

## Toe and Earlobe Capillary Blood Sampling for Lactate Threshold Determination in Rowing

Jacky J. Forsyth, Chris Mann, and James Felix

**Purpose:** In rowing ergometry, blood for determining lactate concentration can be removed from the toe tip without the rower having to stop. The purpose of the study was to examine whether sampling blood from the toe versus the earlobe would affect lactate threshold ( $T_{lac}$ ) determination. **Methods:** Ten physically active males (mean  $\pm$  age  $21.2 \pm 2.3$  y; stature  $179.2 \pm 7.5$  cm; body mass  $81.7 \pm 12.7$  kg) completed a multistage, 3 min incremental protocol on the Concept II rowing ergometer. Blood was sampled simultaneously from the toe tip and earlobe between stages. Three different methods were used to determine  $T_{lac}$ . **Results:** There were wider variations due to the method of  $T_{lac}$  determination than due to the sample site; for example, ANOVA results for power output were  $F(1.25, 11.25) = 11.385$ ,  $P = .004$  for method and  $F(1, 9) = 0.633$ ,  $P = .45$  for site. The greatest differences in  $T_{lac}$  due to sample site in rowing occurred when  $T_{lac}$  was determined using an increase in blood lactate concentration by  $>1$  mmol/L from baseline ( $T_{lac\Delta 1}$ ). **Conclusions:** The toe tip can be used as a suitable sample site for blood collection during rowing ergometry, but caution is needed when using the earlobe and toe tip interchangeably to prescribe training intensities based on  $T_{lac}$ , especially when using  $T_{lac\Delta 1}$  or at lower concentrations of lactate.

**Keywords:** anaerobic threshold, lactic acid, athletic performance, sports

Determining a lactate threshold ( $T_{lac}$ ) during indoor rowing ergometry is useful for setting training regimes and assessing performance capability.<sup>1</sup> Capillary blood is often sampled from the fingertip or earlobe;<sup>2</sup> however, if the exercise test requires the arms and upper body to be in motion, as is the case in rowing, the athlete will need to stop while blood collection takes place. This disruption may distort the lactate profile<sup>3</sup> and may interfere with the flow of exercise and the attainment of other physiological variables.<sup>4</sup> On the rowing ergometer, the rower's feet are secured and relatively immobile, thus making it possible and practical for the experimenter to sample blood from the toe tip without obstructing performance and without the exercise being discontinued.

Two studies have been carried out with a view to validating the use of the toe tip as a sampling site in rowing.<sup>5,6</sup> In the study of Forsyth and Farrally,<sup>5</sup> no significant differences in blood lactate concentration at the earlobe, fingertip and toe tip were reported at exercise intensities equivalent to 76% and 92% of age-predicted maximum heart rate. Mean values of blood lactate concentration at the earlobe were, however, lower than fingertip and toe tip values at both exercise intensities,

consistent with findings of other researchers,<sup>7-10</sup> who have reported earlobe blood lactate concentration to be lower than fingertip blood lactate concentration for other modes of exercise at a range of different exercise intensities. Although Forsyth and Farrally<sup>5</sup> reported no significant differences between sample sites, correlation coefficients for blood lactate concentration between the toe tip and fingertip were low (eg,  $r = .46$  at 92% maximum heart rate), effect magnitude or precision of estimation were not reported, and  $T_{lac}$  was not determined. In the study of Garland and Atkinson,<sup>6</sup> measurements of blood lactate concentration taken at the earlobe were also reported as being lower than those taken at the toe tip, but only at low blood lactate concentrations. At higher exercise intensities, blood lactate concentration was higher at the earlobe than it was at the toe tip. Despite this apparent variance due to exercise intensity, agreement between the earlobe and toe tip was reported as being good when these sites were used to determine power output at a blood lactate concentration of  $4 \text{ mmol}\cdot\text{L}^{-1}$ . As well as using absolute values of lactate to determine  $T_{lac}$ , curve fitting procedures have been used, since absolute amounts can vary with, for instance, glycogen availability<sup>11</sup> and time of day.<sup>12</sup> In rowing, the  $D_{max}$  method,<sup>13</sup> which involves a curve fitting procedure, has been found to be preferable when assessing repeatability.<sup>14</sup> Other techniques, such as an increase in lactate above baseline,<sup>15</sup> have been used as easier, more practical alternatives to determine  $T_{lac}$ . Whether values of blood lactate concentration at the toe

