

JEP^{online}
Journal of Exercise Physiology^{online}

Official Journal of The American
Society of Exercise Physiologists (ASEP)

ISSN 1097-9751

An International Electronic Journal
Volume 5 Number 1 February 2002

Metabolic Responses to Exercise

IMPROVING THE PRECISION OF THE ACCUMULATED OXYGEN DEFICIT USING
VO₂-POWER REGRESSION POINTS FROM BELOW AND ABOVE THE LACTATE
THRESHOLD

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ABSTRACT

IMPROVING THE PRECISION OF THE ACCUMULATED OXYGEN DEFICIT USING VO₂-POWER REGRESSION POINTS FROM BELOW AND ABOVE THE LACTATE THRESHOLD. **A.P. Russell, P.F. Le Rossignol, R.J. Snow, S.K. Lo. JEP^{online}. 2002;5(1):23-31.** The accumulated oxygen deficit (AOD) method assumes a linear VO₂-power relationship for exercise intensities increasing from below the lactate threshold (BLT) to above the lactate threshold (ALT). Factors that were likely to effect the linearity of the VO₂-power regression and the precision of the estimated total energy demand (ETED) were investigated. These included the slow component of VO₂ kinetics (SC), a forced resting y-intercept and exercise intensities BLT and ALT. Criteria for linearity and precision included the Pearson correlation coefficient (PCC) of the VO₂-power relationship, the length of the 95% confidence interval (95% CI) of the ETED and the standard error of the predicted value (SEP), respectively. Eight trained male and one trained female triathlete completed the required cycling tests to establish the AOD when pedalling at 80 rev/min. The influence of the SC on the linear extrapolation of the ETED was reduced by measuring VO₂ after three min of exercise. Measuring VO₂ at this time provided a new linear extrapolation method consisting of ten regression points spread evenly from BLT and ALT. This method produced an ETED with increased precision compared to using regression equations developed from intensities BLT with no forced y-intercept value; (95%CI (L), 0.70±0.26 versus 1.85±1.10, P<0.01; SEP(L/Watt), 0.07±0.02 versus 0.28±0.17; P<0.01). Including a forced y-intercept value with five regression points either BLT or ALT increased the precision of estimating the total energy demand to the same level as when using 10 regression points, (5 points BLT + y-intercept versus 5 points ALT + y-intercept versus 10 points; 95%CI(l), 0.61±0.32, 0.87±0.40, 0.70±0.26; SEP(L/Watt), 0.07±0.03, 0.08±0.04, 0.07±0.02; p>0.05). The VO₂-power regression can be designed using a reduced number of regression points when a forced y-intercept value is included. This provides a time efficient method without compromising the precision of the ETED and therefore the calculated AOD.

Key Words: Cycling, Anaerobic capacity, Exercise testing.

INTRODUCTION

The accumulated oxygen deficit (AOD) is often used as a non-invasive representation of anaerobic capacity (1-4). The AOD is determined as the difference between the estimated total energy demand (ETED)

required to perform an exhaustive exercise task and the actual accumulated oxygen uptake measured during the exercise task (1). The ETED is extrapolated from the linear relationship between VO_2 and power. The fundamental assumption surrounding the estimation of the total energy demand is that the relationship between VO_2 and power is linear for all submaximal intensities and remains linear during exercise at intensities greater than VO_2 peak (1).

