© by IAAF
27:3; 49-56, 2012

Energy Production in the 800m

by Enrico Arcelli, Amos Bianchi, Jennifer Tebaldini, Matteo Bonato and Antonio La Torre

ABSTRACT

Understanding the aerobic and anaerobic energy mechanisms in the 800m can have important practical consequences for coaches trying to correctly plan and manage an athlete's training. This knowledge is especially useful now that low cost, easy to use equipment is available for measuring blood lactate concentration after a competition or in training. The purpose of this study was to examine the contribution of the anaerobic lactate mechanism from the point of view of the total energy expenditure and energy expenditure at different stages of the 800m. Blood lactate concentration was measured in 18 male athletes at the end of a race and after time trials of 300m and 600m run at the same pace as the race. The data confirm earlier findings that blood lactate concentration at the end of the 800m tends to decrease with the increase of the time of the race. It was also found that the contribution of the anaerobic lactate mechanism peaks from the start to 300m, falls between 300m and 600m and is at its minimum at the end of an 800m race. Conclusions include general advice for working with athletes with typical strength-weakness profiles for the two mechanisms studied.

AUTHORS

Enrico Arcelli, MD, was formerly the Italian National Coach responsible for the middle- and long- distances and race walks and an associate professor at the Università degli Studi di Milano.

Amos Bianchi works on Faculty of Sport Science, Università degli Studi di Milano.

Jennifer Trebaldini works on Faculty of Sport Science, Università degli Studi di Milano.

Matteo Bonato is a PhD. Student at the Department of Biomedical Science for Health, Università degli Studi di Milano.

Antonio La Torre is an Associate Professor at the Department of Biomedical Science for Health, Università degli Studi di Milano.

Introduction

From an energetic point of view, both the aerobic and anaerobic mechanisms have considerable quantitative importance in the 800m[1-4]. Understanding how the two mechanisms affect the energy expenditure required to complete the distance at a competitive or winning speed is, of course, interesting for sport physiologists and can have important practical consequences for coaches trying to correctly plan an athlete's training.

Currently, low cost and easy to use equipment is available for coaches who would like to measure the blood lactate concentration of their athletes after a competition or in training. This means it is practical to plan training to emphasise the aerobic or the anaerobic lactic mechanism in training as required based on objective and quantifiable data and to monitor accurately the changes caused by the selected training.

With this in mind, the purpose of this article is to examine the contribution of the anaerobic lactate mechanism to the 800m from two different points of view: 1) the total energy expenditure, 2) energy expenditure at different stages of the race, as a basis for coaches who wish to follow this lineox preparation of their athletes.

Material and Methods

Subjects

Eighteen sub-elite male middle distance runners volunteered for this study. They were fully informed about the nature of the study and the potential risks and each gave written consent to participate.

Before starting with the study protocol, anthropometric measurements and other data were collected from all the subjects. Table 1 gives the mean ±SD and range for their age, height and body weight, body fat, years of training and personal best over 800m.

Experimental design

Data collection measurements were made during the outdoor track season (June-July). The temperature range during this period was between 20°C and 40°C, there was no precipitation and the wind velocity was below 4 $m \cdot s^{-1}$.

All the subjects took part in 800m competitions on synthetic outdoor tracks in national or international events. Prior to their races they used a standard warm-up, which included jogging and mobility exercises. The final performances were measured to the nearest 0.01 second. Split times were recorded for each subject at the 300m and 600m points of their races. At three and six minutes after the completion of the races, 5 µl blood samples were taken from the each subject's ear lobe so that blood lactate concentration could be analysed (Lactate Pro™ LT-1710, Kyoto, Japan).

In addition, 14 of the subjects performed time trials of 300m and 600m at the same pace they had run for the 800m races. These trials took place between 48 hours and seven days after the subject's race. At two and four minutes after the completion of the 300m trial and at three and six minutes after the completion of the 600m trial, 5 µl blood samples were taken from the ear lobe, again so that blood lactate concentration could be analysed.