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and earlobe affected the shape of the lactate curve and hence the assessment of  $T_{lac}$  using a curve-fitting method (such as the  $D_{max}$  method), was not examined in the study of Garland and Atkinson.<sup>6</sup>

Various suggestions have been put forward to explain why blood lactate concentration may vary according to sample site, such as differences in localized and central blood flow, and differences in lactate production and clearance.<sup>7,8</sup> Draper et al<sup>8</sup> suggested that the higher blood lactate concentration observed in the fingertip compared with the earlobe following climbing activity reflected localized lactate production in the forearm, activated through gripping the rock. The gripping of the handle bars when cycling was suggested by Dassonville et al<sup>7</sup> to result in a greater production of blood lactate at the fingertip compared with the earlobe. In rowing, the muscles of the legs, back and arms are all active, suggesting a more homogenous distribution, from both production and utilization, of lactate in the blood, although the squeezing of the handle on the rowing ergometer and the pressure on the footplate during the drive phase have been suggested to elevate fingertip and toe tip blood lactate concentration, respectively.<sup>5,6,9</sup> Using the toe tip, in order to determine  $T_{lac}$  in rowing, is practical, but results are inconclusive regarding its validity. The purpose of this study was to further examine whether the toe tip could be used as a suitable sample site for blood collection during rowing ergometry, by examining whether differences in variables (power output, heart rate [HR], oxygen consumption [ $VO_2$ ], ratings of perceived exertion [RPE]) at  $T_{lac}$ , using three different methods of  $T_{lac}$  determination (including the  $D_{max}$  method)<sup>13</sup> were of practical relevance when blood was sampled from the toe tip compared with when sampled at the earlobe.

## Methods

### Subjects

Following institutional ethical approval, which conformed to the Helsinki Declaration, 10 physically active males (mean  $\pm$  SD, age  $21.22 \pm 2.3$  y; stature  $179.2 \pm 7.5$  cm; body mass  $81.7 \pm 12.7$  kg) were recruited to take part in the study. All subjects regularly used the Concept II rowing ergometer (Model C, Nottingham, UK) as part of their exercise regimes. Subjects were encouraged to refrain from strenuous physical activity, to avoid alcohol and caffeine and to ensure adequate food intake and hydration within 48 h preceding each test. Consent was obtained orally and in writing, after having fully informed subjects of the procedures.

### Design and Methodology

All testing took place between 0900 and 1100 and was completed for each subject during one laboratory visit, since earlobe and toe tip samples were taken at the same time. Subjects completed a warm-up lasting 5 min at an intensity equivalent to between 50% and 60% of maximal

oxygen consumption ( $VO_{2max}$ ). This intensity and the initial intensity of the protocol were determined on an individual basis during a familiarization visit. After the warm-up, subjects rested for 5 min, remaining seated. The mean  $\pm$  SD initial intensity for the protocol was  $102.6 \pm 21.2$  W, which corresponded to  $64.0 \pm 6.3\%$  of  $VO_{2max}$ . The intensity was then increased by a mean  $\pm$  SD of  $20.1 \pm 0.7$  W every 3 min, corresponding to an increase in  $VO_2$  of  $2.76 (\pm$  SD 1.86)  $mL \cdot kg^{-1} \cdot min^{-1}$ , until subjects reached volitional exhaustion, or were unable to maintain the required power output. Subjects were encouraged to maintain a stroke rate of between 24 and 32 strokes  $\cdot min^{-1}$  throughout the test. A drag factor of 130 was used. Mean  $\pm$  SD test duration was  $18.9 \pm 3.5$  min. The reliability of this protocol for determining  $T_{lac}$  has been detailed elsewhere.<sup>14</sup>

The toe tip and earlobe were prepared using nonalcoholic Mediwipes. Capillary blood (5  $\mu$ L) was simultaneously collected from both the toe tip and earlobe between stages (10 s rest intervals). Earlobe samples were analyzed immediately using a precalibrated analyzer (Lactate Pro, Arkray, KDK Corporation, Kyoto, Japan). Toe tip samples were temporarily stored ( $1.12 \pm 0.8$  min) in a nonheparinized collection tube (Microsafe, Hemosense INratio) so that the same Lactate Pro analyzer could be used, with this technique piloted for accuracy ( $r = .99$ ,  $P < .01$ ; 95% confidence interval [CI] =  $-0.09$  to  $0.5$ ; limits of agreement [LoA] =  $0.79$   $mmol \cdot L^{-1}$ ).

