasing the variability between-subjects in $Supra_{BE}$.

Through a critic overview of our results, we point as main limitation of our study the choice of laboratorial environment for tests application. Despite the controlled characteristic of these settings (i.e. whether conditions and equipment's), the ecological valid and field application is questionable. Other bias could be the level of physical fitness of the volunteers. According to De Pauw et al. (2013), they are in second level of performance, with a mean $\dot{V}O_{2MAX}$ of 4.0 ± 0.4 ($L.min^{-1}$) or 51.0 ± 5.5 ($mL.kg^{-1}.min^{-1}$). Thus, our findings cannot be fully extrapolated to elite cyclists or other modalities, since both the time to exhaustion in supramaximal efforts and type of effort could influence the $\dot{V}O_2$ recovery kinetics (Gaesser and Brooks, 1984; Özyener et al., 2001; Short et al., 1996).

Despite of these limitations, our results presents a great application in sports science and exercise physiology, especially for recreational cyclists, since it was possible to estimate $\dot{V}O_{2PEAK}$ without disturbing instrumentation during the efforts. Also, this application could improve the dynamics of laboratory settings, with greater number of subjects evaluated in the same period, once the time for $\dot{V}O_2$ collection was reduced to less than 60 seconds. Further researches should focus in road cycling, since athletes could perform high intensity efforts in field context with only recovery $O_2$ monitoring.

**Conclusion**

In conclusion, based on the results of our exploratory analysis, we concluded that was possible to consistently estimate the conventional $\dot{V}O_2$ values from a supramaximal effort without any respiratory apparatus and with a time efficient analysis. Therefore, we recommended the use of a 60 seconds $\dot{V}O_2$ curve analysis with a negative extrapolation for 3 seconds.

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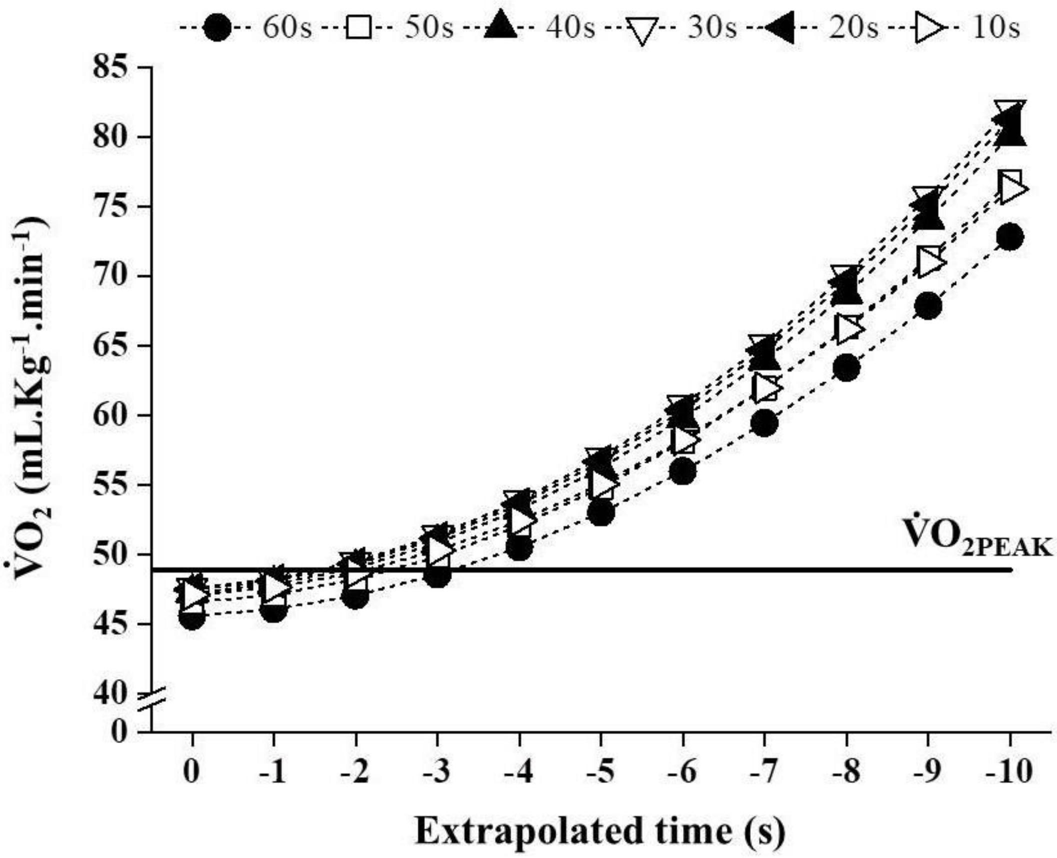


**Figure 1.** performance in both supramaximal efforts with ($Supra_{mask}$) and without ($Supra_{be}$) OM. Dots represents individual data in each performance test; p value obtained using t-test for paired samples.