Table 1: Anthropometric characteristics, years of training and personal best over 800m of the 18 subjects who participated in the study

	Mean ±SD	Range
Age (years)	22.8 ±3.9	16.0 - 32.0
High (cm)	180.5 ±4.9	175.0 - 189.0
Weight (kg)	66.0 ±5.6	57.0 - 74.0
Body fat (%)	5.3 ±1.1	4.2 - 6.4
Years of training (years)	9.0 ±6.0	4.0 - 13.0
Personal Best over 800m (sec)	117.6 ±5 .8	109.8 - 128.4

Calculation of the total energy expenditure

According to RITTWEGER et al.[5] the total energy expenditure (J·kg^{-1}) for running a certain distance is the sum of the following three components:

1. **The non-aerodynamic cost**: According to DI PRAMPERO[6], the non-aerodynamic cost encompasses the energy the athlete spends to lift and accelerate the body for each step, for the friction that the foot meets on each step, for the internal work, for the muscle contraction to maintain the core stability and for the work done by the heart and the respiratory muscles. The cost is equal to 3.8 J·kg^{-1} times the distance in metres. For the 800m, therefore, it is 3.8 J·kg^{-1} × 800 = 3040 J·kg^{-1}.

2. **The cost for overcoming air resistance**: This cost is 0.01 J·kg^{-1} for the distance (m) times the square of the running velocity (m·s^{-1}). For the 800m it is 8 J·kg^{-1}·v^2.

3. **The cost for accelerating the body**: This cost is 2 J·kg^{-1} times the square of the velocity. For the 800m it is 2 J·kg^{-1}·v^2.

Therefore, the total expenditure in J×kg^{-1} for running an 800m race is:

3040 J·kg^{-1} + 8 J·kg^{-1}·v^2+ 2 J kg-1·v2 or
3040 J·kg^{-1} +10 J·kg^{-1}·v^2

To get the total expenditure in mL·kg^{-1}, this formula becomes:

144.08 + 0.48·v^2

Calculation of the energy produced by the anaerobic lactic mechanism

Referring to the lactate peak, each increment of 1 mmol·L^{-1} over the baseline value, assumed to be 1 mmol·L^{-1} [1,3], corresponds to a production of 3 mL·kg^{-1} of lactic energy (*lactate caloric equivalent*[6]).

Results

Blood lactate concentrations

In Figure 1 we see the results obtained for blood lactate concentration after the 800m races of the 18 subjects (diamonds) and the trend of the blood lactate concentration as a function of the time when the sample was obtained (p=0.086).

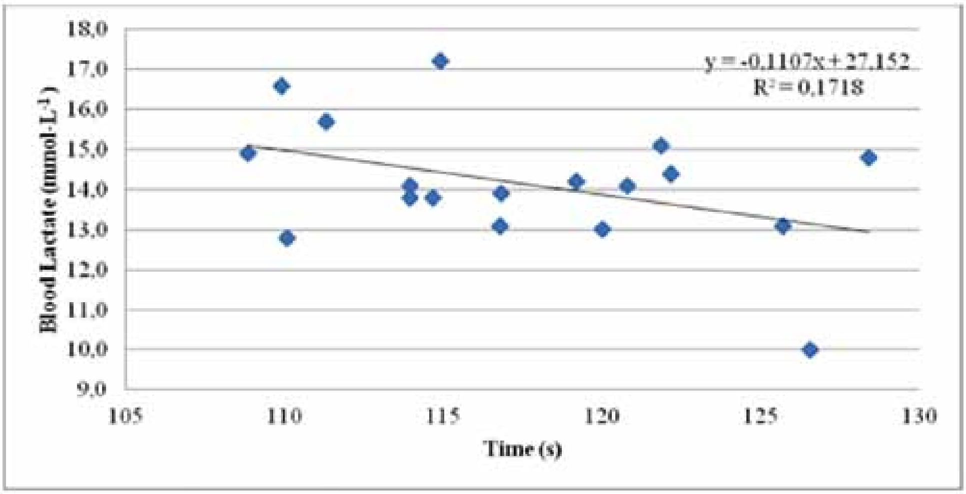

Figure 1: Trend of the blood lactate concentration after an 800m race as a function of the time obtained (p=0.086) in the 18 subjects evaluated

