



Original Research

The Effects of a 10-day Altitude Training Camp at 1828 Meters on Varsity Cross-Country Runners

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ABSTRACT

International Journal of Exercise Science 10(1): 97-107, 2017. Altitude training has been shown to alter blood lactate (BL) levels due to alterations resulting from acclimatization. This study aims to estimate the impact of altitude training on BL changes immediately following an incremental treadmill test and during recovery before and after 10-day altitude training at approximately 1828 meters. Eight varsity cross-country runners performed an incremental treadmill test (ITT), pre and post-altitude training. Resting and post-warm-up BL values were recorded. During ITT, heart rate (HR), oxygen saturation (SpO₂), and time to exhaustion were monitored. BL was also measured post-ITT at 0, 2, 4, 6, and 8 minutes. The average of all BL values was higher following altitude intervention (8.8 ± 4.6 mmol/L) compared to pre-intervention (7.4 ± 3.3 mmol/L). These differences were statistically significant ($t(6) = -2.40$, $p = .026$). BL immediately (0 minutes) after the ITT was higher following the altitude intervention (13.6 ± 3.6 mmol/L) compared to pre-intervention (9.7 ± 3.8 mmol/L) and was statistically significant ($t(7) = -3.30$, $p = .006$). Average HR during the ITT was lower following the altitude intervention (176.9 ± 11.1 bpm) compared to pre (187 ± 9.5 bpm), these differences were statistically significant ($t(28) = 18.07$, $p = <.001$). Time to exhaustion was longer after the intervention, however was not statistically significant $p = 0.13$. These findings indicate that a 10-day altitude intervention at 1828 meters may benefit varsity cross-country runners. The higher post-exercise BL may be attributed to more anaerobic contributions. Lower HR may suggest a larger stroke volume and/ or more efficient O₂ carrying capacity.

KEY WORDS: Blood lactate, heart rate, oxygen saturation, rate of perceived exertion, endurance training

INTRODUCTION

Lactate concentration in blood is one of the most frequent parameters utilized during exercise testing for endurance athletes (12). The reasons for this are: because blood lactate (BL) is a key marker for measuring the extent of anaerobic metabolisms, sampling is innocuous for the

subject; only a few drops of blood are required; and the reliability and validity of testing BL has increased with new technologies (12, 19).

Most of the adenosine triphosphate (ATP) needed for muscular contraction during the initial phases of incremental exercise comes from aerobic sources (22), however, as the intensity of exercise increases, BL levels begin to rise in an exponential manner (13). It is accepted that the sudden rise in BL throughout incremental exercise is due to an increasing dependence on anaerobic metabolism, particularly, glycolysis (5). Studies have established that BL measurements used in amalgamation with other physiological measurements are a valuable interpreter of success in distance running (10, 23). Additionally, possessing a sound understanding of BL may serve as a parameter in planning intensities needed to optimize training results (28).

Since 1968, altitude training has been utilized by both athletes and coaches in their training methodologies, with the aim of augmenting performance (2, 31, 35). The belief is that by living and training at altitude, athletes will enhance performance through various physiological parameters (26). However, one parameter that remains perplexing for researchers is the BL response during and immediately following altitude exposure (26, 37, 38).

The response of BL at altitude is frequently referred to as the lactate paradox. Reeves et al., (1992), described the lactate paradox as a “physiological response in which BL concentration during submaximal and maximal exercise is increased upon acute exposure but decreased with altitude acclimatization.” (29). Simply stated, the paradox defines the finding of lower than expected concentrations during maximal exercise at altitude (25). There is little explanation as to what causes the lactate paradox (6, 7, 24, 36, 37, 38).

Though much research has been conducted on BL levels while subjects are at altitude (24, 36, 37, 38), to the best of our knowledge no study has examined lactate levels following acute exposure to a moderate altitude (1828m). Therefore, the primary purpose of this study was to examine the difference between BL levels pre- and -post a 10-day moderate altitude training camp (1828 meters) in varsity cross-country runners.

METHODS

Participants

Following approval from the Lakehead University Research Ethics Board, eight healthy participants aged 18-22 years were recruited using purposive sampling. Each participant was a member of either a university or a high school varsity track and field and/or cross-country team. In total, there were five male and three female participants. Participants were included in the study if they were healthy (i.e., with no injuries) and competitive runners who had trained and competed for a varsity team.

Protocol

Following an explanation of the purpose and method of the study, consent to participate was obtained from each participant. Each testing session lasted approximately 1 hour.

