Software for calculating blood lactate endurance markers

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(Accepted 21 November 2006)

Abstract
Blood lactate markers are used as summary measures of the underlying model of an athlete's blood lactate response to increasing work rate. Exercise physiologists use these endurance markers, typically corresponding to a work rate in the region of high curvature in the lactate curve, to predict and compare endurance ability. A short theoretical background of the commonly used markers is given and algorithms provided for their calculation. To date, no free software exists that allows the sports scientist to calculate these markers. In this paper, software is introduced for precisely this purpose that will calculate a variety of lactate markers for an individual athlete, an athlete at different instants (e.g. across a season), and simultaneously for a squad.

Keywords: Lactate curves, endurance markers, software

Introduction
A typical lactate curve is quite flat at low exercise intensities until, as the intensity of the exercise increases, a metabolic rate is reached above which the blood lactate response to increasing exercise intensity is curvilinear. Specific features of the lactate curve (i.e. blood lactate endurance markers) are used as to summarize an athlete's blood lactate response to increasing work rate. Exercise physiologists use these endurance markers, typically corresponding to a work rate in the region of high curvature in the lactate curve, to predict and compare endurance ability (Bourdon, 2000).

Bentley, Newell, and Bishop (in press) provide a comprehensive review of blood lactate markers in general with particular emphasis on the affects of modifying an incremental exercise protocol on maximal and submaximal physiological variables related to endurance performance. In particular, it is common for lactate markers to be measured during incremental exercise tests where the stage duration of each work increment is markedly different, ranging between 3 and 8 min, and it is noted that prolonging the stage duration during an incremental exercise test affects the work intensity measured at the lactate markers.

The main controversy surrounding blood lactate analysis, however, is whether there is a breakpoint (i.e. a lactate threshold) present in the lactate curve (Beaver, Wasserman, & Whipp, 1985; Cheng et al., 1992; Davis, Vodak, Wilmore, Vodak, & Kurtz, 1976; Heck et al., 1985; Stegmann, Kindermann, & Schnabel, 1981; Yoshida, Chida, Ichoka, & Suda, 1987) or whether a lactate curve is simply a smooth monotonically increasing function (Hughson, Weisiger, & Swanson, 1987).

Several authors (Bishop, Jenkins, Carey, & McEnier, 2000; Bishop, Jenkins, & Mackinnon, 1998; Brooks, 1985; Campbell, Hughson, & Green, 1989; Hughson et al., 1987; Tokmakidis & Leger 1991) discuss the controversy surrounding the presence of such a threshold. The existence and physiological meaning of the proposed change point has been debated in the literature (Anderson & Rhodes, 1989; Brooks, 1985; Coyle, 1995; Loat & Rhodes, 1993; McLelllan, 1985; Meyer et al., 1996; Walsh & Banister, 1988; Wasserman, Whipp, Koyal, & Beaver, 1973). Note that the presence of a breakpoint implies a discontinuity in the first derivative of the lactate curve. This assumption does not imply that the lactate curve itself is non-continuous, as highlighted by Morton (1989).
Several additional lactate markers have been suggested, where it is assumed that the lactate curve is a smooth process (Cheng et al., 1992; Heck et al., 1985; Kindermann, Simon, & Kuel, 1979; Newell, Einbeck, Madden, & McMillan, 2005; Newell, McMillan, Grant, & McCabe, 2006; Thoden, 1991). There is a tendency in the literature to refer to these markers incorrectly as “lactate thresholds” rather than “endurance markers” (Noakes, 2003). The lactate threshold is a particular marker referring to the presence of a breakpoint, whereas an endurance marker is a general term used to represent any single summary statistics derived from an estimated blood lactate curve.

Papers have appeared in the literature that aim to identify the “best” lactate marker in terms of predicting endurance performance, typically using performance data obtained in a time trial (Bentley, McNaughton, Thompson, Vleck, & Batterham, 2001; Bishop et al., 1998, 2000; Farrell, Wilmore, Coyle, Billing, & Costill, 1979; Grant, Craig, Wilson, & Aitchison, 1997; Hoogeveen & Schep, 1997; Lehmann, Berg, Kapp, Wessinghage, & Keul, 1983; Zhou, Robson, King, & Davie, 1997). On the basis of the results presented in these papers, there is no consistent best marker.