Table 2: Values of blood lactate concentration after time trials of 300m and 600m an 800m race for 14 athletes participating in the study

	Mean	SD
300m	8.6 mmol·L^{-1}	1.6 mmol·L^{-1}
600m	13.6 mmol·L^{-1}	1.6 mmol·L^{-1}
800m	14.2 mmol·L^{-1}	1.7 mmol·L^{-1}

Table 2 gives the mean±SD values of the lactate concentration after the 300m and 600m time trials and the 800m race for the 14 athletes who completed all three of the tests. For the two time trials, the peak value of the two samples taken is considered.

In Figure 2 we show the mean blood concentration at 300m, 600m and 800m for 14 athletes who completed all three of the tests. The baseline blood lactate concentration was considered 1 mmol·L^{-1} [1,3].

Discussion

Blood lactate concentration after an 800m

Table 3 gives the post-800m blood lactate concentration data from five studies that can be found in the current literature plus the data from the present study (last line). Our values do not differ significantly from the average values of the other studies, with the exception of those of LACOUR et al.[1], who were the first to study this area and whose data were obtained from elite-level athletes.

From the data in Table 3 we created Figure 3. The straight line indicating the tendency is different from that in Figure 1 and, indeed, from the one reported by LACOUR et al.[1]. Here below are the three different formulas for the calculation of the blood lactate concentrations (in mmol·L^{-1}) as function of the time of the competition (in sec):

- Present study: 27.15 – 0.11 t
- Scientific literature: 42.21 – 0.21 t
- LACOUR et al.[1]: 86.7 – 0.6 t

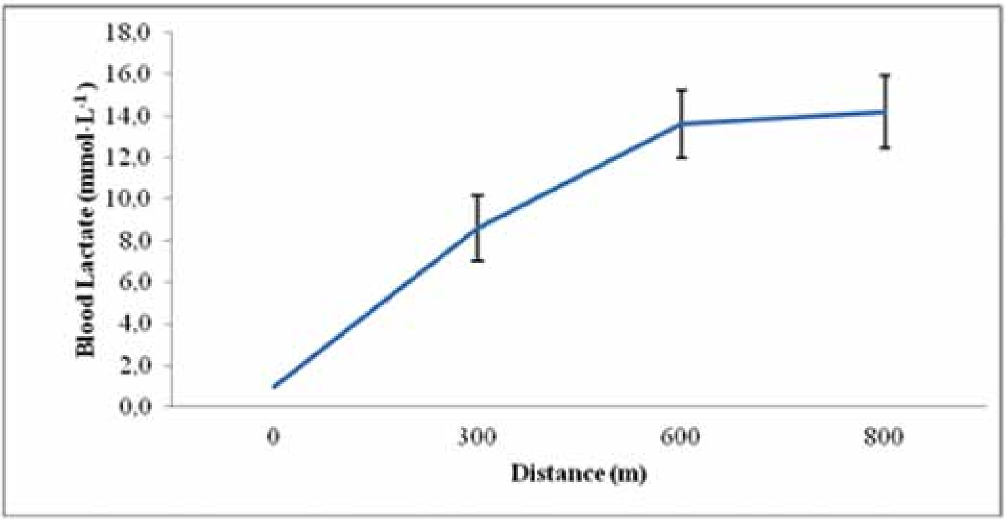

Figure 2: Blood lactate concentration (Mean±SD) at the start, after a 300m time trial, after a 600m time trial and after an 800m race

To explain the differences between the three formulas, we have to consider that (as shown in Table 3) the different studies were carried out with different criteria. In three cases, for example, the blood lactate concentrations were not taken after a competition, but after a time trial, which could possibly give a different result. Moreover, in most cases the number of subjects in these studies was limited, particularly for LACOUR et al.[1], where there were only five subjects, even if there were a total of 18 tests. In all cases, the blood lactate concentration tends to decrease with the increase of the 800m time recorded.

