Blood lactate levels of decathletes during competition

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There are many detailed physiological profiles of athletes who participate in a wide variety of sporting activities but few data have been obtained on decathletes. This study defines some physiological characteristics of these athletes and measures capillary lactate concentrations $[La_b]$ during a laboratory test of progressive maximal exhaustion and the different events during competition. The treadmill test is similar to the 100 m, 400 m and 1500 m in terms of $[La_b]$ accumulation but only similar to the 1500 m in terms of velocity. The 400 m is the most demanding event with the greatest blood lactate accumulation (mean(s.d.) $16.38(2.36)$ mmol l^{-1}). The $[La_b]$ at the end of the 110 m hurdles is significantly lower than in any other racing events (mean(s.d.) $6.96(1.32)$ mmol l^{-1}) compared with mean(s.d.) $12.14(2.87)$ and mean(s.d.) $11.44(2.16)$ for the 100 m and 1500 m respectively. The $[La_b]$ after the long jump, the high jump and the pole vault are not significantly different (mean(s.d.) $5.30(2.23)$, $4.64(1.39)$ and $5.36(1.34)$ mmol l^{-1} respectively).

Keywords: sports physiology, lactate, anaerobic threshold, track and field

The decathlon is an athletic competition extending over two days and includes four track and six field events. The order of events are, on the first day: 100 metres, long jump, shot put, high jump, and 400 metres; on the second day: 110 metres hurdles (110 mH), discus throw, pole vault, javelin, and 1500 metres. The decathlon was first introduced by the Greeks (708 BC) as a five event competition to venerate the 'complete athlete'.

Although there are many physiological profiles of athletes participating in a wide variety of sporting events, few data are available on this select group of competitors¹. The purpose of this investigation was to assess the physiological profiles and capillary lactate concentrations ($[La_b]$) of these athletes both in training and competition.

Methods

Seven male decathlon athletes (six competing at national level) were investigated during training at the Regional Institute of Sports Medicine of

Bordeaux, France and then, again, one month later during an official competition (The Regional Combined Events Championship). Informed consent was obtained from the athletes prior to investigation. Table 1 shows the general characteristics of the subjects.

The tests performed in the laboratory included measurements of weight, height, skinfold measurements, spirometry, heart rate (electrocardiography), maximal O_2 uptake ($\dot{V}\text{O}_{2\text{max}}$) and blood lactate during progressive exercise to exhaustion.

Skinfold measurements were taken at four sites (biceps, triceps, subscapular and suprailiac) using a skinfold caliper². The respiratory function tests were measured with an electronic spirometer (Fukuda CSA 800, Japan) and consisted of the following: forced vital capacity (FVC), forced expiratory volume in one second (FEV_1), peak expiratory flow rate (PEFR) and maximum breathing capacity (MBC). The maximum oxygen uptake was measured indirectly on a cycle ergometer (Siemens Elema, Germany), as described by Åstrand³, with work rate increments of 20 W every 2 min until a stable heart rate of 150 bpm was obtained. This test was chosen because it served as a warming up period before undergoing (approximately 20 min later) the treadmill exercise which then lead to complete exhaustion.

The progressive exercise test was performed on a treadmill (Serres, France) with an initial speed of 8 km h^{-1} (slope 3%) and increased every 2 min (10, 12, 14, 16, 18, 18 [slope 6%] km h^{-1}), with 1 min rest between each level, until complete exhaustion.

The continuous heart rate of each athlete was measured during both the determination of the $\dot{V}\text{O}_{2\text{max}}$ and the progressive exercise using Holter's method⁴.

Samples of free flowing arterialized capillary blood were obtained from the extremity of a finger using an Autolet (a device used for drawing blood). Arterial lactate appears to be preferable to venous lactate because it is not contaminated by the effect of resting muscle lactate metabolism⁵. Blood lactate concentration was obtained using a lactate electrode (Sétric Génie Industriel, France). It was measured first at rest, then during the 1 min interval at each treadmill level and finally 3 min after the end of the test, giving six to eight measures for each athlete.