To date, no free software exists to calculate these markers. In this paper, software is introduced for precisely this purpose. In particular, the software will allow sport scientists to calculate a variety of lactate markers for an individual player, a player at different instants (e.g. across a season), and simultaneously for a team.

Methods

The algorithms used to estimate the markers in question are now presented.

1. Lactate threshold (LT)

Traditionally, the lactate threshold was determined subjectively from plots of the lactate concentration versus work rate by visually identifying the treadmill velocity or work rate that best corresponds to a departure from a linear baseline pattern. Lundberg, Hughson, Weisiger, Jones, and Swanson (1986) proposed fitting a linear spline where the lactate threshold is the estimated work rate corresponding to the location of the knot (i.e. the point of intersection between the two linear splines). The location of the knot and the parameters of the lines are estimated by minimizing the sum of the squared differences between the observed lactate values and the fitted values.

Under this model it is assumed that the relationship between blood lactate $L$ and work rate $w$ for individual $i$ is given by

$$ L_{1i} = \beta_0 + \beta_1 w_i + \beta_2 (w_i - LT)_+ + \varepsilon_i $$  \hspace{1cm} (1.1)

(for $i = 1, \ldots, N$ individuals, $j = 1, \ldots, n_i$ work rates)

where the error term $\varepsilon$ is assumed independently distributed with mean zero and finite variance. Note that the notation $(\ldots)_+$ means the positive part of the argument. This model is an example of a “broken stick” regression model, with the “break” (i.e. knot) occurring at the lactate threshold (Neter, Kutner, Nachtsheim, & Li, 2005). The value of the lactate threshold can be estimated using simple linear regression by fitting model (1.1) and identifying the work rate $LT$ corresponding to the model with minimum mean squared error.

A log transformation of both the work rate and blood lactate concentration has been suggested ($LT_{loglog}$) in an attempt to gain a better estimate of the lactate threshold (Beaver et al., 1985).

2. DMMax

This marker corresponds to the work rate corresponding to the point that yields the maximum perpendicular distance from a line $L_2$, joining the first and last lactate measurements to the estimated lactate curve $L_3$ (Cheng et al., 1992).

The line $L_2$ joining the first and last lactate measurements can be estimated using simple linear regression:

$$ L_{2i} = \beta_0 + \beta_1 w_i + \varepsilon_i $$  \hspace{1cm} (2.1)

(for $i = 1, \ldots, N$ individuals, $j = 1, n_i$ work rates only)

An estimate of the true lactate curve is calculated by fitting a polynomial regression model (typically of degree 3)

$$ L_{3i} = \beta_0 + \beta_1 w_i + \beta_2 w_i^2 + \beta_3 w_i^3 + \varepsilon_i $$  \hspace{1cm} (2.2)

(for $i = 1, \ldots, N$ individuals, $j = 1, \ldots, n_i$ work rates)

The point of maximum perpendicular distance from $L_2$ and $L_3$ corresponds to the work rate $w_{DMax}$ where

$$ \frac{dL_2}{dw} = \frac{dL_3}{dw} $$

(i.e. the work rate where the first derivatives of $L_2$ and $L_3$ are equal).
3. **Fixed blood lactate concentration (FBLC)**

This marker is the work rate corresponding to a fixed blood lactate concentration, typically 4 mmol \(\cdot\) \(\text{L}^{-1}\) (Heck et al., 1985; Kindermann et al., 1979). It is calculated using inverse prediction by finding the work rate \(w\) (in model 2.2) corresponding to a lactate value equal to the FBLC.