Prior to testing, participants were asked to:

- Not eat a substantial meal within 3 hours before the test;
- Abstain from alcohol 24 hours prior to the test;
- Abstain from coffee, tea, or other caffeine sources at least 1 hour before the test; and
- Abstain from vigorous training or high intensity physical work for 24 hours prior to the test

A Physical Activity Readiness Questionnaire (PAR-Q) (1) and a lab specific Maximal Testing Pre-Participation Screening Questionnaire were completed to ensure participants were physically able to participate in the study. Upon completion of the required questionnaires, each participant had anthropometric measures (height, weight) taken. Measurements were recorded using a My Weigh MD 500tm digital scale and a Tanita HR - 100tm stadiometer (Tanita Corporation; Japan). Following these measures, participants had their resting HR (after 5 minutes in a supine position), resting blood pressure, and a resting BL measured and recorded. BL was measured using a capillary fingertip blood sample and a calibrated lactate protm portable analyzer (KDK, corporation, Kyoto, Japan, Arkray factory Inc., KDK corporation Shiga Japan) by the same clinician, using the same technique for each participant. A summary of the participants' baseline measurements can be seen in Table 1.

Table 1. Age, Gender, Height, Body Mass Pre-Altitude, Body Mass Post-Altitude, Resting Heart Rate Pre-Altitude, Resting and Heart Rate Post-Altitude of Varsity Cross Country Runners

Age (years)	20.50 ± 1.77
Gender	5M, 3F
Height (cm)	171.18 ± 9.46
Weight (kg) Pre-Altitude	59.25 ± 6.53
Weight (kg) Post-Altitude	59.7 ± 6.46
Resting HR (bpm) Pre-Altitude	55.37 ± 4.62
Resting HR (bpm) Post-Altitude	54.75 ± 7.55

M= males, F=Females, cm = Centimeters, kg = Kilogram HR= Heart Rate, bpm = beats per minute

Participants warmed-up for 10 minutes on a treadmill at 6 M.P.H. (9.65 K.P.H.) and completed 5 minutes of dynamic warm-up that focused on major muscle groups predominantly used during running.

Following the complete warm-up, participants' BL values were obtained and recorded. Further, a Polar RS 400 Heart Rate Monitor strap (Polar Electro Inc. Kempele, Finland) was fixed on the participant, as well as a NONIN GO2 Achieve fingertip pulse oximeter (Nonin Medical Inc. MN, USA). Participants were then fitted with a Hans Rudolph Inc. 7940 series mask (Hans Rudolph Inc. Shawnee Mission, KS, USA), connected to the AD instruments model ML206 Gas Analyzer metabolic cart (AD Instruments Pty Ltd, Castle Hill, Australia),

and placed on the Woodway Inc. model ELG treadmill (Woodway Inc., Waukesha, WI, USA) set at an incline of 0% grade.

An incremental treadmill protocol was then started, which consisted of two stages. In stage one, male and female participants underwent 3x3 minute treadmill increments. Following completion of the 3 minute increments, participants entered stage two, which consisted of 1 minute increments until exhaustion. This protocol was chosen, as stage one, allowed participants to achieve a steady-state, and stage two, allowed the speed at exhaustion to be determined. Three male participants, started at 9.3 M.P.H (14.96 KPH) and two male participants started at 9.9 M.P.H. (15.93 KPH) (based on their most recent race results). All three of the female participants started at 8.3 M.P.H (13.35 KPH). Table 2 indicates the starting speeds and speed increases for each group.

Table 2. Incremental Treadmill Test used pre-and-post altitude training camp.

	Time	Male Group 1 Speed (M.P.H.)	Male Group 2 Speed (M.P.H.)	Female Speed (M.P.H.)
Stage One (3 minute increments)	3	9.3	9.9	8.3
	6	10.1	10.7	8.8
	9	10.9	11.5	9.3
Stage Two (1 minute increments)	10	11.4	12	9.7
	11	11.9	12.5	10.1
	12	12.4	13	10.5
	13	12.9	13.5	10.9
	14	13.4	14	11.3

Speed in M.P.H at the various times (minutes), for all three of the groups. The Male participants in Group 1 had 3 participants in it, the male participants Group 2 had 2 participants in it. The male participants in Group 2 started slightly faster (based off of most recent race results). All of the 3 of the female participants started at the same speed. All of participants continued until they were no longer able to do so.