Several studies have demonstrated that during cycling exercise the VO_2 -power relationship was non-linear when exercise intensity was increased from below to above the lactate threshold during an incremental exercise test (5-7). Similarly, for independent exercise tests a non-linear VO_2 -power relationship consisting of two tests below and two tests above the ventilation threshold (ALT) was observed (8), however the lactate threshold (LT) was not determined during this study. This non-linear increase in VO_2 is a result of the slow component of VO_2 kinetics (SC). The SC begins approximately between 1.33 and 2.5 min during exercise ALT and finishes with end VO_2 reaching a delayed plateau or continuing to VO_2 max (8). However, the fast and slow component of VO_2 kinetics are independent of each other, and the amplitude of the fast component has been demonstrated to be linear across four power outputs measured from 38-100% of VO_2 max (8). Consequently, it may be possible to select a time interval that reduces the effect of the SC on VO_2 . Using a mathematical modelling technique based on recursive residuals (6), it was demonstrated that for a continual exercise test consisting of 30 W/min increases intensity, the intensity at which VO_2 increased disproportionately was not significantly different to the intensity eliciting the LT. A linear regression utilising three min VO_2 values (average of previous 30 sec) across all powers may be suitable as the fast component of VO_2 is likely to be completed for all individuals by 2.5 min (8). This relatively short time frame will prevent alterations in VO_2 caused by the SC. Since the constant load AOD test is completed at intensities above VO_2 max, where VO_2 increases monoexponentially to maximum, the SC has negligible impact on VO_2 . Therefore, it is intuitive that the effect of the SC on the VO_2 -power regression needs to be reduced to produce a linear relationship for exercise intensities below and above the lactate threshold. Consequently the main aim of the study was to examine if a non-linear regression vs. linear regression model better describes the VO_2 -power relationship when using VO_2 values measured after 3 min of exercise. In addition, the influence of the relative exercise intensity was determined by classifying intensities as below to above the lactate threshold.

Another major issue surrounding the AOD method is the number and spread of the regression points used to develop the VO_2 -power relationship for estimating the total energy demand. Medbø et al. (1) claimed that 10 regression points spread between 35% and 100% of VO_2 max is the minimum required to obtain a precise AOD value on a treadmill. In addition, when the number of regression points is reduced a forced y-intercept should be included as described by their "procedure 3". Buck and McNaughton (20) also support the need for 10 points to accurately measure AOD; however, they have included the effect of the SC at intensities ALT.

Studies measuring the AOD during cycling have generally used between four and eight intensities BLT to develop the VO_2 - power regression (9-11). However these studies have a reduced spread of regression points and have not included a forced y-intercept value as suggested by Medbø et al. (1). We have previously observed during rowing ergometer exercise that using a linear regression with five regression points and no forced y-intercept compared to including the y-intercept value increased the mean length of the 95% CI of the ETED by 53% (4). This observation demonstrated a reduction in the precision of the ETED value when a forced y-intercept was not included. The influence of a reduced spread of regression points with and without the inclusion of a forced y-intercept value on the precision of the ETED during cycling is not known. The secondary aim of the study was to compare regression equations from BLT and ALT with and without the inclusion of a forced y-intercept value with the 10-point regression equation developed in the first part of this study. Our 10 point regression method utilising three min VO_2 values will also be compared to the more common approach employed by others (9-11) on a series of criteria that evaluates the efficacy of each of the approaches.

METHODS

Subjects

Eight trained male triathletes (mean±SD: age= 7±6 yr; mass=73.4±3.1 kg; VO₂peak=4.7±0.5 L/min) and 1 trained female triathlete (age=20 yr; mass=57 kg; VO₂peak=3.4 L/min) signed informed consent and volunteered to participate in the present study which was approved by the Deakin University Ethics Committee. The subjects were asked not to participate in any physical activity 24 hours prior to testing and to abstain from eating for at least three hours prior to testing.

VO₂peak Test

The VO₂peak test required the subjects to ride at 80 rev/min on an electronically braked cycle ergometer (Lode Excalibur) at 100 Watts for 10 min followed by an increase in work rate of 25 Watts/min until the respiratory exchange ratio (RER) was above 1.1 for one min. The work rate was then increased by 13 Watts/min until the subjects could no longer maintain 80 rev/min. Expired gases were collected and analysed by a Medical Graphics metabolic cart (Cardio2 and CPX/D System) to determine VO₂ and the RER. The metabolic cart was calibrated prior to each test using alpha calibrated gases that have an error of 0.01%. VO₂ peak was established as the highest 30 sec VO₂ value measured during the test. The work rate at which VO₂ peak occurred was also recorded.