It has been shown that lactate diffuses from the muscles and has a peak plasma concentration

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Table 1. Subject's characteristics

Subject	Age (yr)	Height (cm)	Weight (kg)	Fat (%)	Heart rate (rest) bpm	$\dot{V}O_{2\max}$ (ml/kg/min)
1	28	182	74.6	15.13	56	52.82
2	21	185	73.1	8.97	68	51.22
3	24	191	89.4	12.56	51	49.71
4	18	181.5	72.4	14.56	51	45.81
5	21	177	75.2	12.98	46	60.85
6	19	175	66.5	11.09	76	49.41
7	21	178.5	71.9	10.39	56	54.97
Mean(s.d.)	21.71(3.35)	181.43(5.39)	74.73(7.06)	12.24(2.23)	57.71(10.59)	52.11(4.81)

Table 2. Spirometry measurements

Subject	Forced vital capacity (l)	Forced expiratory volume in 1 s (l)	Maximum breathing capacity (l/min)	Peak expiratory flow rate (l/s)
1	5.78	4.77	175.20	10.53
2	5.43	4.69	190.82	10.23
3	6.05	5.27	181.64	8.98
4	4.69	4.22	131.45	9.05
5	4.80	3.98	130.66	7.86
6	4.77	3.79	157.27	10.30
7	4.73	3.63	105.27	7.15
Mean(s.d.)	5.18(0.57)	4.34(0.59)	153.19(31.63)	9.16(1.3)

between 3 and 6 min after the end of an exercise⁶⁻⁸. $[La_b]$ was measured 3 min after each event except for the 400 m, where it was measured at 6 min after the event (higher $[La_b]$ were expected in this event). During the competition $[La_b]$ measurements were made at rest (after a short warm-up period) at the beginning of each day and then as follows:

First day: 3 min after the 100 m, 3 min after the long jump, before the 400 m (after the high jump), 6 min after the 400 m, 20 min after the 400 m; and on the second day: 3 min after the 110 m hurdles, 3 min after the pole vault, before the 1500 m, 3 min after the 1500 m and 20 min after the 1500 m.

The statistical analyses were performed using StatView and SPSS. The paired *t* test was used to compare data within our group of decathlon athletes and the unpaired *t* test for data between the two groups (Faris and ours). $P < 0.05$ was considered statistically significant. Results are presented as mean(s.d.).

Table 3. Heart rates

Subject	Rest	8 km/h	10 km/h	12 km/h	14 km/h	16 km/h	18 km/h	18 km/h (6%)	3 min after end exercise
1	56	145	162	166	180	190	189	—	137
2	68	162	172	182	192	194	200	200	150
3	51	155	162	180	180	185	193	—	113
4	51	170	180	190	192	199	—	—	125
5	46	—	—	—	—	—	—	—	—
6	76	166	175	184	190	195	200	—	132
7	56	148	162	169	177	181	186	188	129
Mean(s.d.)	57.71(10.59)	157.67(10.01)	168.83(7.91)	178.5(9.2)	185.17(6.88)	190.67(6.71)	193.6(6.35)	194(8.49)	131(12.35)

Results

The clinical examination and the electrocardiographic recordings of the athletes were all within normal limits. The mean(s.d.) bradycardia, 57.7(10.5) bpm, of normal athletes in training was noted. These athletes (mean age 21) had a mean(s.d.) $\dot{V}O_{2\max}$ of 52.11(4.81) ml min⁻¹ kg⁻¹. Table 2 gives the results of the respiratory function tests.

The values of heart rate and $[La_b]$ during the treadmill exercise are given in Tables 3 and 4 respectively. The mean(s.d.) maximal heart rate achieved was 195(5.37) bpm and mean(s.d.) maximal $[La_b]$ reached was 14.15(2.34) mmol l⁻¹. Figure 1 shows heart rate and blood lactate measurements against different powers of exercise on the treadmill.