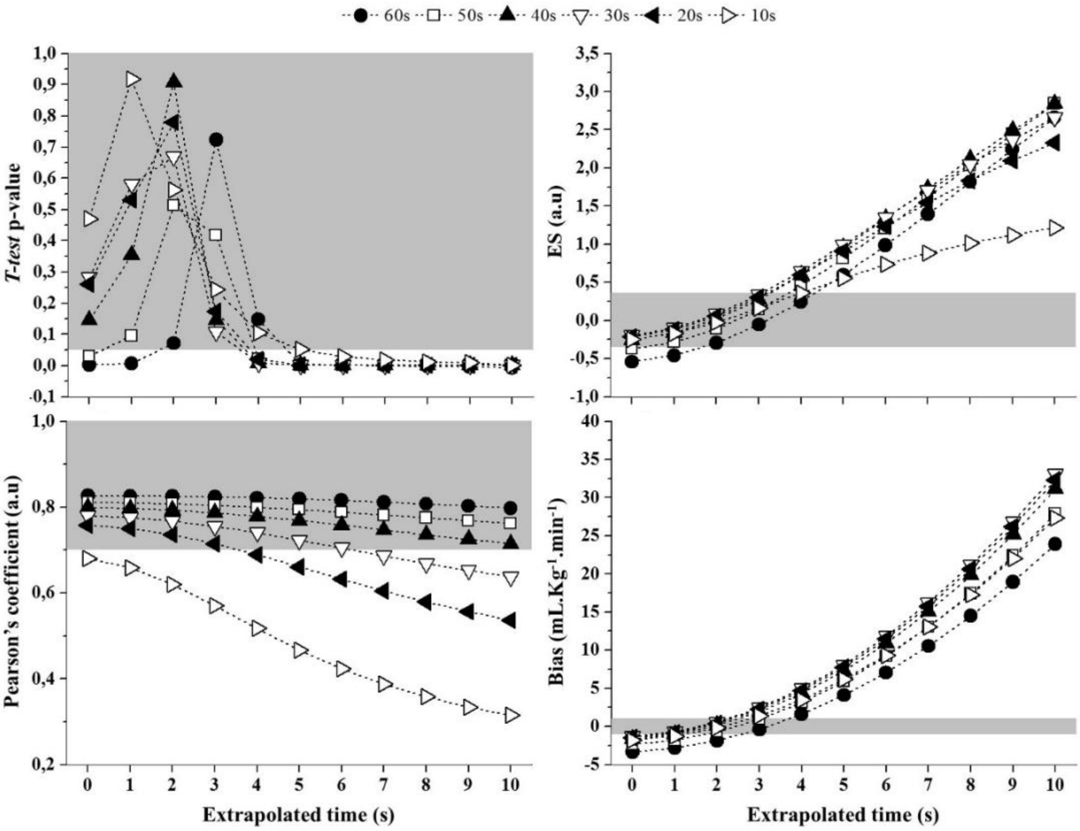


**Figure 2.** Mean values of oxygen consumption (V̇O2) obtained with different length of recovery curve (i.e., 10 – 60 s) and with several negative regressions (i.e., 0 – 10 s). The solid horizontal line represents the mean value of the maximal oxygen consumption observed during a supramaximal exhaustive effort (V̇O2PEAK).