Lactate threshold test

A lactate threshold (LT) test was performed to determine the exercise intensity that caused >1.0 mmol/L accumulation of lactate in the plasma (12). After a 10 min warm up at 100 Watts the subjects began exercising at 60% of VO₂peak for four min and subsequently the work rate was increased by 5% up to 90% of VO₂peak every 4 min. Prior to exercise a 22-gauge catheter was inserted in an antecubital forearm vein. A 2.5mL blood sample was obtained immediately after the warm-up and at the end of each four min work rate. The blood samples collected during the LT test were spun in a centrifuge and 10 µL of plasma was added to 600 µL of 3 M perchloric acid and spun again. The supernatant (10 µL) was then analysed for plasma lactate in triplicate, using an enzymatic fluorometric technique (13). The work rate at which plasma lactate accumulation increased by 1 mmol/L above baseline was defined as the lactate threshold (12).

Submaximal tests and the slow component of VO₂ kinetics (SC)

Each subject completed 10 constant load cycling tests lasting up to six min using the same cycle ergometer as previously described. The duration of six min was chosen as this time was approximately the average duration used to measure VO₂ for establishing the VO₂-power regression in previous AOD cycling studies (14, 15). Five tests were performed between 70 and 90% of lactate threshold power output (BLT) with the other five tests performed between 75 and 95% of VO₂peak power output (ALT). Two tests were performed each session with one test BLT and the other test ALT. The lowest intensity test was always performed first. The tests were paired so that the lowest intensity test BLT was performed during the same session as the highest intensity ALT. The following constant load testing sessions were paired in the same manner so that the second lowest test BLT was performed before the second highest test ALT and so on. Completion of the five paired-intensity tests occurred in a randomly selected order. Prior to each testing session, two min of resting VO₂ was collected while seated on the bicycle and used as the individual y-intercept value. At the conclusion of the two min rest period the subjects began cycling at the required power output for six min. The first test was followed by 10 min of rest. This recovery period provided a rest to work ratio of greater than 1.6:1 and was chosen as it has previously been observed that a work to rest ratio of 1:1, 15 min recovery between two 15 min work bouts, did not significantly influence the relationship between VO₂ and power (11). Although the work bouts in our study were of a shorter duration than in Green et al. (1996), several of our intensities were higher therefore a greater rest to work recovery was provided. Immediately after the rest period the subjects completed the second trial at the higher intensity. VO₂ was measured breath-by-breath using the Medical Graphics metabolic cart as previously described. The SC was established as the difference in VO₂ between min three and six of exercise for intensities BLT and ALT (5, 16,17).

Measuring the accumulated oxygen deficit (AOD)

After a 10 min warm up at 100 Watts the subjects cycled to exhaustion at their individually selected work rates which corresponded to 110% of VO_2 peak power output. Exhaustion was determined when the subjects could no longer maintain 80 rpm. The AOD was calculated as the difference between the ETED and the accumulated oxygen uptake measured during the exhaustive test (1). VO_2 was measured breath-by-breath using the Medical Graphics metabolic cart as previously described.

Establishing the total energy demand required to perform the AOD test

The total energy demand required to perform approximately 2 min of exhaustive exercise was calculated from the regression equation derived from the relationship between submaximal VO_2 and power (1). The exhaustive intensity was set at 110% of VO_2 peak power as previous studies have observed this intensity to exhaust subjects in approximately 2 min (1,10,11). The total energy demand required to perform at 110% of VO_2 peak power was estimated using both linear and non-linear regressions to establish the "best fit" for the VO_2 -power relationship with VO_2 measured after three min of exercise. "Best fit" was determined using mathematical modeling (see below). The relationship between VO_2 and power was established using all 10 intensities and separately for exercise intensities from BLT and ALT with and without a y-intercept value.