Heart rate was monitored throughout by means of short-range radio telemetry (Cardiosport First, Cardiosport Ltd., Taiwan), and RPE was rated at the end of each increment. Respiratory variables were determined using a breath-by-breath gas analyzer (Quark b2, Cosmed, Italy), precalibrated with a 3 L turbine and known concentrations of gas. Data were averaged every 30 s, with the highest 30 s average used for each exercise stage.

Methods used to determine  $T_{lac}$  included the  $D_{max}$  method,<sup>13</sup> a method using an absolute increase of 1  $mmol \cdot L^{-1}$  in blood lactate concentration from initial values ( $T_{lac\Delta 1}$ ),<sup>15</sup> and a fixed blood lactate concentration of 4.0  $mmol \cdot L^{-1}$  ( $T_{lac-4 mM}$ ).<sup>16</sup> For the  $D_{max}$  method, third-order polynomial regressions of the variables used ( $VO_2$ , HR, power output and RPE) against blood lactate concentration were determined. The slope of the straight line formed by the two endpoints of each curve was calculated, and  $D_{max}$  was defined as the maximal perpendicular distance from the curve to the straight line. The polynomials and  $D_{max}$  determination were calculated using a MathCAD program (MathCAD 2000i Professional, MathSoft Engineering & Education Inc., Surrey, England): given a set of data points  $(x_1, y_1), \dots, (x_n, y_n)$ , and provided that  $n \geq 4$ , a cubic curve "of best fit" could be found in the form  $y = a_0 + a_1x + a_2x^2 + a_3x^3$  using the method of least squares. For each individual case in the data set, the actual calculations of the coefficients  $a_0, a_1, a_2$  and  $a_3$  were performed in the first half of the bespoke MathCAD worksheet. Once the cubic curve for a data set was found, then the  $D_{max}$  method of Cheng et al<sup>13</sup> was applied in the second half of the MathCAD worksheet.

Assuming that the data are labeled with  $x_1 \leq x_2 \leq \dots \leq x_n$ , then the points at  $x_1$  and  $x_n$  are joined by a straight line,  $l$ . The  $D_{\max}$  method finds that point,  $M$ , on the cubic curve which is furthest from  $l$ . A consequence of this is that the gradient of line  $l$  must be the same as the gradient of the tangent to the curve at  $M$ . The MathCAD worksheet utilizes this fact to find the coordinates of  $M$ .

The  $T_{\text{lac}\Delta 1}$  method was defined as exercise intensity preceding a lactate increase of  $\geq 1$  mmol·L<sup>-1</sup> above initial values,<sup>15</sup> with initial values being taken as the value of lactate after the first exercise stage. For  $T_{\text{lac-4 mM}}$  determination, plots of blood lactate concentration against all variables were drawn and values were interpolated from the curve using an algebraic equation, as follows:

$$x = (4x_2 - 4x_1 - x_2y_1 + x_1y_2)/(y_2 - y_1)$$

where

$x$  = the variable, eg, power output, that occurred at 4.0 mmol·L<sup>-1</sup> (the interpolated variable)

$x_1$  = the variable, eg, power output, that occurred at  $y_1$

$x_2$  = the variable, eg, power output, that occurred at  $y_2$

$y_1$  = the lactate concentration that was a value  $< 4.0$  mmol·L<sup>-1</sup> (which occurred at the stage before a value of 4.0 mmol·L<sup>-1</sup> being reached)

$y_2$  = the lactate concentration that was a value  $> 4.0$  mmol·L<sup>-1</sup> (which occurred at the stage after a value of 4 mmol·L<sup>-1</sup> was reached)

All methods of  $T_{\text{lac}}$  determination were described according to power output,  $\text{VO}_2$ , HR and RPE. The lactate concentration at  $T_{\text{lac}\Delta 1}$  and  $D_{\max}$  were also calculated.