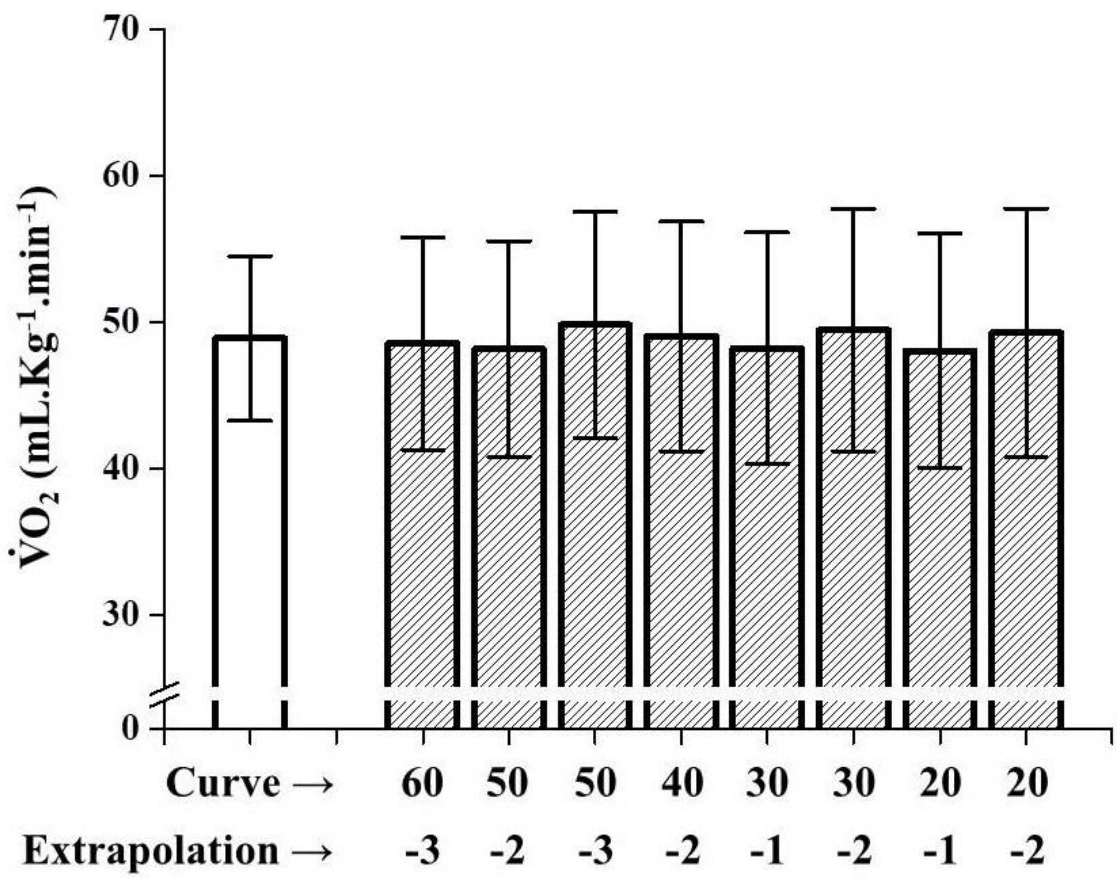


**Figure 3.** Statistical criteria used to discriminate the best procedure for backward extrapolation technique. The values were obtained with different lengths of recovery curve (i.e., 10 – 60 s) and with several negative regressions (i.e., 0 – 10 s). The gray area represents the pre-establish cut-offs for the different criteria (see statistical analysis section).