Statistics

Both linear and non-linear regressions were fitted to data obtained from each individual. We recorded the parameter estimates and "goodness of fit" statistics measured for each of the VO_2 -power regressions fitted with three min VO_2 values from below and above the lactate threshold (BLT and ALT) as well as including a forced y-intercept value. These included the slope of the VO_2 -power relationship, the estimated total energy demand (ETED), the AOD and the standard error and length of the 95% CI of the ETED. The correlation coefficient between the observed and predicted values of the dependent variable for each regression, denoted as r in this manuscript, was computed to compare the relative fit of the various models (18). Paired t-tests were used to locate differences in these variables when using the linear and non-linear regression. Repeated measures ANOVA followed by all pairwise linear contrasts were performed to test for differences in the above mentioned dependent variables when using combinations of regression points from the different intensities. These intensities included 1) five intensities BLT + five intensities ALT + a y-intercept value, 2) five intensities BLT + a y-intercept value, 3) five intensities BLT without a y-intercept value, 4) five intensities ALT + a y-intercept value and 5) five intensities ALT without a y-intercept value.

Paired t-tests were again used to test for differences in the dependent variables when using the 10 x 3 min VO_2 regression with a commonly used regression method consisting of 5 x 6 min VO_2 measures BLT without a y-intercept. All analysis was performed using SPSS statistical software. Statistical significance was set at $p \leq 0.05$ for all analysis. The "Sharpened" Bonferroni procedure (19) was used to adjust the significance level when multiple testings were carried out. All data are reported as mean \pm standard deviation (SD).

RESULTS

Figure 1 demonstrates changes in VO_2 between min three and six at exercise intensities below and above the lactate threshold. There was a significant increase (all $p < 0.01$) in VO_2 from min three to six for the highest intensity below the lactate threshold (BLT) and for all intensities above the lactate (ALT). There was a SC as defined by a greater than 200 mL increase in VO_2 for the four highest intensities ALT.

The VO_2 -power regression established using 10 x 3 min VO_2 values evenly spread from BLT to ALT and a y-intercept was better fitted by using a non-linear quadratic regression ($r=0.999$) compared to a linear regression ($r=0.998$). There was no difference between the two regression methods with respect to the estimated total energy demand's (ETED's) (Table 1), however the length of 95% confidence interval (CI) for the ETED was 31% shorter when using a linear compared to a non-linear regression ($p < 0.01$).

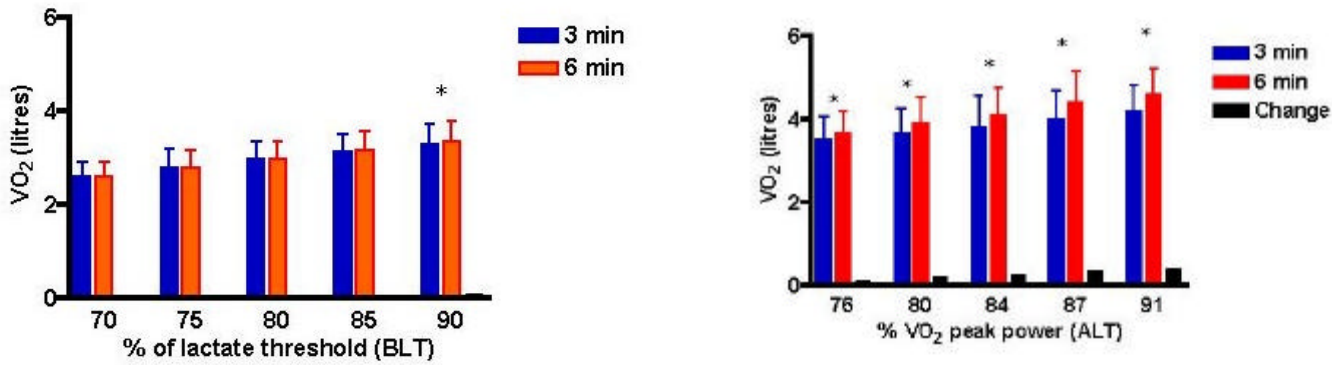


Figure 1. VO₂ measured after 3 and 6 min of exercise at intensities below and above the lactate threshold. Values are means + SD, n = 9. * different from three min (P<0.01). BLT, exercise intensities below the lactate threshold; ALT, exercise intensities above the lactate threshold; %LT power, % of the power at which the lactate threshold occurs; %VO₂ peak power, % of the power at which VO₂ peak occurs.