Researchers observed and recorded heart rate (HR) and oxygen saturation (SpO₂) every 30 seconds during the incremental treadmill test (ITT) until exhaustion. Expired gases were collected using the metabolic cart and recorded in real time using Power Lab 26T (AD Instruments Pty Ltd, Castle Hill, Australia), and were analyzed using the software lab chart version 7 (AD Instruments Pty Ltd, Castle Hill, Australia). Immediately after exhaustion, subjects had their BL and rate of perceived exertion taken and recorded using a 6-20 Borg Rate of Perceived Exertion Scale (3). Participants began running their cool down, both men and women ran at 6 M.P.H. and had BL values obtained and recorded immediately post-exercise and at minutes 2, 4, 6, and 8 post-exhaustion.

The subjects were tested in Thunder Bay, Ontario, Canada (Elevation 183 meters or 600 feet) within 10-days prior to attending a 10-day altitude training camp (located at Teary Peak, near the town of Lead, in the Black Hills of South Dakota, USA), at an elevation of approximately 1828 meters (6000 feet). At altitude, the subjects' training paralleled their typical training in Thunder Bay. The training matched their absolute sea-level intensities and subjects recorded their training sessions in a daily log.

Upon conclusion of the altitude training camp, subjects were re-tested within 3-days of returning to Thunder Bay, Ontario, Canada (183meters or 600 feet), using the same equipment and procedure as pre-altitude testing. Room temperature (degrees Celsius) and barometric pressure (mmHg) were recorded prior to every testing session.

Statistical Analysis

The software IBM SPSS Statistics Data Editor 20 (SPSS Inc., Armonk, N.Y., USA) was used to analyze the data. One categorical independent variable (pre-altitude exposure and post-altitude exposure), and twelve continuous dependent variables (average lactate, resting lactate, post-warmup lactate, lactate 0 minutes post-exercise, 2 minutes post-exercise, 4 minutes post-exercise, 6 minutes post-exercise, 8 minutes post-exercise, oxygen saturation, heart rate, time to exhaustion, and perceived exertion) were examined. The data were analyzed using paired samples t-tests to examine the effect of a 10-day altitude training camp intervention on the dependent variable for intervals of rest, post-warm-up, immediately after all out incremental exercise, 2,4,6, and 8 minutes post-exhaustive exercise. The rejection criteria was set with an alpha level $p < .05$.

RESULTS

The average of all blood lactate (BL) values were higher post-altitude intervention (8.8 ± 4.6 mmol/L) compared to lactate values pre-altitude (7.4 ± 3.3 mmol/L). These differences were statistically significant $t(6) = -2.40, p = .026$.

BL was slightly lower at rest and post warm-up following a 10-day altitude intervention. The resting BL before 10-day altitude intervention was ($2.1 \pm .5$ mmol/L), compared to post-altitude ($1.8 \pm .7$), however, the difference between the means was not statistically significant $t(7) = -1.30, p = 0.22$. The post-warm-up BL was (3.7 ± 1.9 mmol/L) following the altitude intervention, compared to the lactate pre-altitude intervention (4.2 ± 3.7 mmol/L), however, the difference did not reveal any statistical significance $t(7) = .279, p = 0.39$.

BL immediately post-ITT following 10-days of altitude intervention was higher (13.6 ± 3.6 mmol/L), as opposed to the BL immediately post-exercise in the pre-altitude trial (9.7 ± 3.8). This difference was statistically significant $t(7) = -3.304, p = .006$. BL was also taken and recorded at 2, 4, 6, and 8 minute's post- ITT.

On average, BL was higher following the 10-day altitude intervention (Figure 1), however, these differences were not statistically significant.