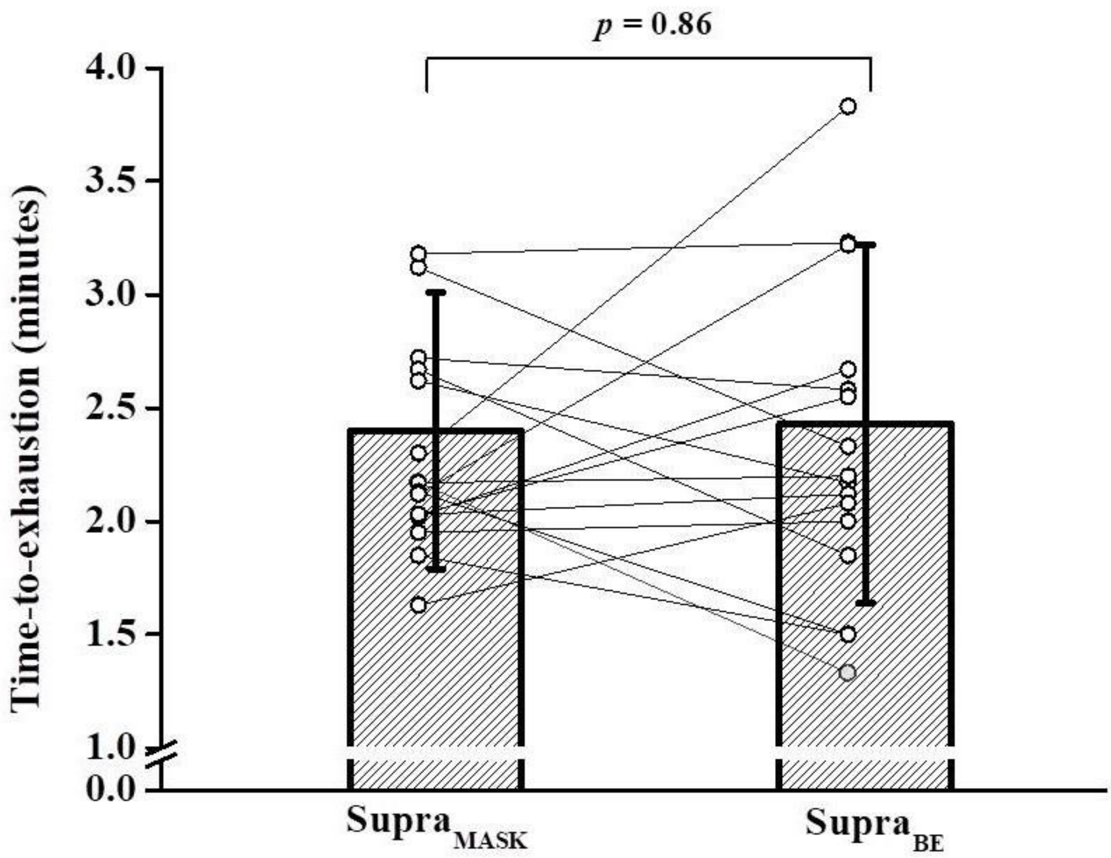


**Figure 4.** Mean and standard deviation values of oxygen consumption ($\dot{V}O_2$) determinate through the eight adjustments that met statistical criteria. These adjustments varied by curve length and the time used to back extrapolations. White bar represents the oxygen consumption after a supramaximal effort with OM ($\dot{V}O_{2PEAK}$) (i.e. standard criteria).

*Table 1. Physiological parameters obtained after graded exercise test (GET).*

| Parameter | Mean | SD |
|---|---|---|
| $\dot{V}O_{2MAX}$ (L.min$^{-1}$) | 4.0 | 0.4 |
| $\dot{V}O_{2MAX}$ (mL.kg$^{-1}$.min$^{-1}$) | 51.0 | 5.5 |
| i$\dot{V}O_{2MAX}$ (W) | 301 | 26 |
| RER (arbitrary unit) | 1.1 | 0.1 |

| | | |
|---|---|---|
| $HR_{MAX}$ (beats.min$^{-1}$) | 182 | 6 |
| HR/age (%) | 99 | 4 |

$\dot{V}O_{2MAX}$ (L.min$^{-1}$): maximal oxygen uptake; $\dot{V}O_{2MAX}$ (mL.kg$^{-1}$.min$^{-1}$): maximal oxygen uptake relative to body mass; i$\dot{V}O_{2MAX}$ (W): intensity correspondent to $\dot{V}O_{2MAX}$; RER (arbitrary unit): maximal respiratory exchange ratio; $HR_{MAX}$ (beats.min$^{-1}$): maximal heart hate; HR/age (%): percentage of age-predicted maximal heart rate.

**Table 2.** Frequency of oxygen consumption values obtained by negative extrapolations that met the statistical criteria in the different $\dot{V}O_2$ recovery curve lengths (10 s a 60 s).

| | Statistical criteria | | | | |
|---|---|---|---|---|---|
| | Differences | ES | Correlation | Bias | Extrapolations |
| 10 s | 6 | 4 | 0 | 0 | ---- |
| 20 s | 4 | 4 | 4 | 2 | -1 and -2 s |
| 30 s | 4 | 4 | 4 | 2 | -1 and -2 s |
| 40 s | 4 | 4 | 4 | 1 | -2 s |
| 50 s | 3 | 3 | 3 | 2 | -2 and -3 s |
| 60 s | 3 | 3 | 3 | 1 | -3 s |

Differences: no difference with the $\dot{V}O_2$ obtained at the end of supramaximal exercise (*t* test); ES: effect size value smaller than 0.35; Correlation: Pearson's coefficient positive and higher than 0.70; Bias: mean difference between procedures smaller than 1 mL.kg$^{-1}$.min$^{-1}$; Extrapolation: times that the regression was back extrapolated and met the statistical criteria.

**Table 3.** Specifications of statistical criteria observed for the eight selected adjustments of backward extrapolation technique. All procedures were performed in relation of the maximal values observed at the end of supramaximal effort.

| Adjustment | | Statistical criteria | | | |
|---|---|---|---|---|---|
| Curve Length (s) | Extrapolation Time (s) | Differences | ES | *r* | Bias ± LoA95 (mL.kg$^{-1}$.min$^{-1}$) |
| 60 s | -3 s | 0.723 | - 0.055 | 0.824 | - 0.36 ± 7.72 |
| 50 s | -2 s | 0.513 | - 0.108 | 0.807 | - 0.71 ± 7.86 |
| 50 s | -3 s | 0.417 | 0.140 | 0.804 | 0.94 ± 10.05 |
| 40 s | -2 s | 0.901 | 0.020 | 0.793 | 0.14 ± 9.56 |
| 30 s | -1 s | 0.581 | - 0.101 | 0.775 | - 0.69 ± 9.14 |
| 30 s | -2 s | 0.669 | 0.081 | 0.767 | 0.57 ± 11.07 |
| 20 s | -1 s | 0.530 | - 0.121 | 0.750 | - 0.83 ± 9.61 |
| 20 s | -2 s | 0.779 | 0.056 | 0.736 | 0.40 ± 11.73 |

Differences: no difference with the $\dot{V}O_2$ obtained at the end of supramaximal exercise (*t* test); ES: effect size; *r*: Pearson's product moment correlation coefficient; Bias: mean difference between procedures; LoA: 95% limits of agreement.