4. **Fixed rise post baseline (FRPB)**

This marker (Thoden, 1991) corresponds to a work rate preceding an increase in lactate concentration of a fixed rise post baseline (e.g. 1 mmol \(\cdot\) \(\text{L}^{-1}\) from baseline). Let \(L_{\text{baseline}}\) represent the lactate reading at baseline. The FRPB marker is calculated by finding the work rate \(w\) corresponding to a selected rise from baseline (e.g. 1 mmol \(\cdot\) \(\text{L}^{-1}\)):

\[ \hat{L}_{3j} - L_{\text{baseline}} = \text{FRPB} \]

A variation of this marker (the technical error in measurement, TEM) exists that represents the work rate preceding an increase in lactate concentration greater than the determined error of measurement of the lactate analyser. It is calculated in the same manner as the FRPB by finding the minimum work rate \(w\), such that:

\[ \hat{L}_{3j+1} - \hat{L}_{3j} > \text{TEM} \]

(for \(j = 1, \ldots, n - 1\) work rates)
5. **D2LMax**

This marker (Newell et al., 2005, 2006) represents the work rate corresponding to the point of maximum acceleration of the estimated underlying lactate curve (i.e. the maximum of the second derivative of the lactate curve). It is assumed that the lactate data for the $i$th individual can be modelled as a smooth function $L_i$ of the work rate $w_{ij}$ as

$$L_{\text{smooth},ij} = L_i(w_{ij}) + e_{ij}$$

(for $i = 1, \ldots, N$ individuals, $j = 1, \ldots, n_i$ work rates)

and that second derivatives of lactate with respect to workload can be evaluated. Smoothing procedures involving polynomial or B-splines are becoming increasingly popular alternatives when interest involves estimating the second derivative of a curve constructed with no parametric model assumptions. The smoothing procedure chosen must also take into account that smooth estimates of the first two derivatives of the lactate curve $L_{\text{smooth}}$ are required. Penalized smoothing splines (Ramsay & Silverman, 1997) using polynomials of degree 4 are one such choice in order to have a continuous second derivative. A value for the smoothing parameter must also be provided in addition to the chosen degree of the polynomial required. Previous research (Newell et al., 2005, 2006) suggested that choosing the smoothing parameter corresponding to $n - 3$ degrees of freedom should be adequate.

The work rate corresponding to the maximum of the $D^2L_{\text{smooth}}(w)$ is calculated as

$$D2LMax = \max(D^2L_{\text{smooth}}(w))$$

A simple approximation of the D2LMax is easily obtained by finite differences of second order by...
identifying the corresponding work rate to the lactate reading where

$$D_{2\text{LMax}}_{\text{Discrete}} = \max (L_{w+2} - 2L_{w+1} + L_w)$$

(for $w = 1, \ldots, n-2$)

It should be noted that the $D_{2\text{LMax}}_{\text{Discrete}}$ will always correspond to a work rate where data were collected.

**The software**

Code is available to calculate the various markers described above in the form of an Excel template (Microsoft Excel 2003) and as a function in R, a freely available statistics package (http://www.cran.r-project.org). Due to the unavailability of smoothing routines in Excel, the current version of the Excel code does not calculate the $D_{2\text{LMax}}$ marker, whereas the code provided for R calculates all the markers.

Markers may be calculated for a single athlete (Figures 1 and 2), the same athlete at different instants (Figure 3), or collectively for a squad of athletes. The squad analysis allows the sports scientist to calculate the various markers for the complete squad in one batch. In addition to a report for each player individually, a dataset with the estimated lactate markers for the squad is generated. Interpolated estimates of variables such as oxygen uptake ($\dot{V}O_2$) and rating of perceived exertion at the lactate marker work rates are available also (Figure 1).

The software is available for download (http://www.nuigalway.ie/maths/jn/Lactate) and includes a tutorial page for each platform.

**Conclusion**

Blood lactate endurance markers are statistics representing unique features of a blood lactate curve. These markers are typically used to monitor the training status of athletes and to assist in individualized training programmes. A short theoretical background for commonly used blood lactate markers is given for each marker and references are provided so
that the reader can investigate each marker in more detail.

This paper provides a useful preliminary background for the exercise physiologist who wishes to carry out blood lactate testing on a regular basis. The package will enable the sports physiologist to determine blood lactate markers objectively and easily and is likely to be a useful addition to the sports physiologist’s armoury.

Acknowledgements

The lead author gratefully acknowledges the assistance provided by the National University of Ireland, Galway Millennium Research Fund. The authors wish to acknowledge the useful comments made by reviewers.