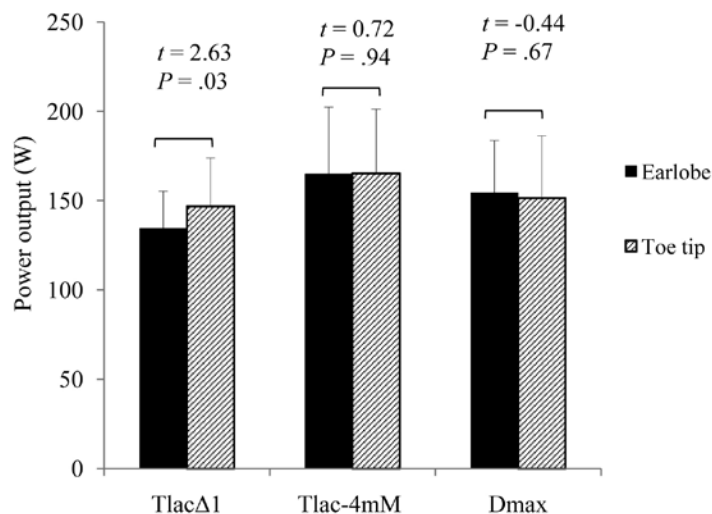
## Statistical Analysis

The experimental design is within subject, since data were collected simultaneously and at one time point. Data are expressed as mean  $\pm$  SD, and described using Pearson product-moment correlation, 95% CI, and LoA<sup>17</sup> between the toe and earlobe for power output at each  $T_{\text{lac}}$  method. A two-way repeated measures ANOVA (method of  $T_{\text{lac}}$  determination  $\times$  sample site) was used to examine differences for all the variables at  $T_{\text{lac}}$ . To compare sample site independently from method (since sample site was the main outcome measure being considered), a paired samples  $t$  test was also conducted for each of the variables measured at each of the  $T_{\text{lac}}$  methods, and to examine differences due to sample site in mean blood lactate concentration for the first and final stages of the exercise protocol. Limits of agreement were calculated using Microsoft Excel, and all other analyses were conducted using SPSS, version 17 (Chicago, IL, USA) for Windows.

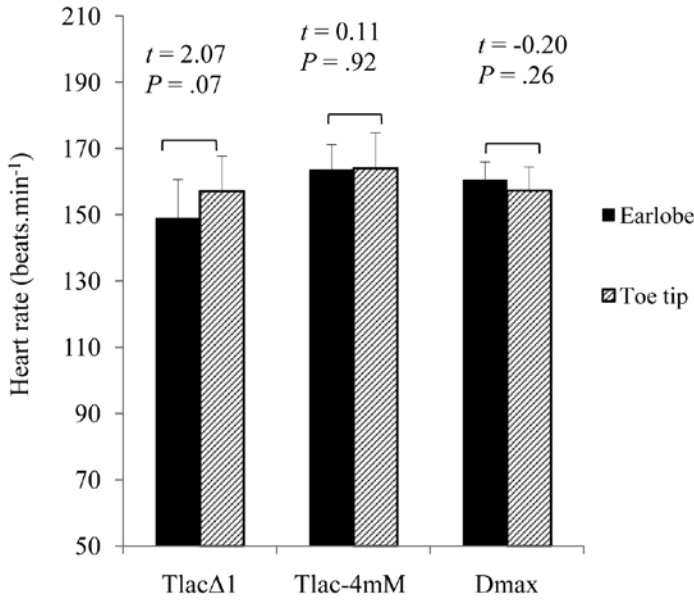
It was estimated that a sample size of 9 would have 80% power to detect a difference in blood lactate concentration between the toe tip and earlobe, assuming a common SD of  $\pm 0.3$  mmol·L<sup>-1</sup>, using a  $t$  test with a .05 two-sided significance level. Data for the power calculation were derived from previous research.<sup>6</sup>