As the linear compared to the non-linear regression technique estimated a more precise total energy demand the linear regression was used for all extrapolations (see discussion). Utilising regression points from BLT and ALT with and

Table 1. Influence of linear and non-linear regressions on the correlation between observed and predicted values, and the estimate and length of the 95% CI, and the ETED.

Variable	3 min VO ₂	
	linear	Non-linear
<i>r</i>	0.998±0.000 *	0.999±0.000
ETED (L/min)	4.89±0.73	4.97±1.06
Length of the 95%CI (L)	0.71±0.26 **	0.93±0.32

Values are means±SD, n=9; ** p<0.01, * p <0.05, different from non-linear regression; r, correlation coefficient between the observed and predicted values of the dependent variable in the regression; ETED, estimated total energy demand. The VO₂-power regressions consist of the combination of 5 points BLT + 5 points ALT + a y-intercept value. VO₂ was measured after 3 min of exercise.

without a forced y-intercept value did not influence the slope of the VO₂-power regression, the ETED or the AOD (Table 2). The precision of estimating the total energy demand was increased for three of the five regressions presented in Table 2, as indicated by a smaller SEP and a shorter 95% CI of the ETED. These three regressions are (a) the regression consisting of 10 regression points combined from BLT and ALT and a forced y-intercept value; (b) the inclusion of a forced y-intercept value with 5 regression points BLT; and (c) 5 regression points ALT plus the y-intercept. There was no significant

difference in any of the parameters measured between these three regression models. The Pearson correlation coefficient was greater when using regression points BLT or ALT combined with a forced y-intercept compared to the other regressions (Table 2). The y-intercept was combined with the regression consisting of 10x3 min regression points as it decreased the SEP (p<0.01) and increased the correlation coefficient between VO₂ and power compared to using only the 10 x 3 min regressions without a y-intercept (p<0.05). The inclusion of the forced y-intercept did not change any of the other dependent variables (p>0.05) (data not shown).

Ten regression points have been suggested as the minimum to calculate the AOD (20). Therefore, the regression using 10x3 min regression points and a forced y-intercept was compared to the commonly used AOD method comprising five regression points BLT without a y-intercept. A number of differences were found (Table 3). The slope of the VO₂- power regression, ETED, AOD and SEP were all lower and the 95% CI was shorter (all P<0.001) for the 10 points plus a y-intercept model compared with the commonly used AOD method. The correlation coefficient was greater (p<0.01) when using the AOD method comprising of five regression points BLT without a y-intercept compared to the method of 10 x 3 min regression points and a forced y-intercept.

Table 2. Influence of exercise intensity BLT and/or ALT with and without a forced y-intercept on the slope of the VO₂-power regression, AOD, ETED, 95% CI, SEP and the PCC.

<i>Parameter</i>	<i>10 x 3 min VO₂ points BLT and ALT + y-intercept</i>	<i>5 points BLT + y intercept</i>	<i>5 points BLT with no y intercept</i>	<i>5 points ALT + y intercept</i>	<i>5 points ALT with no y intercept</i>
<i>Slope (L/W)</i>	0.011±0.000 1	0.011±0.001	0.013±0.004	0.011±0.001	0.019±0.019
<i>AOD (L)</i>	3.71±0.98	3.69±0.70	4.68±1.72	3.73±1.19	3.87±1.78
<i>ETED (L/min)</i>	4.89±0.73	4.88±0.59	5.26±0.82	4.89±0.82	4.96±0.01
<i>95%CI (l)</i>	0.70±0.26 *	0.61±0.32 *	1.85±1.10	0.87±0.40 *	1.65±0.81
<i>SEP (L/W)</i>	0.07±0.02 *	0.07±0.03 *	0.28±0.17	0.08±0.04 *	0.24±.12
<i>r</i>	0.995±0.003	0.998±0.001 *	0.988±0.009	0.998±0.002 *	0.969±0.035

Values are means±SD, n=9; * p<0.01; different from the other regressions but not different from each other. BLT, exercise intensities below the lactate threshold; ALT, exercise intensities above the lactate threshold; AOD, accumulated oxygen deficit; ETED, estimated total energy demand; 95% CI, 95% confidence interval of the ETED; SEP, standard error of the predicted value; r, correlation coefficient between the observed and predicted values of the dependent variable.