References


Lactate-E 2.0 Help

- Starting Lactate-E
- Closing Lactate-E
- Performing a single analysis (Single mode)
- Analysing more than one athlete's data (Team mode)
- Analysing one athlete's data over time (Timeline mode)
- Arranging the data
- The options pane
  - The markers (parametric and non-parametric)
  - The graphs
  - The training zones
- References

Disclaimer:

This software eases the calculation of lactate endurance markers. Results should only be interpreted by a trained professional. Microsoft Excel was chosen as the program environment in order to increase the ease of use of the software. Due to the nature of Excel however, some markers will on occasion be miscalculated, such mistakes should be easy for a professional to recognise but not for the lay user.

Starting Lactate-E

In order to start Lactate-E first open Microsoft Excel. Ensure that Macros are enabled by clicking on Macro on the Tools menu and selecting Security. The security level must be set to Medium or lower for Lactate-E to be allowed to run. Now, to start Lactate-E, from the Excel File menu click on Open. In the dialog box navigate to the folder into which you installed Lactate-E. Select the file Lactate-E.xls and click Open. If a security warning appears you must select Enable Macros in order for Lactate-E to run. The Lactate-E worksheet should appear and a message box should pop up stating, "Lactate Analysis Software Installed." A new menu will also be installed in the toolbar entitled Lactate Analysis. This menu can be used to access the features of the software.

Closing Lactate-E

In order to close Lactate-E first ensure that all Lactate-E dialog boxes are closed, by clicking Cancel on them. Then, with the Lactate-E worksheet open in front of you, click on Close from the File menu. You should be left with a blank Excel window, with no worksheet open in it, in front of you. You are now free to work on other problems or close Excel entirely. Please note if your intention is to exit Excel entirely it is ok to choose Exit from the File menu while the Lactate-E worksheet is still open. Lactate-E will be automatically closed before the window exits.

Performing a single analysis (Single mode)

Single mode can be used to calculate the lactate endurance markers for a single athlete at a time. In addition to calculating the endurance markers it can produce graphs of workload vs lactate, workload vs heartrate and a combined graph of both of the previous graphs. It can also be used to calculate training zones according to a number of schemes published in the literature.

In order to analyse the data from a single athlete follow this step by step procedure:

1. Arrange Data
2. Choose "Single Analysis" from the Lactate Analysis drop down menu in the Excel menubar.
3. Choose your desired **Options**.
Lactate-E saves your options between uses so if you wish to use your last options again you can skip this step.

4. **Select workload values**.
In the lactate analysis program box, click the mouse cursor in the range box to the right of the label for "Workload:" then select the workloads at which the athlete was measured in the test. As you are selecting the workloads the athlete was measured at you should see text appearing in the range box similar to that in this picture.

5. **Select lactate values**.
Click the mouse cursor in the range box to the right of the label for "Lactate:". Select the recorded lactate values, following the same procedure as with selecting the workload values.

6. **Choose workload units of measurement**.
In the dropdown box to the right of the workloads range box select the units of measurement that the workload was measured in. If a suitable unit is not available it is possible to type it directly into the dropdown box.

**Optionally:**

7. **Enter baseline lactate value**.
In the box labelled "Baseline Lactate Value:" you may enter a resting lactate value for the athlete, if recorded. Some of the markers will use this as the baseline above which rises are measured. If you do not enter a value in this box the first recorded lactate value is taken as the baseline value.

8. **Select heart rate values**.
If heart rate values were recorded during testing, click the mouse cursor in the range box to the right of the "Heart Rate Values:" label. Then select the heart rate values using the same procedure as that for the workload and lactate values.

9. **Select VO₂ values**.
If VO₂ values were recorded during testing, click the mouse cursor in the range box to the right of the "VO₂ Values:" label. Then select the VO₂ values using the same procedure as that for the workload and lactate values.

10. **Choose VO₂ units of measurement**.
In the dropdown box to the right of the VO₂ range box select the units of measurement that the VO₂ uptake was measured in. If a suitable unit is not available it is possible to type it directly into the dropdown box.

