Monitoring altitude acclimatization – a case study of an élite woman athlete

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A simple study monitoring altitude acclimatization, which is not intrusive to the athlete's training, is described. Particular attention is drawn to the change in production of lactate in response to steady state exercise, before and after altitude. The results suggest that a more thorough assessment of aerobic ability at altitude is required than that described in the British Association of Sports and Exercise Science (BASES) guidelines. It is also relevant to note that elevations in haemoglobin, promoted by altitude, can mask iron abnormalities. It is therefore recommended to assay for iron in addition to haemoglobin.

Keywords: altitude, lactate, iron, acclimatization

All middle- and long-distance coaches, when supporting an élite endurance athlete have to consider the benefits or otherwise of training at altitude. The literature suggests that altitude training benefits performance but it is clear that the time needed to acclimatize to altitude and the time of reacclimatization after altitude training depend on the individual. Inevitably, therefore, athletes training at altitude for the first time have to treat it as an experiment.

It is not possible to be excessively intrusive into any athlete's critical preparation for a major event thus only simple analysis can be carried out. However, it is important for those who support and advise these athletes to learn as much as possible in order that an information resource can be developed which will aid athletes of the future.

This article outlines some simple physiological monitoring which was conducted on one élite woman athlete and identifies two important areas which should be considered by others embarking on a similar project.

Methods

Altitude training was achieved by exposure in two phases. Initially, 5 weeks were spent in Johannesburg, South Africa (Phase I) based at 5709 feet above sea level, followed by 6 weeks in Capetown, South Africa, which lies at sea level, and then a 4-week return to Johannesburg (Phase II).

Fluid replacement

Fluid replacement was accomplished by drinking 3 l of spring water per day supported by a proprietary supplemented water (glucose 3.56 g, sodium chloride (NaCl) 0.47 g, potassium chloride (KCl) 0.30 g, disodium citrate ($\text{Na}_2\text{HC}_6\text{H}_5\text{O}_7$) 0.53 g), taken after exercise. Half a litre of additional general fluid was taken with meals.

Urine specific gravity was measured using Ames Multistix and bodyweight was recorded daily.

Heart rate and rate of perceived exhaustion scale

Resting heart rate was recorded every morning before rising and all sessions were given a perceived exertion rating using the Borg rate of perceived exhaustion (RPE) scale¹.

Iron supplementation

Iron supplementation was cautious due to a tendency for the athlete to suffer from stomach disorders. During menstruation and 7 days after menstruation the athlete took a vitamin B and C complex which contributed 130 mg ferrous iron per day. Between these times a general multivitamin tablet was taken contributing 24 mg ferrous iron per day.

Training load

Training load was as described in *Figure 1*.

Lactate production

Onset of blood lactate (OBLA) was determined using essentially the method of Mader². The methodological difference was that there was no sample taken 3 min after the onset of exercise. Samples were therefore taken at 5, 10, 15, 20 and 25 min at – week 1 (part of a routine test in Scotland), week 2 after altitude Phase I (Capetown) and week 2 after altitude Phase II. The test in Capetown was carried out by Professor Tim Noakes of the University of Capetown to whom instructions had been sent before the athlete's departure. Lactate was determined, while in Scotland, from fingertip blood samples which were analysed at the time of the test using a semiautomated lactate analyser (Analox). When OBLA was determined in South Africa it was not possible to use

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Figure 1. The mix of training sessions undertaken during the altitude acclimatization period: 1a, quality 80/100 s; 1b, quality 300/600 s; 2, strength; 3, speed endurance; 4, strength endurance; 5, aerobic; 6, rest (in days)

automated analysis and spectrophotometric methods were used on venous blood samples. The method of blood analysis has been shown to produce similar results and appropriate quality controls were used in all assays. Venous samples, however, have been shown to produce lactate values approximately 7% higher than capillary samples³. This has been taken into account in the interpretation of the results.

The running pace at which steady state lactate was attained was then used as the training pace for OBLA training runs⁴.

In order to identify whether it was possible to indicate any changes in the ability to buffer lactate on a daily basis, it was simple to use Ames multistix to measure urine pH.

Blood analysis

The athlete presented herself for blood sampling not less than 14 h after an exercise session and a sample was obtained by venepuncture from an antecubital vein. Resting blood samples were taken for routine haematology at week 1, week 4 altitude Phase I, week 6 after altitude Phase I (Capetown), week 4 altitude

Phase II and week 3 after altitude Phase II. The sample taken at altitude Phase II and the sample taken after altitude on return to Scotland were taken at similar times after menstruation. All the blood analyses were conducted at major city hospitals where standard quality control procedures were used. The locations and times of sampling are displayed diagrammatically in Figure 2.

Statistics

All results are expressed as mean $\pm$ standard error of the mean (s.e.m.).

Results

Fluid replacement and body weight

There was no change in urine specific gravity (1.001) nor significant changes in body weight (52.0 kg) throughout the test period.

Heart rate and RPE scale

Resting heart rate increased at altitude Phase I, (30(1.0) rising to 34(1.6) beats min^{-1}). It then reduced on returning to sea level (33(2.3) beats min^{-1}). On returning to altitude Phase II it reached its highest level averaging (36(1.9) beats min^{-1}) throughout the period.

RPE values recorded after training sessions varied considerably over the period of time but served as good feedback to the athlete's coach in Scotland. The RPE associated with the various OBLA training runs throughout the period are presented in Figure 3.

Lactate production

Urine pH did not alter significantly throughout the period abroad. Steady state OBLA was achieved at 5 min 5 s at 1 week preceding altitude training and similarly at week 3 after altitude Phase II. Lactate plateau levels were significantly lower in the latter test. The range of lactate values achieved at the plateau was 2.2–3.2 mmol l^{-1} in the first test and was 1.4–2.4 mmol l^{-1} , 15 weeks later.