Table 3. The influence of the method combining 3 min VO₂ values from BLT and ALT with a y-intercept and the method using values BLT measured at 6 min with no y-intercept value on the slope of the VO₂ -power regression, ETED, and the associated 95% CI, AOD, PCC, and the SEP.

<i>Variables</i>	<i>3 min VO₂ values measured BLT and ALT with y-intercept</i>	<i>6 min VO₂ values BLT with no y- intercept</i>
<i>Slope (L/Watt)</i>	0.0106±0.0001 *	0.0135±0.0032
<i>ETED (L/min)</i>	4.89±0.73 *	5.43±0.85
<i>95% CI (L)</i>	0.70±0.26 *	1.89±1.1
<i>AOD (L)</i>	3.71±0.98 *	5.15±1.52
<i>r</i>	0.994±0.003	0.998±0.000
<i>SEP (L/Watt)</i>	0.07±0.02 *	0.29±0.17

Values are means±SD, n=9, *=p<0.01; different from 6 min VO₂ values BLT with no y-intercept; ETED=estimated total energy demand; AOD=accumulated oxygen deficit; r=correlation coefficient between the observed and predicted values of the dependent variable; SEP=standard error of the predicted value (SEP); 95% CI=95% confidence interval of the ETED.

DISCUSSION

The major findings from the present study were that the VO₂-power relationship established from the combination of 10x3 min regression points from below and above the lactate threshold, with a forced y-intercept, produced the most precise estimate of the total energy demand (ETED). Such estimates were when based on extrapolation from a linear compared to a quadratic regression, which produced the best fit among the eleven non-linear regression models available in a widely used statistical software package. There was no difference in the ETED's from either the linear or non-linear regression. Utilising regression points from below the lactate threshold (BLT) without including a forced y-intercept value did not influence the ETED of the AOD, but it did reduce the precision of the estimated value and therefore the precision of the AOD. Including a forced y-intercept value enabled a reduced number of regression points to be used without compromising the precision of the ETED.

We observed a SC for the four highest intensities above the lactate (ALT) confirming the findings from previous studies (5,8,11). Although there was a significant increase in VO_2 from min three to min six at 90% BLT the increase of approximately 100 ml is not enough to suggest an influence of the SC (21). The mechanism causing the SC is not exactly clear, however it is believed to be caused predominantly by the recruitment of type II muscle fibers (22,23). Other factors which may make a minor contribution to the SC include support mechanisms such as increased ventilation and cardiac work (24).

The SC has been previously observed to change the VO_2 -power relationship from linear to non-linear (5,8,16). We therefore decided to use a regression consisting of three min VO_2 values which would reduce the contribution of the SC for intensities ALT. This approach also allowed other criteria to be followed for improving the precision when estimating the total energy demand. These criteria included using a minimum of 10 regression points and having regression points measured as close to the estimated value as possible (1). The potential criticism with this approach is that the VO_2 measured at three min ALT is not a steady state value and that this may underestimate the ETED and the AOD. However the increased VO_2 value at intensities ALT is due to the SC which occurs after approximately two to three min of exercise. As the AOD test lasts for approximately two to three min the SC would not influence the VO_2 measured during the AOD trial. In addition, a SC cannot exist during exercise in which the exercise energy demand exceeds VO_2 max.