**Finally:**

11. Click the button labelled "Next"
If you wish to cancel at any stage click the button labelled "Cancel".
Analysing more than one athlete's data (Team mode)

Team mode can be used to calculate the individual lactate endurance markers for a group of athletes all at once. In addition to calculating the endurance markers it can produce graphs of workload vs lactate, workload vs heart rate and a combined graph of both of the previous graphs. It can also be used to calculate training zones according to a number of schemes published in the literature.

In order to analyse the data from a group of athletes follow this step by step procedure:

1. **Arrange Data**
2. Choose "Team Analysis" from the Lactate Analysis drop down menu in the Excel menu bar.
3. Choose your desired Options. Lactate-E saves your options between uses so if you wish to use your last options again you can skip this step.
4. Select workload values.
   In the lactate analysis program box, click the mouse cursor in the range box to the right of the label for "Workload:" then select the workloads at which the athlete was measured in the test. As you are selecting the workloads the athlete was measured at you should see text appearing in the range box similar to that in this picture.

5. Select lactate values.
   Click the mouse cursor in the range box to the right of the label for "Lactate:". In selecting the recorded lactate values there are two alternative procedures you may follow. You may simply select all of the lactate values; which should have the same number of rows as the workload values and one column corresponding to each athlete. Or you may wish to top each column of lactate values with a name or other label to identify the athlete those values belong to, you can then select the row of labels along with the block of lactate values; in this case the lactate data will have one row more than the workload data and one column corresponding to each athlete.

Note: When working with multiple athlete's data the athletes may not have performed the tests at the same workload values, it is ok if the differences are only on the higher or lower ends of the workloads, but there cannot be any gaps in the middle of the table of lactate values (See Arranging the Data). If there are gaps the athletes' sessions must be analysed separately. It is also important to select a full rectangular area of lactate values even if some columns don't extend fully to the top or bottom of the selected area, as long as at least one column extends to each margin.

6. Choose workload units of measurement.
In the dropdown box to the right of the workloads range box select the units of measurement that the workload was measured in. If a suitable unit is not available it is possible to type it directly into the dropdown box.

Optionally:
7. Enter baseline lactate value.
   In the box labelled "Baseline Lactate Value:" you may enter a resting lactate value for the athletes, if recorded. Some of the markers will use this as the baseline above which rises are measured. Only one value may be entered in this box so it is unlikely to be of much use with a group of athletes. If you do not enter a value in this box the first recorded lactate value, for each athlete, is taken as their individual baseline value.
8. Select heart rate values.
   If heart rate values were recorded during testing, click the mouse cursor in the range box to the right of the "Heart Rate Values:" label. Then select the heart rate values using the same procedure as that for the lactate values.
9. Select VO2 values.
   If VO2 values were recorded during testing, click the mouse cursor in the range box to the right of the "VO2 Values:" label. Then select the VO2 values using the same procedure as that for the lactate values.
10. Choose VO2 units of measurement.
    In the dropdown box to the right of the VO2 range box select the units of measurement that the VO2 uptake was measured in. If a suitable unit is not available it is possible to type it directly into the dropdown box.

Finally:
11. Click the button labelled "Next"

If you wish to cancel at any stage click the button labelled "Cancel".

**Analysing one athlete's data over time (Timeline mode)**

Timeline mode can be used to calculate the lactate endurance markers for multiple testing sessions for a single athlete. In addition to calculating the endurance markers it can produce graphs of workload vs lactate and workload vs heart rate.

In order to analyse the data from an athlete follow this step by step procedure:

1. **Arrange Data**
2. Choose "Timeline Analysis" from the Lactate Analysis drop down menu in the Excel menubar.
3. Choose your desired Options.
   Lactate-E saves your options between uses so if you wish to use your last options again you can skip this step.
4. Select workload values.
   In the lactate analysis program box, click the mouse cursor in the range box to the right of the label for "Workload:" then select the workloads at which the athlete was measured in the test. As you are selecting the workloads the athlete was measured at you should see text appearing in the range box similar to that in this picture.
5. Select lactate values.
Click the mouse cursor in the range box to the right of the label for "Lactate". In selecting the recorded lactate values there are two alternative procedures you may follow. You may simply select all of the lactate values; which should have the same number of rows as the workload values and one column corresponding to each testing session. Or you may wish to top each column of lactate values with a date or other label to identify the testing session those values belong to, you can then select the row of labels along with the block of lactate values; in this case the lactate data will have one row more than the workload data and one column corresponding to each testing session.