## Results

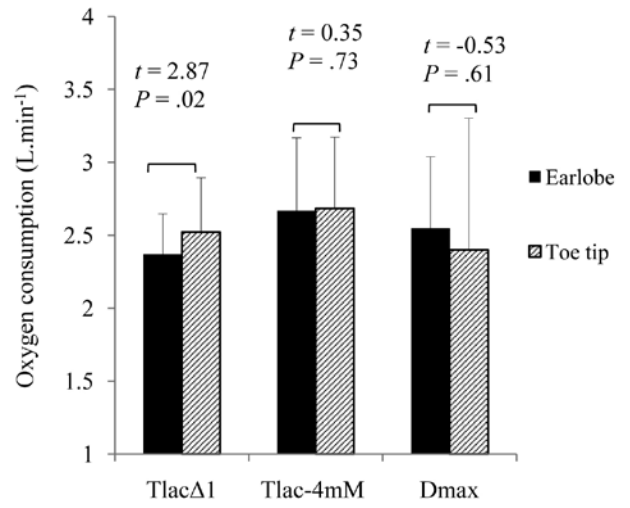
Regarding the methods used for determining  $T_{\text{lac}}$ , there were no cases where  $D_{\max}$ ,  $T_{\text{lac-4 mM}}$  or  $T_{\text{lac}\Delta 1}$  could not be resolved. Based on the results from the ANOVA, there was no significant difference in mean power output at  $T_{\text{lac}}$  according to sample site,  $F(1, 9) = 0.633$ ,  $P = .447$ ; however, there was a difference due to method of  $T_{\text{lac}}$  determination,  $F(1.25, 11.25) = 11.385$ ,  $P = .004$ . Post hoc tests (using Bonferroni correction) for this variable gave a  $P$  value of .016 when comparing the  $T_{\text{lac}\Delta 1}$  method and  $D_{\max}$  method,  $P = .017$  when comparing the  $T_{\text{lac}\Delta 1}$  method and  $T_{\text{lac-4 mM}}$ , and  $P = .085$  when comparing the  $D_{\max}$  method and  $T_{\text{lac-4 mM}}$  method. Similarly, according to the results from ANOVA, when using HR,  $\text{VO}_2$ , RPE, and blood lactate concentration as the variable at  $T_{\text{lac}}$ , there were no significant differences in means of these variables between the earlobe and toe tip. Significant differences were only apparent when comparing the different methods of  $T_{\text{lac}}$  determination:  $F(2, 18) = 7.508$ ,  $P = .004$ , for HR at  $T_{\text{lac}}$ ;  $F(1.12, 10.1) = 5.71$ ,  $P = .035$ , for  $\text{VO}_2$  at  $T_{\text{lac}}$ ;  $F(2, 18) = 4.686$ ,  $P = .023$ , for RPE at  $T_{\text{lac}}$ ; and  $F(1, 9) = 26.98$ ,  $P = .001$ , for blood lactate concentration at  $T_{\text{lac}}$ . From post hoc analysis, the differences due to method of  $T_{\text{lac}}$  determination mainly arose due to mean values at  $T_{\text{lac}\Delta 1}$  being lower than those at  $T_{\text{lac-4 mM}}$  (eg,  $P = .019$  using HR as the descriptive variable). This trend for mean values to be lower at  $T_{\text{lac}\Delta 1}$  compared with when using the other two methods of  $T_{\text{lac}}$  determination is reflected in Figures 1 through 5. When using  $T_{\text{lac}\Delta 1}$ , mean values for power output,  $\text{VO}_2$ , and RPE were significantly lower when the earlobe was used as a sample site compared with mean values when the toe tip was used; these significant results from the paired samples  $t$  test analyses are given in Figures 1 to 4.



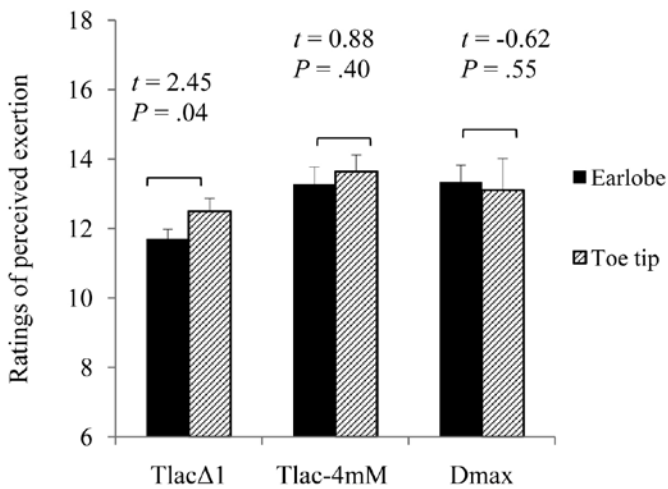
**Figure 1** — Mean  $\pm$  SD (given as error bars) of power output for the three methods of lactate threshold determination ( $T_{\text{lac}\Delta 1}$ ,<sup>15</sup>  $T_{\text{lac-4 mM}}$ <sup>16</sup> and  $D_{\max}$ <sup>13</sup>) when using the earlobe and toe tip as the sample site. Results from the  $t$  test ( $t$  and  $P$ ) are also shown.