Table 3: Mean blood lactate concentration of the scientific literature after 800m (The last line reports the values of the present study.)

Authors	Numer of subjects	Time (s)	Velocity ($m.s^{-1}$)	Blood Lactate ($mmol.L^{-1}$)	Type of test
Lacour et al. (1990) [1]	5 (18 race)	108,4	7,39	21,9±2,1	Race
Hill (1999) [3]	5 (17 race)	120,2	6,66	18,1±2,2	Race
Duffield et al. (2005) [4]	9	126,0	6,35	12,4±1.9	Race
Thomas et al. (2005) [10]	5	120,8	6,52	17,5±1,3	Time trial on outdoor track
Bosquet et al. (2005) [7]	17	137,2	5,87	15,08±1,48	Time trial on outdoor track
Billat et al. (2009) [8]	8	129	6,20	16,9±1,9	Time trial on indoor track
Ditroilo et al. (2012) [11]	72	134,6		13,6±1,1	Indoor Athletic Race
Present Studies (2012)	18	118,8	6,73	14,0±1,5	Race

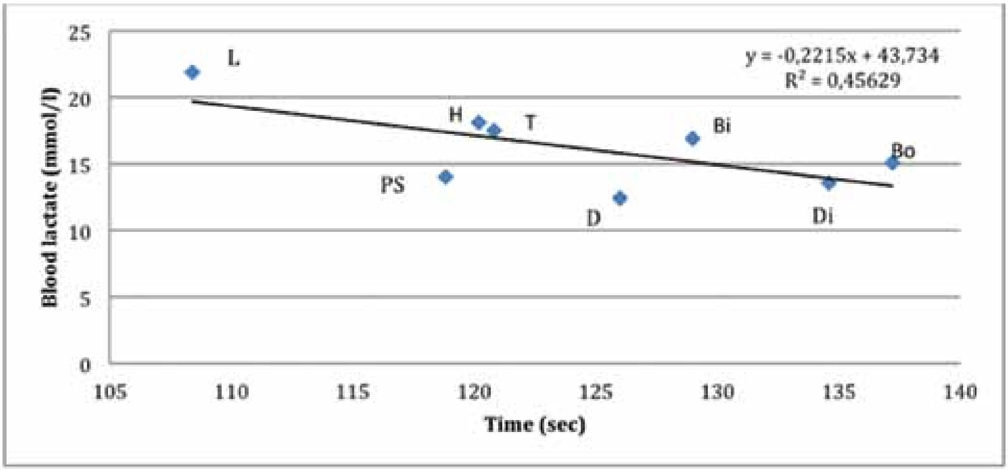

Figure 3: Trend of blood lactate concentration after an 800m as a function of the final time according to data reported in literature as shown in Table 3 (p=0.135) (The symbols refer to the following authors: L = LACOUR et al.[1]; PS = Present Study (2012); H = HILL[3]; T = THOMAS et al.[10]; D = DUFFIELD et al.[4]; Bi = BILLAT et al.[8]; Bo = BOSQUET et al.[7]; Di = DITROILO et al.[11])

Table 4: Energy expenditure in the 800m for performances from 105 sec to 120 sec (calculated with the RITTWEGER et al. formula), the contribution of the anaerobic lactic mechanism (calculated according to di PRAMPERO et al. formula) and the contribution of the anaerobic lactic mechanism as a percentage of the total energy expenditure

Time over 800m (sec)	Total Energy Expenditure (mL·kg^{-1})	Lactic Component (mL·kg^{-1})	Lactic Component (%)
110	169.1	42.15	24.9%
115	167.0	40.50	24.2%
120	165.1	36.60	22.2%

Contribution of the anaerobic lactate mechanism on the total energy cost for the 800m

Table 4 was created by calculating the total energy cost for the 800m run in different times using the RITTWEGER et al.[5] formula and the contribution of the anaerobic lactic mechanism with the caloric lactate equivalent[6], according to the mean lactate values of the present study (the straight line in Figure 1).