The individual values of the $[La_b]$ during competition are given in Table 5. The maximum mean(s.d.) $[La_b]$ is obtained 6 min after the 400 m (16.38(2.36)

Figure 1. Mean(s.d.) heart rate and blood lactate measurements against different powers of exercise on the treadmill

Table 4. Blood lactates

Subject	Rest	8 km/h	10 km/h	12 km/h	14 km/h	16 km/h	18 km/h	18 km/h (6%)	3 min after end exercise
1	0.73	3.22	4.54	3.61	4.61	8.34	12.08	—	9.96
2	0.54	4.10	4.17	5.40	5.37	6.70	11.23	14.17	17.51
3	0.86	2.27	2.42	—	7.32	8.16	12.38	—	16.68
4	1.75	—	3.61	5.84	7.32	10.26	—	—	12.44
5	—	—	—	—	—	—	—	—	—
6	0.98	4.03	3.42	3.46	5.80	7.02	9.94	—	12.69
7	1.04	2.97	2.44	—	4.43	6.21	10.25	13.49	13.42
Mean(s.d.)	0.98(0.42)	3.24(0.71)	3.43(0.87)	4.50(1.07)	5.62(1.27)	7.78(1.47)	11.18(1.08)	13.83(0.48)	13.78(2.83)

Table 5. Blood lactate levels during competition

Subject	1° day rest	3 min after 100 m	3 min after long jump	Before 400 m	6 min after 400 m	20 min after 400 m	2° day rest	3 min after 110 mH	3 min after pole vault	Before 1500 m	3 min after 1500 m	20 min after 1500 m
1	3.20	12.83	6.13	6.03	18.57	9.18	—	9.28	7.32	6.44	8.20	1.30
2	1.51	17.06	2.33	3.58	16.75	7.78	2.05	6.80	4.77	4.50	14.04	3.37
3	2.73	10.41	3.86	2.63	15.95	9.47	1.92	7.64	5.72	2.69	10.75	3.81
4	1.53	11.07	3.46	6.50	12.38	5.21	2.74	6.07	—	—	—	—
5	2.17	11.48	5.39	4.11	14.38	6.78	2.91	6.85	3.36	2.71	10.34	5.29
6	3.20	14.03	8.54	5.43	17.65	9.29	3.13	5.01	6.03	3.26	13.52	4.72
7	2.45	8.07	7.36	4.20	18.96	7.45	2.88	7.10	4.96	1.24	11.81	3.83
Mean(s.d.)	2.40(0.71)	12.14(2.87)	5.30(2.23)	4.64(1.39)	16.38(2.36)	7.88(1.57)	2.61(0.50)	6.96(1.32)	5.36(1.34)	3.47(1.79)	11.44(2.16)	3.72(1.38)

mmol⁻¹). 95% confidence intervals for lactate concentration for the four races and the maximal values obtained in the laboratory are presented in Table 6.

Discussion

The general characteristics of our athletes compared with a group of nine world class decathlon athletes¹ show that they are on average younger (21.7 versus 27.2 years [$P = 0.009$]) and much lighter (74.7 versus 84.7 kg [$P = 0.004$]) but have similar height (181.4 versus 183.9 cm [$P = 0.28$]), and have similar percentages of fat (12.2 versus 12.8 [$P = 0.66$], vital capacities (5.18 versus 5.16 l) and $\dot{V}O_{2\max}$ (52.1 versus 57.6 [$P = 0.20$]). The difference in weight may be due to more emphasis on weight lifting in the world class athletes and more years spent in training. The maximum oxygen uptake in the 50–60 range, is what is expected in explosive (non-endurance) athletes.

In the same study, Faris *et al.*¹ analysed body build using anthropometric fractionation and stated that 'the most outstanding features of anthropometric fractionation appear to be very large biceps and small abdomens' (94.0 and 74.4 cm respectively).