Note: When working with tests over time the athlete may not have performed each test at the same workload values, it is ok if the differences are only on the higher or lower ends of the workloads, but there cannot be any gaps in the middle of the table of lactate values (See Arranging the Data). If there are gaps the testing sessions must be analysed separately. It is also important to select a full rectangular area of lactate values even if some columns don't extend fully to the top or bottom of the selected area, as long as at least one column extends to each margin.

6. Choose workload units of measurement.
In the dropdown box to the right of the workloads range box select the units of measurement that the workload was measured in. If a suitable unit is not available it is possible to type it directly into the dropdown box.

Optionally:

7. Enter baseline lactate value.
In the box labelled "Baseline Lactate Value:" you may enter a resting lactate value for the athlete, if recorded. Some of the markers will use this as the baseline above which rises are measured. Only one value may be entered in this box so it is unlikely to be of much if there is a long interval between the tests. If you do not enter a value in this box the first recorded lactate value, for each testing session, is taken as that session's baseline value.

8. Select heartrate values.
If heart rate values were recorded during testing, click the mouse cursor in the range box to the right of the "Heart Rate Values:" label. Then select the heart rate values using the same procedure as that for the lactate values.

9. Select VO2 values.
If VO₂ values were recorded during testing, click the mouse cursor in the range box to the right of the "VO₂ Values:" label. Then select the VO₂ values using the same procedure as that for the lactate values.

10. Choose VO₂ units of measurement.
In the dropdown box to the right of the VO₂ range box select the units of measurement that the VO₂ uptake was measured in. If a suitable unit is not available it is possible to type it directly into the dropdown box.

Finally:

11. Click the button labelled "Next"

If you wish to cancel at any stage click the button labelled "Cancel".

Back

Arranging the data

In order to allow Lactate-E to know which workloads correspond to which lactate values it is important to correctly arrange the data prior to analysis. Unless otherwise stated Lactate-E assumes the data is arranged in columns, with the top element in the column corresponding to the first recording during testing and the bottom entry corresponding to the final recording during testing. All elements in between should be in the order they were recorded during testing.

We suggest the following layout for Simple Mode:

<table>
<thead>
<tr>
<th>Workload</th>
<th>Lactate</th>
<th>Heart Rate</th>
<th>VO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>1.8</td>
<td>150</td>
<td>3.7</td>
</tr>
<tr>
<td>11</td>
<td>1.8</td>
<td>158</td>
<td>3.9</td>
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<tr>
<td>12</td>
<td>1.9</td>
<td>167</td>
<td>4.2</td>
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<tr>
<td>13</td>
<td>2.2</td>
<td>177</td>
<td>4.3</td>
</tr>
<tr>
<td>14</td>
<td>2.6</td>
<td>183</td>
<td>4.6</td>
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<tr>
<td>15</td>
<td>5.1</td>
<td>185</td>
<td>4.6</td>
</tr>
<tr>
<td>16</td>
<td>6.6</td>
<td>191</td>
<td>4.7</td>
</tr>
</tbody>
</table>

In Team Mode it is important that the lactate values are organised in a block, with the heart rate values in a separate block and the VO₂ values in another block. We find it useful to label each column with a player id, Lactate-E can use the player ids to label the individual results output. We suggest the following layout for your data:

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
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<tbody>
<tr>
<td></td>
<td>Speed (km/h)</td>
<td>Player 1</td>
<td>Player 2</td>
</tr>
<tr>
<td>1</td>
<td>10</td>
<td>2.3</td>
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<td>2</td>
<td>11.5</td>
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<td>3</td>
<td>11.5</td>
<td>2.1</td>
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<td>12.5</td>
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<td>182</td>
<td>182</td>
<td></td>
</tr>
</tbody>
</table>