The total energy expenditure calculated by the RITTWEGER et al.[5] formula is very similar to that established with different criteria by LACOUR et al.[1], HILL[3], DUFFIELD et al.[4], BOSQUET et al. [7] and BILLAT et al.[8]. These authors propose an energy expenditure of 0.211, 0.198, 0.205, 0.221 and 202 mL·kg^{-1}.min^{-1}, which is equal to 168.8, 158.4, 164, 176.8 and 161.6 mL·kg^{-1}, respectively.

As we can see in the far right-hand column of Table 4, the anaerobic lactic mechanism contributes 25.5% where the 800m time is 110 sec, 24.2% where the time is 115 sec and for 22.2% where the time is 120 sec.

Intervention of the anaerobic lactic mechanism in different sections of the 800m

It is possible to calculate the increase of blood lactate concentration from the start to 300m, from 300m to 600m and from 600m to 800m, by considering the time spent in each section and the average lactic power of 6 mL·kg^{-1}·min^{-1}, that is the energy produced by the anaerobic lactic mechanism per unit of time.

As can be seen in Figure 4, the lactic power reduces significantly from the first section (start-300m), to the second section (300m – 600m) and the last section (600m – finish). As would be expected from this, the authors who evaluated the maximal kinetic oxygen consumption during an 800m race (DUFFIELD et al. and SPENCER & GASTIN) reported that oxygen consumption rises very quickly after the first ten seconds and provides the maximal contribution to the total expenditure during the final section of the race[4, 9].

Conclusions

The 800m is a race in which the percentages of the energy contribution of the aerobic and anaerobic mechanisms are very close. The current availability, low cost and ease of use of equipment for blood lactate measurement allows coaches to know the blood lactate of their athletes after a race of 800m and consequently to direct the preparation more towards the aerobic or the anaerobic lactic mechanism as required. Moreover it can also allow coaches to control the changes caused by training.

For example, with an athlete who runs the 800m between 110 and 125 sec and has a low concentration of lactate compared to that indicated by the line in Figure 1 it might be that the glycolytic mechanism is the less effective of the two. The coach, therefore, should adjust the training programme to stimulate that mechanism.