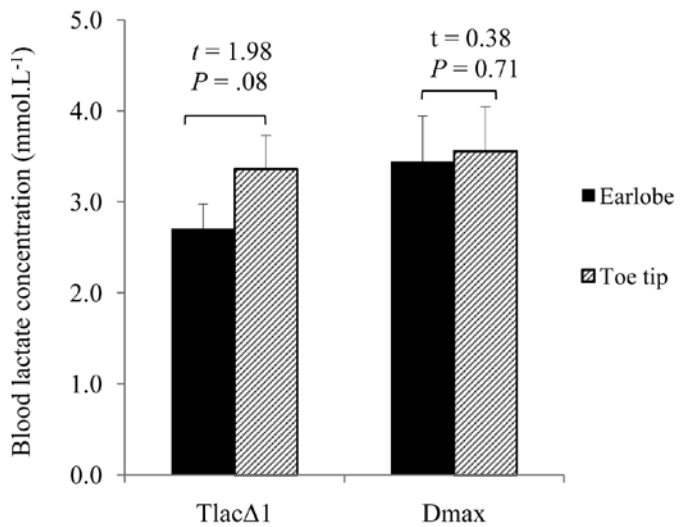
**Figure 2** — Mean  $\pm$  SD (given as error bars) of heart rate for the three methods of lactate threshold determination ( $T_{lac\Delta 1}$ ,<sup>15</sup>  $T_{lac-4\text{ mM}}$ <sup>16</sup> and  $D_{max}$ <sup>13</sup>) when using the earlobe and toe tip as the sample site. Results from the  $t$  test ( $t$  and  $P$ ) are also shown.



**Figure 3** — Mean  $\pm$  SD (given as error bars) of oxygen consumption for the three lactate threshold determination ( $T_{lac\Delta 1}$ ,<sup>15</sup>  $T_{lac-4\text{ mM}}$ <sup>16</sup> and  $D_{max}$ <sup>13</sup>) when using the earlobe and toe tip as the sample site. Results from the  $t$  test ( $t$  and  $P$ ) are also shown.



**Figure 4** — Mean  $\pm$  SD (given as error bars) of ratings of perceived exertion for the three methods of lactate threshold determination ( $T_{lac\Delta 1}$ ,<sup>15</sup>  $T_{lac-4\text{ mM}}$ <sup>16</sup> and  $D_{max}$ <sup>13</sup>) when using the earlobe and toe tip as the sample site. Results from the  $t$  test ( $t$  and  $P$ ) are also shown.



**Figure 5** — Mean  $\pm$  SD (given as error bars) of ratings of blood lactate concentration for two methods of lactate threshold determination ( $T_{lac\Delta 1}$ ,<sup>15</sup>  $T_{lac-4\text{ mM}}$ <sup>16</sup> and  $D_{max}$ <sup>13</sup>) when using the earlobe and toe tip as the sample site. Results from the  $t$  test ( $t$  and  $P$ ) are also shown.

**Table 1 Limits of agreement (LoA), 95% confidence intervals (95% CI), and Pearson correlation (*r*) between earlobe and toe tip samples for the three methods of lactate threshold determination using power output as the descriptive variable**

$T_{lac}$ Method (Earlobe vs Toe Tip)	LoA (W)	95% CI (W)	<i>r</i>
$T_{lac\Delta 1}$	-17.5 to +42.3	+1.71 to +23.1	.84
$T_{lac-4mM}$	-32.9 to +33.7	-11.5 to +12.3	.90
$D_{max}$	-45.1 to +39.2	-18.0 to 12.1	.80

$T_{lac\Delta 1}$ : Lactate threshold determination using an absolute increase of 1 mmol·L<sup>-1</sup> in blood lactate concentration from initial values;<sup>15</sup>  $T_{lac-4mM}$ : Lactate threshold determination using a fixed blood lactate concentration of 4.0 mmol·L<sup>-1</sup>;<sup>16</sup> and  $D_{max}$  continuous model derived by Cheng.<sup>13</sup>

Results from the LoA, Pearson correlation and 95% CI for power output for the three  $T_{lac}$  methods at both the earlobe and toe tip are given in Table 1. Limits of agreement were greater than would be expected when the intensity of exercise is increased by a value equivalent to an increase in  $VO_2$  of 2.76 mL·kg<sup>-1</sup>·min<sup>-1</sup> (the mean increase for the protocol). When using  $T_{lac\Delta 1}$ , LoA and 95% CI for the upper limit were greater than when using other methods of  $T_{lac}$  determination (Table 1).