As can be seen from the image if one athlete is measured at a lower workload than the other athletes then blank cells must be left at this workload for the other athletes. Likewise if an athlete, or athletes, is measured at a workload higher than the other athletes blanks must be left for the athletes who did not perform the test at that workload. Note: Blanks can not be left in the middle of an athlete's test data, if an athlete does not perform the test at the same intervals as the other athletes then their data must be analysed.
In **Timeline Mode** the data must be arranged as in **Team Mode**. We suggest that each column of lactate data is headed by an identifier such as the date of testing or a label in order to identify each set of results in the final output. Example of data arrangement for Timeline Mode:

<table>
<thead>
<tr>
<th>Speed (km/h)</th>
<th>Test 1</th>
<th>Test 2</th>
<th>Test 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>12.5</td>
<td>0.7</td>
<td>0.8</td>
<td>0.6</td>
</tr>
<tr>
<td>13</td>
<td>0.7</td>
<td>0.8</td>
<td>0.35</td>
</tr>
<tr>
<td>13.5</td>
<td>0.7</td>
<td>0.9</td>
<td>0.6</td>
</tr>
<tr>
<td>14</td>
<td>0.7</td>
<td>0.8</td>
<td>0.5</td>
</tr>
<tr>
<td>14.5</td>
<td>1.15</td>
<td>0.95</td>
<td>0.6</td>
</tr>
<tr>
<td>15</td>
<td>1.3</td>
<td>1</td>
<td>0.8</td>
</tr>
<tr>
<td>15.6</td>
<td>1.75</td>
<td>1.5</td>
<td>0.95</td>
</tr>
<tr>
<td>16</td>
<td>2.5</td>
<td>2</td>
<td>1.15</td>
</tr>
<tr>
<td>16.5</td>
<td>3.25</td>
<td>2.45</td>
<td>1.0</td>
</tr>
<tr>
<td>17</td>
<td>4.4</td>
<td>3.4</td>
<td>2.4</td>
</tr>
<tr>
<td>17.5</td>
<td>5.65</td>
<td>5</td>
<td>3.4</td>
</tr>
<tr>
<td>18</td>
<td></td>
<td></td>
<td>4.86</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Heart Rate 1</th>
<th>Heart Rate 2</th>
<th>Heart Rate 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>117</td>
<td>117</td>
<td>117</td>
</tr>
<tr>
<td>128</td>
<td>128</td>
<td>128</td>
</tr>
<tr>
<td>130</td>
<td>130</td>
<td>130</td>
</tr>
<tr>
<td>131</td>
<td>131</td>
<td>131</td>
</tr>
<tr>
<td>140</td>
<td>140</td>
<td>140</td>
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<tr>
<td>143</td>
<td>143</td>
<td>143</td>
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<tr>
<td>152</td>
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<td>160</td>
<td>160</td>
<td>160</td>
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<tr>
<td>162</td>
<td>162</td>
<td>162</td>
</tr>
<tr>
<td>166</td>
<td>166</td>
<td>166</td>
</tr>
<tr>
<td>172</td>
<td>172</td>
<td>172</td>
</tr>
</tbody>
</table>

**The Options Pane**
There are a number of different sections in the Options Pane of Lactate-E. The top half of the box controls which lactate markers are calculated, and if the markers have parameters which can be modified they can be set here. The next section of the box controls which charts will be produced alongside the markers. The final section controls the calculation of training zones.

Checkboxes and radio buttons control whether an individual feature is enabled or disabled. Click on them to enable/disable a feature. The modifiable parameters are better explained in the markers section of this help file, once you understand their operation enter the new parameter value in the appropriate textbox.

Click the button labelled "Save" to keep changes for future (and current) use.
Click the button labelled "Cancel" to discard changes and return to the main Lactate-E screen.

The Markers

Click on the checkboxes to enable or disable which markers are calculated. Those that take parameters can be modified by entering the new parameter in the textbox beside the marker checkbox.