Table 6. 95% confidence intervals of blood lactate concentrations for treadmill test and races

Laboratory test	10.81 to 16.75 mmol l ⁻¹ (2.97)
100 m	9.48 to 14.79 mmol l ⁻¹ (2.65)
400 m	14.2 to 18.56 mmol l ⁻¹ (2.18)
110 mH	5.74 to 8.19 mmol l ⁻¹ (1.22)
1500 m	9.17 to 13.71 mmol l ⁻¹ (2.27)

Blood lactate levels may provide a useful indication of the energy derived from anaerobic glycolysis during exercise. In the decathlon, lactate values obtained at the end of each event could be an important indication of the contribution of anaerobic mechanisms to the total energy requirements⁶.

The [La_b] during the competition showed four peaks, which were, in order of magnitude, (1) the 400 m is the most demanding event and therefore incurs the greatest lactate accumulation; 6 min after the 400 m, mean(s.d.) [La_b] = 16.38(2.36) mmol l⁻¹. Other workers^{9,10} have found that 400 m athletes have higher [La_b] after exhaustion tests than runners from other specialities. [La_b] of 16 to 17 mmol l⁻¹ have been found in these runners^{8,11}; (2) after 100 m, mean(s.d.) [La_b] = 12.14(2.87) mmol l⁻¹. One author¹¹ found mean(s.d.) [La_b] of 8.9(1.3) mmol l⁻¹ in athletes with a lower level of performance at the 100 m; (3) after the 1500 m, mean(s.d.) [La_b] = 11.44(2.16) mmol l⁻¹; (4) following the 110 mH mean(s.d.) [La_b] = 6.96(1.32) mmol l⁻¹. This very technical event, longer in time and distance than the 100 m, is associated with significantly ($P = 0.018$) lower blood lactate values. This could be explained by lower running speed during the event as shown below.

When considering only the races, it is possible to look at the peak [La_b] according to the running speed (velocity) of the athlete during the competition (in other terms the performance of the athlete for each race) (Figure 2); the data from the progressive exhaustion test in the laboratory are also plotted. Four groups are identified. Although the fastest race (around 9 m s⁻¹), the 100 m lasted just above 11 s on average and blood lactate values are in the

Figure 2. Relationship between peak blood lactate and running speed of the 100 m, 400 m, 110 mH and 1500 m, and the laboratory test

12 mmol l⁻¹ range. As discussed above, the 110 mH was performed at a lower speed (6.68 m s⁻¹ on average) than the 100 m. In the 400 m, the highest peak [La_b] can be explained by a velocity of nearly 8 m s⁻¹ but this was maintained for 49 to 55 s. The 1500 m and the test performed in the laboratory seemed to be very similar in terms of velocity and blood lactate values. Peak blood lactate was found to correlate significantly with running speed for the 1500 m ($r = 0.86$, $P < 0.05$). In the other races and the laboratory test, it failed to attain statistical significance.

A paired t test was used to compare the laboratory results with the results of the races (100 m, 400 m, 110 mH and 1500 m). The only significant difference was in the 110 mH ($P = 0.005$). We corrected for multiple significance testing by using the Bonferroni correction¹².

The highest [La_b] before the races was before the 400 m (4.64 mmol l⁻¹ versus 2.40, 2.61, 3.47 mmol l⁻¹ before the 100 m, 110 mH and 1500 m respectively) and this is significantly different. One athlete had a [La_b] of 6.44 mmol l⁻¹ before the 1500 m and it is interesting to note that he was the one who performed best at pole vault, and therefore had the least time to recover between the last three events and who finally had the worst performance at the 1500 m (5'05''97) and had the least increase in blood lactate at the end of this event!

The [La_b] at the beginning of each day (mean of 2.40 and 2.61 mmol l⁻¹) may seem already high following only a warm-up period, but similar values were reported by De Saedeleer *et al.*¹¹ in sprinters.