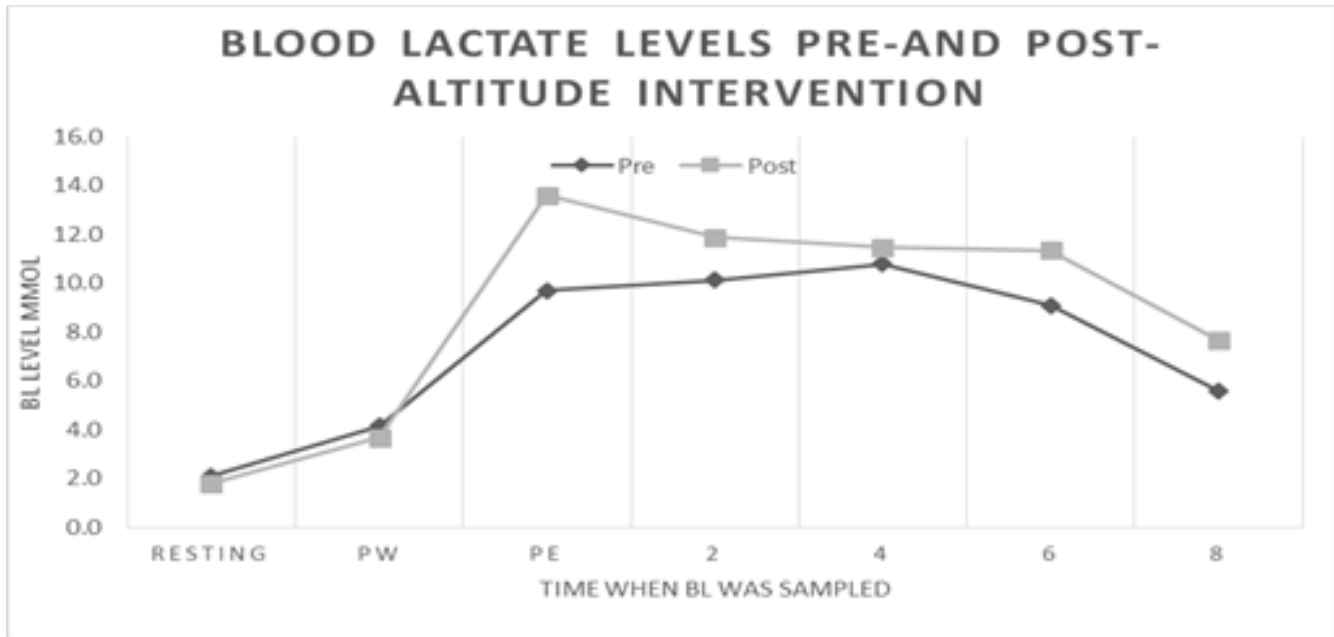


Figure 1. Depicts average BL levels pre-altitude and post-altitude in mmol/L taken at rest, post-warm-up (PW), post-exercise (PE), and at minutes 2, 4, 6, and 8 post-exercise.

Oxygen saturation (SpO₂) levels were constantly monitored and recorded every 30 seconds. SpO₂ levels on average were higher during the ITT following the 10-day altitude intervention ($94.6 \pm .932$ %O₂), compared to the average SpO₂ levels before altitude intervention (92.2 ± 1.23 %O₂). These differences were statistically significant $t(28) = -9.82, p < .001$.

Similarly, HR was constantly monitored and recorded every 30 seconds. The average HR during the ITT was lower following the altitude intervention (176 ± 11 bpm), when compared to the average HR values prior to the altitude intervention (187 ± 9 bpm). These differences were statistically significant $t(28) = 18.07, p < .001$.

The average peak HR was lower post-altitude intervention (193.5 ± 6.23 bpm) compared to (197.90 ± 6.90 bpm). However, this was not statistically significant $t(7) = 1.63, p = 0.07$.

Time to exhaustion (seconds) increased in 5 out of 8 participants post-altitude. On average, time to exhaustion for all participants post-altitude was (815.6 ± 50.26), compared to pre-altitude (784.5 ± 95.24). However, the difference was not statistically significant $t(7) = -1.21, p = 0.13$. Additionally, the rate of perceived exertion post-altitude was lower (17.37 ± 1.50) compared to ($17.87 \pm .991$) pre-altitude intervention, and was not statistically significant $t(7) = 1.87, p = 0.51$.

DISCUSSION

The study examined the effect of a 10-day altitude training camp at approximately 1828 meters on the parameters of BL, SpO₂, HR, time to exhaustion, and rate of perceived exertion following an incremental treadmill test.

The results show that the average of all BL levels immediately following ITT, post-altitude intervention, are significantly increased. There was no significant difference on BL levels at rest, post-warm up, or at intervals 2, 4, 6, and 8 minutes post- ITT following altitude, however, most of these values were higher on average. These results were in contrast to previously reported findings (6, 7, 15, 16), that established a decrease, or no change in peak BL values post-altitude intervention. This contrast may be attributed to a difference in altitudes investigated and the participants studied.

The ITT was chosen as it is most often studied during exercise testing (12). This particular ITT was chosen, as stage one, allowed participants to achieve a steady-state, and stage two, allowed the speed at exhaustion to be determined

The average peak BL value both pre (9.68 mmol/L), and post -altitude intervention of 13.6 mmol/L, are similar to previous findings in the literature (12). Withers and colleagues (1991) study on human subjects at sea-level identified BL values following a normal incremental exercise test to be between 9-25 mmol/L after exercise and lasting into the first few minutes, post-exercise (39).