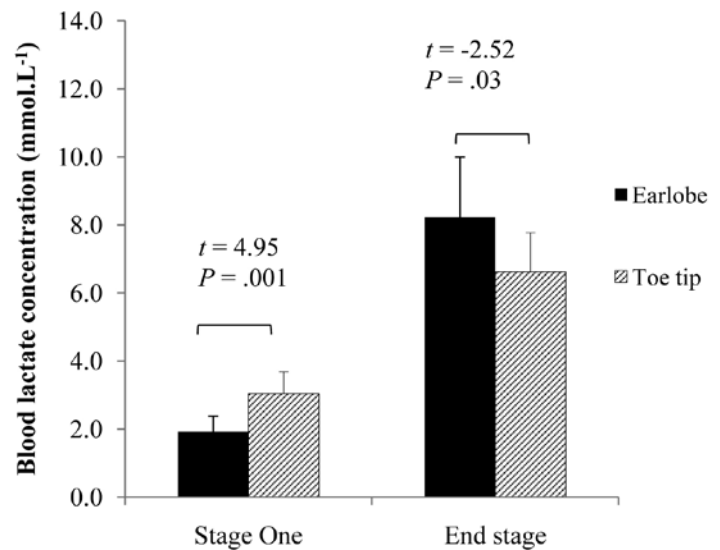
## Discussion

The purpose of the current study was to examine whether possible differences in blood lactate concentration between the toe tip and the earlobe would affect  $T_{lac}$  determination among physically active males. Based on the ANOVA results, mean values for all variables (power output,  $VO_2$ , HR, RPE and blood lactate concentration) at  $T_{lac}$  were similar regardless of whether the toe tip or the earlobe were used. This finding is in agreement with those of others,<sup>5,6</sup> where it has been suggested that the toe tip may be used as a suitable alternative to the earlobe or fingertip from which to collect blood.

In the current study, three methods were used to determine  $T_{lac}$ . Mean values for the variables assessed at  $T_{lac\Delta 1}$  were generally lower than those for  $T_{lac-4mM}$  (Figures 1, 3 and 4). Other authors have also reported  $T_{lac}$  to vary according to the method of  $T_{lac}$  determination.<sup>18,19</sup> Based on the results from the ANOVA in the current study, it can be suggested that the difference in power output, HR and RPE due to the choice of method used to determine  $T_{lac}$  outweighs the difference caused by changing the sample site. Practically, this finding suggests that, in repeat trials using  $T_{lac}$ , it is more important to keep the method of  $T_{lac}$  determination the same than it is to keep the sample site (earlobe or toe tip) the same. When using  $T_{lac\Delta 1}$ , however, mean values for power output,  $VO_2$ , and RPE were significantly lower when the earlobe was used as a sample site compared with mean values when the toe tip was used (Figures 1 through 4). Consideration should, therefore, be given to the choice of sample site (earlobe vs. toe) when  $T_{lac\Delta 1}$ , or a similar method, is used to determine  $T_{lac}$ .

Limits of agreement using any of the methods of  $T_{lac}$  determination exceeded the mean increment of 20.1 W for the protocol (Table 1), which has practical implications for training zone prescription. For instance, the upper limits for the  $T_{lac\Delta 1}$  method were particularly high (Table 1), suggesting that when using this method of  $T_{lac}$  determination, training intensity might be set too low when using the earlobe, and set too high when using the toe tip. If using the  $T_{lac\Delta 1}$  method, keeping to the same sample site is recommended when setting training intensities.

At the first exercise stage, mean lactate concentration, when blood was sampled from the earlobe, was significantly lower than lactate concentration when blood was sampled from the toe tip and the opposite occurred at the highest exercise stage (Figure 6). These findings are in agreement with those of Garland and Atkinson,<sup>6</sup> and may be explained by differences in blood flow and distribution of lactate due to muscle activation patterns in rowing.<sup>6,20</sup>



**Figure 6** — Mean  $\pm$  SD (given as error bars) blood lactate concentration when blood was sampled at the earlobe and the toe tip at the first stage of exercise (Stage One) and the final stage (End stage). Results from the *t* test (*t* and *P*) are also shown.