The mean(s.d.) [La_b] after the three jumps, 5.30(2.23), 4.64(1.39) and 5.36(1.34) mmol l⁻¹ were not significantly different. Adenosine triphosphate (ATP) and creatine phosphate (CP) stores are probably depleted in 3–5 s when the effort is maximal. For the long jump and the pole vault, repeated sprints of 30–40 m are usual and this may explain why the ATP and PC stores may not provide all the energy required, and the moderate lactate accumulation of 5 mmol l⁻¹ seen.

The actual protocol did not allow us to assess the throws, with the exception of the javelin. The [La_b] values recorded before the 1500 m were in fact taken shortly after the end of the javelin (only 30 min separated the end of the javelin from the start of the 1500 m). It seems unlikely that the throws are associated with marked increases in [La_b], especially for the shot and the discus (efforts of less than 3 s with utilization of high-energy phosphates). The javelin is expected to be more demanding in terms of energy expenditure, but probably not sufficient to see a significant increase in [La_b]. The mean(s.d.) levels of blood lactate found after this event (3.47[1.79] mmol l⁻¹), measured within 1 h after the end of the pole vault, may correspond to decreasing blood lactate from this event.

Controversy exists concerning the change of [La_b] with increasing levels of exercise in man^{13–16}. The anaerobic threshold (AT), also called 'onset of blood lactate accumulation' (OBLA), is for some identified as the work-rate (running speed in our study) at which blood lactate reaches 4 mmol l⁻¹ in an incremental test¹⁷. For others [La_b] increases as a continuous function in progressive exercises^{5, 14, 18, 19} and does not behave as a threshold phenomenon where [La_b] suddenly increases at a critical work rate^{16, 19–21}.

The determination of the AT in our athletes has been done using the techniques described by Orr and Green^{22, 23}: the AT is determined from individual plots of blood lactate and power output where a breakaway point is calculated using the technique of linear regression. A regression line was fitted through the three lowest energy levels (8, 10, 12 km h⁻¹) and the significance of the slope assessed. If not significant, progressively higher energy levels were added to the data and another regression line fitted. This process was repeated until a significant slope was found. In our study, the slope changed from non-significance to significance between 12 and 14 km h⁻¹ ($P = 0.04$).

At these levels of exercise, namely 12 and 14 km h⁻¹, the mean(s.d.) corresponding heart rate was 178.5(9.2) and 185.17(6.88) bpm and the mean(s.d.) [La_b] 4.50(1.07) and 5.62(1.27) mmol l⁻¹. These values are much less than those found in middle and long-distance international athletes^{24, 25} (AT at 18 km h⁻¹ and heart rate of 176 bpm). However, this is to be expected because decathletes, due to their specific training and performance, are physiologically closer to sprinters than endurance athletes. It has been shown that with endurance training these curves of lactate accumulation with progressive increase in exercise are shifted to the right^{24, 25}.

Finally there is no significant difference between the [La_b] measured on the first day before the competition started (after a warming up period) and 20 min after the 1500 m at the end of the second day, following an active recovery period (mean(s.d.) difference 1.32 mmol l⁻¹(0.53)) ($P > 0.1$).

The progressive exhaustion test on the treadmill, performed in the laboratory, can help to estimate the increase of lactic acid in the blood during competition. It gives a profile of peak values of [La_b], which is

statistically not significantly different from that of the 100 m, 400 m and 1500 m respectively, and it was run at similar velocity with the 1500 m. The decathlon, with a series of races, jumps and throws throughout the two days of competition, stimulates both the aerobic and anaerobic pathways. Lactate production in this setting is complex and is not assessed satisfactorily using only intermittent blood lactate measurements. However, the ability to produce lactate is essential for high intensity efforts⁷.

It is hoped this study may help gain a better physiological understanding of $[La_b]$ variations during a decathlon.

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