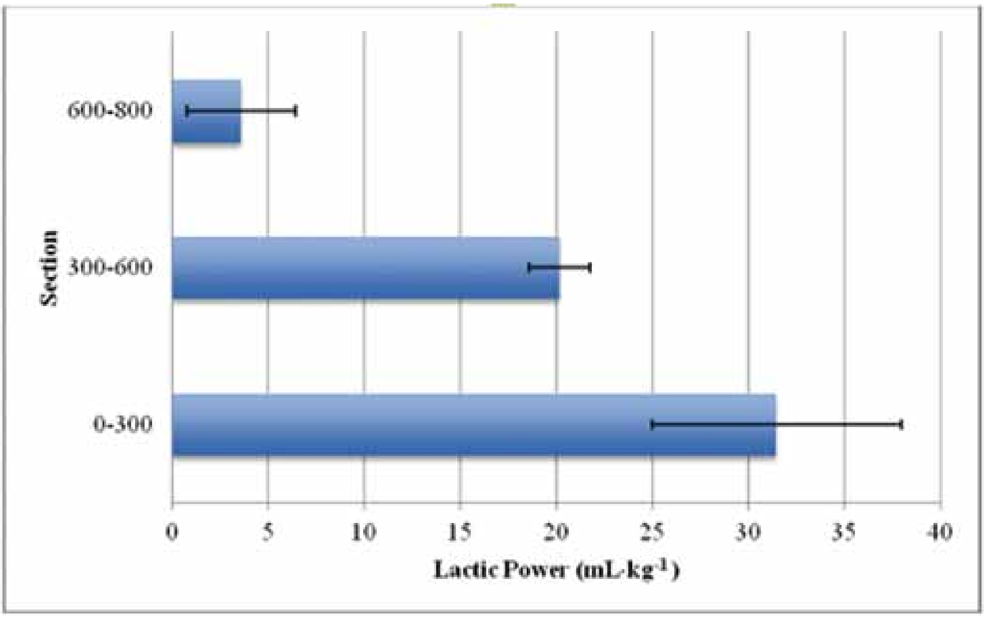

Figure 4: Contribution of the anaerobic lactic mechanism to the total energy expenditure in different sections of an 800m race

Conversely, for an athlete who comes from a 400m background and has a very high lactate concentration in relation to the average values, especially if his/her running technique does not result in a very high-energy expenditure, an improvement of the aerobic components may lead to a significant improvement of the performance.

The second example highlights the blood lactate data relating to the theoretical transition from 300m to 600m, which shows that, contrary to the feeling of athletes during the race, the production of energy during the 800m becomes less lactic and more aerobic as the race progresses. However, even a small increase in the concentration of lactate in the muscles significantly affects the feeling of fatigue and the efficiency of the muscles. Therefore, there is need to develop the ability to run with a correct technique, despite the increased concentration of lactate.

Please send all correspondence to:
Antonio La Torre
antonio.latorre@unimi.it

REFERENCES

1. LACOUR, J. R.; BOUVAT, E. & BARTHÉLÉMY, J. C. (1990). Post-competition blood lactate concentration as indicators of anaerobic energy expenditure during 400m and 800m races. European Journal of Applied Physiology, 61:172-176.

2. WEYAND, P. G.; CURETON K., CONLEY D. & SLONIGER M. (1993). Percentage anaerobic energy utilized during track running events. Medicine and Science in Sports and Exercise, 25, S105.

3. HILL, D. W. (1999). Energy system contributions in middle distance running events. Journal of Sports Sciences, 17: 477-483.

4. DUFFIELD, R.; DAWSON, B. & GOODMAN, C. (2005). Energy system contribution to 400 metre and 800 metre track running. Journal of Sports Sciences, 23: 299-307, 2005.

5. RITTWEGER, J.; DI PRAMPERO, P. E.; MAFFULLI, N. & NARICI, M. V. (2009). Sprint and endurance power and ageing: an analysis of masters athletic world records. Proc. R. Soc. B 276, 683-689.

6.DI PRAMPERO, P.E. (1981) Energetics of muscular exercise. Review of Physiology, Biochemistry and Pharmacology, 89: 143-262.

7.BOSQUET, L.; DELHORS, P. R.; DUCHENE, A.; DUPONT, G. & LEGER, L. (2007). Anaerobic running capacity determined from a 3-parameter systems model: relationship with other anaerobic indices and with running performance in the 800m run. Int J Sports Med. 28(6):495-500.

8. BILLAT, V.; HAMARD, L.; KORALSZTEIN, J. P. & MORTON, H. (2009) Differential modeling of anaerobic and aerobic metabolism in the 800m and 1,500m run. Journal of Applied Physiology, 107: 478-487.

9. SPENCER, M. R. & GASTIN, P.-B. (2001). Energy system contribution during 200- to 1500m running in highly trained athletes. Medicine & Science in Sports & Exercise, 33:157-162.

10. THOMAS, C.; HANON, C.; PERREY, S.; LE CHEVALIER, J. M.; COUTURIER, A. & VANDEWALLE, H. (2005). Oxygen uptake response to an 800m running race. Int J Sports Med. 26(4): 268-273.

11. DITROILO M, CASTAGNA C, LUCERTINI F.: *Post-Competition Blood LactateConcentration in Regional Level and Master Athletes.* New Studies in Athletics, 27: 1-2; 67-74, 2012.