In experienced rowers, the drive phase is initiated by the extension of the lower legs, followed immediately and sequentially by activation of the trunk and arms.<sup>21</sup> The major muscle groups (the legs and trunk) may be recruited in the earlier stages of exercise,<sup>22</sup> and be the main producers of lactate, with the muscles in the upper body being largely responsible for lactate clearance, which might explain the lower net lactate at the earlobe in the first stage. In the later stages of exercise, when the major muscle groups become fatigued, the smaller muscles of the upper body may be recruited to maintain exercise intensity<sup>22</sup> leading to a higher lactate concentration in the upper body. Changes in lactate production and clearance have previously been put forward to explain differences due to sample site in capillary blood lactate.<sup>6–8,10</sup> Without isotope analysis of lactate kinetics and oxidation, only speculation can be made at changes in net lactate in capillary blood at different sample sites. Further research in lactate kinetics during rowing is warranted to explain the differences in earlobe and toe tip blood lactate concentration that were observed at the first stage and the final stage of the exercise protocol.

There are some limitations associated with the current study. The short pause at the end of each exercise stage, and the technique of analyzing the blood for lactate, whereby blood was analyzed with the same analyzer but with one of the samples being temporarily stored, may have caused errors in blood lactate determination. The storage of the toe tip sample might explain the higher blood lactate concentration for the toe tip compared with the earlobe sample at the higher exercise intensity, if it is assumed that glycolysis was still occurring while the sample was being stored; however, in pilot testing, differences due to storage were not found to be apparent. These limitations in design could not be overcome, since a pause was needed to take the earlobe samples, and the delay in assay was necessary to ensure that the same lactate analyzer could be used. An additional limitation was that only recreationally active males were used in the study. Different patterns of muscle recruitment may occur between nonrowers and rowers,<sup>22</sup> which may result in changes in glycolysis and net lactate concentration. A further limitation is that, from a practical point of view, the results are confined to ergometry rowing; further research would be needed to determine whether or not blood samples can practically be taken on water using the toe and then used for comparison with samples taken in the laboratory. Advantages of the study are that different methods of  $T_{lac}$  determination were used, and that the  $D_{max}$  method for determining  $T_{lac}$  was included; this method has been found to have good agreement, compared with models that rely on breakpoints.<sup>14,19</sup> Although it was useful to include several methods of  $T_{lac}$  determination, the methods are limited in that they do not provide any indication as to what is happening physiologically. Morton et al<sup>23</sup> for instance, claimed that using models to fit data in order to detect a threshold should be regarded with caution, since the models are phenomenological—

they model the data, rather than considering why the data are produced. The intention of the study was not to question why  $T_{lac}$  occurred, or what  $T_{lac}$  signifies with regards to rowing performance. Further research is, therefore, also required on whether an assessment of  $T_{lac}$  using the toe tip as the sample site is relevant for predicting rowing performance or for validating the use of the  $T_{lac}$  methods against maximal lactate steady state.

## Practical Application

On the rowing ergometer, if using blood lactate parameters to assess endurance capability or set training intensities, it would make more sense to use the toe tip (rather than the earlobe) as a sampling site, since blood samples can be taken without the rower having to stop, or without interfering with the rowing stroke. Based on the current results, there was more variation due to method of  $T_{lac}$  determination than there was due to whether the toe tip or the earlobe was used as the sampling site. If determining  $T_{lac}$  using  $T_{lac\Delta 1}$  or if examining blood lactate concentration at a low or high exercise intensity, care should be taken to ensure that the toe tip is not used interchangeably with the earlobe, due to differences in blood lactate concentration observed between these two sites.

## Conclusions

Measuring blood lactate concentration in rowing is important owing to the contribution of the glycolytic energy system in a 2000 m event,<sup>24</sup> and owing to the importance of  $T_{lac}$  in determining 2000 m ergometry rowing performance.<sup>25</sup> There is, therefore, a need to find a method of attaining a lactate value from capillary blood during rowing whereby the rower does not have to stop, and using the toe tip would aid this process. Lactate concentration was lower at the toe tip compared with the earlobe at a low exercise intensity, resulting in differences in  $T_{lac\Delta 1}$ . Differences between samples taken from the earlobe and the toe tip did not affect  $T_{lac}$  when determined using the  $D_{max}$  and  $T_{lac-4mM}$  methods. The toe tip can be used as a suitable sample site for  $T_{lac}$  determination when using these two methods.

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