The cause of the higher BL levels may be attributed to the fact that 5 out of 8 participants started an additional workload post-altitude. Although, there was no statistical difference in time to exhaustion, when comparing the pre- and post-altitude values, the slight increase in time to exhaustion can provide practical significance. The average time to exhaustion increased, and although it was not statistically significant, the results imply that 5 out of 8 participants experienced favorable gains. For many athletes or coaches, this would be worth exploring. In addition to the aforementioned reasons, it is possible that the lower HR levels in combination with the higher SpO₂ levels allowed the participants to last slightly longer during the ITT (20). The impact from both of these parameters will be discussed below.

It is possible that the average lower heart rates observed post-altitude intervention is due to a larger stroke volume. This would be consistent with Sime and colleagues (33) findings. In highly trained endurance athletes who possess a much higher cardiac output, pulmonary diffusion can become a limiting factor in regards to endurance performance. A high cardiac output shortens the time during which the blood can pick up oxygen in the lungs, which may lead to lower blood SpO₂ (8, 30). In contrast to these potential explanations, our results indicate a decrease in heart rate, accompanied by an increase in oxyhemoglobin saturation. Additionally, on average, participants were able to perform the test for slightly longer durations post-altitude. The mechanism that mediates the test performance at longer duration could possibly be due to an increased release of erythropoietin (EPO) following altitude intervention (11). An increased release of EPO would cause a transient increase in red blood cell mass, thus, allowing more O₂ transport (11, 32). Previous research indicates that these processes could take longer than 2-weeks, hence, this may only partially explain our results (33).

The timeline for changes in the bicarbonate buffer system may provide additional explanation. Some authors (17, 27) suggest that due to the respiratory alkalosis that occurs with hyperventilation at altitude, the kidneys react to this by excreting more bicarbonate in an attempt to reinstate normal pH. As bicarbonate is an important buffer of H⁺, this adaptation has a negative impact on anaerobic capacity. Fortunately, as adaptation occurs, the hyperventilation response becomes blunted, causing resting and exercise ventilatory volumes to diminish towards, but never achieve those at sea-level. As a result, the kidneys excrete less bicarbonate and slowly return blood bicarbonate levels towards those of sea-level (17, 27). This physiological mechanism may lead to higher lactate tolerance, which may explain our results, however, this notion should be further explored.

The 10-day training had a noteworthy impact on HR and SpO₂ levels during performance. These changes were statistically significant, and the impact of this application in sport training is high. Previous research has presented positive physiological variations in regards to HR and SpO₂ (14, 21). However, these studies differ as they were all 14-24 days long, and at altitude equal to or greater than 2100 meters (6890 feet). Additionally, these studies used different altitude training techniques; chiefly live-high, train low.

Based on our results, we posit that cardiovascular changes such as, HR and oxyhemoglobin saturation, can be obtained at altitudes as low as 1828 meters and intervention duration as short as 10-days. Additionally, training at altitudes as low as 1828 meters may provide advantages of altitude training without some of the potential disadvantages, including: decrease in absolute training intensity (34), a significant decrease in plasma volume (40), and increased respiratory muscle work upon return to sea-level (18). Further research in this area is required to optimize applicability in training methodologies.

Significant limitations of the study include: the small number of participants (n=8), and a lack of measurement of related indices (i.e. lactate threshold, hematocrit, and bicarbonate). Another limitation can be associated with the design of the study. A one-group pre-test post-test design was used and future studies may consider including a control group.

The study is delimited to a small age range (18 - 22), that participants were all varsity level runners, and that the altitude was approximately 1828 meters.

We experienced several equipment errors. The monitor did not capture one participant's HR accurately during the post-altitude test. As a result, some of the HR readings from this test had to be omitted. Further, the pulse oximeter did not remain on one participant's finger near the end of the incremental test. As a result, the SpO₂ data obtained during this test was also omitted when analyzing the results.

In conclusion, altitude training has been a popular training intervention since the 1968 Summer Olympics. Although altitude training has been extensively researched, controversy exists over the best techniques to use, the potential physiological benefits, the exact timeline

that physiological changes occur, and its overall effectiveness for endurance athletes (40). The findings of this study have shown that blood lactate (BL) levels following a 10-day altitude intervention at approximately 1828 meters are higher on average, and are statistically significant immediately after maximal exercise. The fact that 5 out of 8 participants increased their time to exhaustion following the altitude intervention, yet the average rate of perceived exertion was lower, may have some practical significance for training and competition. Additionally, the study suggests, that 10-days of altitude training at approximately 1828 meters, may be enough to alter physiological parameters such as, lower heart rate, higher SpO₂, and enhanced coping to higher levels of blood lactate, thus, leading to a potential advantage in training and competition alike. Further study is required, and could expand upon the current findings.

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