We used the SPSS curve estimation module to determine whether the VO_2 -power relationship from our new regression method consisting of 10x3 min regression points as well as a forced y-intercept was best described by a linear or non-linear regression. Statistically the regression was "best-fit" by a non-linear regression, however practically this was not the case. The correlation coefficient for the non-linear regression (0.999) was greater ($p < 0.01$) than the linear regression (0.998). Although the correlation coefficient was statistically different there was no practical influence when using either the non-linear or the linear regression equations, as there was no difference ($p > 0.05$) in the ETED's. As the linear regression increased the precision of the ETED it was decided that a linear regression was more suitable for estimating the total energy demand. These observations raised the question as to the statistical and/or practical significance of using the correlation coefficient to determine which regression technique was the most appropriate. Previous studies have suggested that the correlation coefficient of the VO_2 -power relationship may not be an appropriate indicator of the accuracy of the estimated value (20). Although the correlation coefficient is used as a "goodness-of-fit" measure, the size of the 95% CI of the ETED is used to establish the variability of estimates (25,26), with a smaller 95% CI indicating a less variable and more precise estimated value. As the AOD method is based on a precise estimation of the total energy demand the 95% CI of the estimated value may be more appropriate than the r-square value or the correlation coefficient as a criteria to determine which regression method best suits the VO_2 -power relationship. Reducing the variability and increasing the precision of the ETED not only provides a more precise AOD but also impacts on the relationship between the AOD and other variables. For example, a more precisely calculated AOD value when combined with VO_2 peak correlated with 200 m rowing ergometer performance, while a less precisely calculated AOD value combined with the same VO_2 value did not correlate with performance (4).

Using linear regression analysis we investigated the influence of reducing the number of regression points with and without including a forced y-intercept value. There was no influence on the ETED and AOD values. However, reducing the number of regression points to either five BLT or five ALT without the inclusion of a forced y-intercept reduced the precision of the ETED as indicated by a larger 95% CI of the ETED and a greater SEP. The SEP is a more precise measure of errors than the standard error of the estimate (SEE) as the SEE is a broad term and may refer to the SE of the intercept or SE of the slope (both a and b in the equation $y = a + bx$). This observation supports our previous findings during rowing ergometer exercise (4). Including a forced y-intercept value when reducing the number of regression points to either BLT or ALT, resulted in a similar ETED and similar precision of the estimate when compared to the regression using 10 points. It has been suggested that 10 regression points is the minimum required to establish the VO_2 -power regression and minimise the error of the ETED (1,20). Our findings demonstrate that the inclusion of a forced y-intercept value allows the number of regression points to be reduced to five while maintaining the same level of precision when VO_2 is measured after three min of exercise

Previous studies have used approximately five regression points BLT with no forced y-intercept to establish the regression equation to predict the total energy demand (9,11,14). After comparing our regression method, consisting of a forced y-intercept combined with VO_2 values measured after three min of exercise at 5 intensities BLT and 5 intensities ALT, with the commonly used method of five regression points BLT with no y-intercept several differences were observed. Our newly proposed method resulted in a lower slope of the VO_2 -power regression, ETED and AOD when compared to the commonly used method. However the standard error of the regression was lower and the 95% CI shorter when using our newly proposed method. The correlation coefficient was greater when using the commonly used method of five regression points BLT with no y-intercept. This observation demonstrates the potential of the correlation coefficient to provide false-positive results when only using this variable to establish the accuracy of the AOD method. These observations demonstrate that using 10 regression points from BLT and ALT with a forced y-intercept value provides a more precise estimation of the total energy demand and therefore a more precisely measured AOD value than when the VO_2 - power regression is established using five regression points from BLT only.

Conclusion

Measuring VO_2 at the end of three min of cycling exercise reduces the influence of the SC at 80 rev/min, allows for the inclusion of regression points from below and above the lactate threshold, and produces a shorter 95% CI of the estimated total energy demand (ETED). Reducing the number of regression points without including a forced y-intercept value decreases the precision of the ETED compared to using 10 regression points. Including a forced y-intercept with a reduced number of regression points increases the precision of the estimated value to a similar level observed when estimated using 10 regression points. The same precision was obtained when either using five regression points plus an individual forced y-intercept value from intensities either below the lactate threshold) BLT or (above the lactate threshold) ALT, respectively. Although using intensities from BLT or ALT result in similar AOD values, the lower intensity trials from BLT may allow the subject to perform five trials in the same testing session. Consequently, an expedient method for estimating total energy demand, without compromising the precision of this estimate, could be achieved by developing a regression using a forced y-intercept combined with five intensities BLT with VO_2 measured after three min of exercise.

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