Non-parameterised markers

- Lactate Threshold. We use a broken stick model to solve the lactate threshold marker. We divide the recorded workload/lactate pairs into two groups and draw a straight line through each group of points. By varying the membership of the groups we minimise the sum of the squared error between the lines and the points they fit. The lactate threshold marker is the intersection point of the two lines where the sum of the squared error is a minimum.
- Log-log Lactate Threshold is calculated in the same manner as the Lactate threshold marker but the log of the workloads and lactate values are used instead of the original measured values.
- Dmax. The workload/lactate pairs are interpolated by a degree three polynomial. We also draw a straight line between the first workload/lactate pair and the last workload lactate pair. The Dmax marker is the point on the interpolated line parallel to the straight line.
- Modified Dmax is calculated in a similar manner to the Dmax but the straight line is drawn from the recorded workload/lactate pair directly preceding a 0.4mmol rise in lactate, to the highest workload/lactate pair, instead of from the first workload/lactate pair.
- Adapt LT1 is the recorded workload directly preceding a 0.4mmol rise in lactate above baseline.
Parameterised markers
The parameterised markers all use a degree three polynomial to interpolate the workload/lactate points. From this we can calculate the workload corresponding to any lactate value. In the following descriptions \(x\) corresponds to the variable entered in the textbox in the options pane corresponding to the marker under description.

- Initial Rise is the workload corresponding to the baseline lactate value plus \(x\).
- Technical Error of Measurement (TEM) is used to measure when the blood lactate value has changed by more than the limit of measurement of the testing equipment. It is the workload corresponding to the baseline lactate value plus \(x\).
- Fixed Blood Lactate Accumulations, of which it is possible to calculate 5 at a time with our software, are the workloads corresponding to \(x\).

Back

The Graphs

Any combination of the following three graphs can be produced for an individual athlete's results in either Single Mode or Team Mode operation. In Timeline Mode only the first two graphs can be produced. Simply click on the check box, so that a tick mark appears, in the Charts section of the option pane for the graphs you wish displayed, as in the following picture:

If no heartrate values are available for an athlete then the graphs containing heartrates will not be drawn, even if the checkbox is ticked.

Graph of workload against lactate values:

![Graph of workload against lactate values](image1)

Graph of workload against heartrate values:

![Graph of workload against heartrate values](image2)

Combined graph of workload against lactate and heartrate values:

![Combined graph of workload against lactate and heartrate values](image3)
The Training Zones

Training zones are calculated from the heart rate values as follows:

AIS/Adapt Method

LT₁ = Heart rate equivalent to 0.4 mmol rise in lactate above baseline.
LT₂ = Heart rate equivalent to Modified Dmax marker.

\[ z₁: \quad x < LT₁ \]
\[ z₂: \quad LT₁ < x < LT₁ + \frac{(LT₂ - LT₁)}{2} \]
\[ z₃: \quad LT₂ - \frac{(LT₂ - LT₁)}{2} < x < LT₂ \]
\[ z₄: \quad LT₂ - 3 < x < LT₂ + 3 \]
\[ z₅: \quad x > LT₂ + 4 \]

AIS/VCP Method

LT₂ = Heart rate equivalent to Modified Dmax marker.

\[ z₁: \quad x < 80\% LT₂ \]
\[ z₂: \quad 81\% LT₂ < x < 85\% LT₂ \]
\[ z₃: \quad 86\% LT₂ < x < 95\% LT₂ \]
\[ z₄: \quad 96\% LT₂ < x < 102\% LT₂ \]
\[ z₅: \quad x > 103\% LT₂ \]

Coggan Method

LT₁ = Heart rate equivalent to 1 mmol rise in lactate above baseline.

\[ z₁: \quad x < 68\% LT₁ \]
\[ z₂: \quad 69\% LT₁ < x < 83\% LT₁ \]
\[ z₃: \quad 84\% LT₁ < x < 94\% LT₁ \]
\[ z₄: \quad 95\% LT₁ < x < 105\% LT₁ \]
\[ z₅: \quad x > 106\% LT₁ \]

Choose which method you want by clicking the radio button beside it. The zones will be displayed in the lower right-hand corner of the output sheet. If you do not wish for training zones to be calculated select "None".

The alternative LT₁ is calculated as the recorded workload preceding a rise of 0.4 mmol/l in lactate above baseline. This is calculated only from recorded values and does not use an interpolated line to find points in between recorded values. Click
checkbox labelled "Use Adapt LT1 for AIS/Adapt method" to enable it as the LT1 value in the AIS/Adapt method of calculating training zones.

References


Author: David Higgins
Last Revised: 2 September, 2008