The athlete was unable to achieve steady state when tested at 4 min 55 s min mile^{-1} when in Cape-town and it was not possible to retest.

Figure 2. A diagrammatic representation of the timing and location of blood sampling

Figure 3. The onset of blood lactate (OBLA) training runs from January to May with the corresponding Borg RPE scale: ○, min mile⁻¹ (4 miles); ●, min mile⁻¹ (3 miles); ■, RPE; ▲, treadmill tests

Blood analysis

Assay results for haemoglobin, and iron are presented in Table 1. All other blood tests, including ferritin and transferrin fell within the normal range.

Discussion

Although it would appear that modest elevations in haemoglobin were evident it is difficult to be sure that they are not due to normal variation. Routine samples taken earlier in the year, approximately 10 months and 4 months before altitude training revealed values of 14.2 g dl⁻¹ and 13.5 g dl⁻¹ respectively. Of more significance is the abnormally low iron value of 3.7 μmol l⁻¹ 4 weeks into the second altitude phase. The analysis was carried out in the same laboratory as that of the sample which was recorded as normal in altitude Phase I and all other blood haematology and biochemistry was normal at this time. There is little reason therefore to assume that it was methodological error. Earlier iron values assayed from blood samples taken at the 10-month and 4-month sample before altitude were 26 μmol l⁻¹ and 29 μmol l⁻¹ respectively.

The reason for this acute drop in iron, which was not reflected as depressed haemoglobin levels, remains to be clarified although it is likely to be a result of the increased requirement of iron by the body as a result of the altitude training. It must be accepted that the level of iron supplementation was significantly below the 100–300 mg day⁻¹ recommended by the National Event Coach for 800/1500 m⁷. In retrospect, the support team should have persevered in finding a product which did not cause the athlete stomach discomfort. The relatively low level of iron supplementation is most probably the principal reason for the lack of an enhanced haemoglobin level.

Table 1. Results from blood samples taken before altitude; week 4, altitude Phase I; week 6 after altitude, Phase I; week 4, altitude Phase II; and week 3 after altitude Phase II

	Before altitude	Altitude Phase I week 4	After altitude Phase I week 6	Altitude Phase II week 4	After altitude Phase II week 3
Hb g dl ⁻¹ (11.5–15.5)*	13.3	14.5	13.7	13.8	14.2
Iron μmol l ⁻¹ (11–30)*		21.4	16.4	3.7	26

*Normal range given in parentheses

It had been anticipated that the altitude training would have improved aerobic performance but this was not evident from the determination of OBLA before and after exposure to altitude. It had been anticipated that OBLA post-altitude Phase I would have improved and indeed the feedback from the athlete's training runs indicated that this was the case. However, when tested, the athlete was unable to hold circulating lactate at a steady state at the faster pace of 4 min 55 s although the athlete was able to complete the test. The results of the lactate test were not received until some 3 weeks later due to the time required to conduct the assay. Therefore incorrect paces were used for the subsequent two training runs. The absolute values, as expected, were higher for the venous samples. This does not affect the interpretation of the assessment as absolute values are not used. It could be considered that maintenance of OBLA was in effect an achievement as the athlete had carried out a substantial amount of speed and strength work. In addition, the lack of a significant enhancement in haematological parameters would give little cause for an increased endurance performance.

Changes in the metabolic response to the OBLA determination test were, however, observed after altitude. The absolute values of the test before altitude were similar to many others carried out over the years for this athlete. It was the plateau figures after altitude which had decreased by approximately 1 mmol l⁻¹ in spite of the running pace at which steady state was reached being identical. The dietary pattern surrounding the tests was monitored closely and had not altered significantly. The drop in circulating lactate (the equating of production with removal) has been noted in other papers^{5,6}. These authors conclude that the lower lactate levels reflect less net release of lactate by the exercising muscle. This implies that although the performance of the athlete was similar both before and after altitude, the metabolic response is different and further work is required to understand what effect this has on actual track performance. It also has important consequences in terms of testing athletes' aerobic ability. The British Association of Sports and Exercise Science (BASES) guidelines use the absolute value of 4 mmol l⁻¹ as the indicator of aerobic threshold when testing athletes, i.e. an average value drawn from a population. If this methodology was used to assess the value of altitude

training in improving aerobic performance, the interpretation of the results would tend to overestimate the athlete's aerobic ability after altitude training. It was only because the more time-consuming original method was used that the true aerobic performance was measured accurately.

As expected, the heart rate rose at altitude, because of physiological stress and decreased on return to sea-level. However, a second exposure to altitude led to an unexpected rise in heart rate. Normally it would be expected that the second period of altitude exposure would provoke a less severe effect on heart rate. These results are complicated by the changes in training during the period in Capetown, where there was a significant increase in the number of speed and strength endurance sessions. These changes would normally be expected to increase heart rate. Therefore it would appear that training effects confounded the result.

The specific gravity data suggest that the fluid replacement was sufficient. The athlete had experienced training and competing in hot countries before and was practised in ensuring sufficient fluid was taken. In addition, the RPE ratings suggested that the training load was not over-stressful for the athlete.

The results presented in this paper highlight the difficulty in assessing an athlete's performance at altitude. It provides some data which can perhaps give a better insight into the backup requirements of an athlete in order to ensure maximum benefit from altitude training.

In summary, therefore, it is clear that when athletes are training at altitude in the hope of enhancing performance that:

1. national BASES guidelines for the measurement of aerobic performance may not appropriate;

2. athletes must persevere with iron supplementation and find an appropriate product that minimizes any potential gastrointestinal problems;
3. when profiling blood, assays should be conducted for serum iron.

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