ACTA UNIVERSITATIS CAROLINAE
KINANTHROPOLOGICA Vol. 50, 1 – 2014 Pag. 5–14

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CHANGES OF SELECTED HEMATOLOGICAL PARAMETERS AND MORNING REST RATE DURING TEN DAYS HIGH ALTITUDE STAY AND TRAINING

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ABSTRACT

This article describes the influence of a ten day stay and training in a high altitude area (1850 m ASL) on selected blood count parameters and morning resting heart rate. Three tests were performed on a group of young cross country skiers ($n = 10$, age: 18.7 ± 4.8): two days before, two days after and ten days after the altitude training camp. Two day after the return, significant ($p < 0.05$) increases in hemoglobin level (5.4%), red blood cell (3.2%) and hematocrit (4.3%) were observed. Ten days after the return to the lowland, were found significant increases in concentration of hemoglobin and red blood cell ($p < 0.05$) compared with the check measurement before high altitude. Increases in hematocrit were not significant. The heart rate was higher during the camp than before ($p < 0.01$). The average decrease in heart rate (2.6%) ten days after the return in comparison with basal data was not statistically significant ($p > 0.05$).

The study in a group of young cross country skiers has shown positive effects of a ten-day training camp in high altitude on blood count parameters and morning resting heart rate monitored in lowland two and ten days after the return from high altitude.

Keywords: altitude, blood count, morning heart rate, sports training

INTRODUCTION

Utilizing lower partial pressure of oxygen is currently one of the most frequently discussed legal ways to influence sports performance. Lower partial pressure of oxygen can be evoked naturally (i.e. by altitude stay) or artificially (i.e. by staying in special tents, barochambers or "oxygen" houses). Exposure to hypoxia induces number of physiological changes – decrements in arterial oxyhemoglobin saturation and maximal oxygen consumption, changes in heart rate (HR), hydration status, immune function etc. These changes may limit athlete's ability to train or compete. Monitoring of morning resting heart rate as a part of cardiovascular response of the body is one of the possibilities how to control athlete's adaptation to altitude training (Schmitt et al., 2008). An important part of the training (not only for the lower partial pressure of oxygen) is regular blood analysis. It is necessary to monitor, above all the parameters that are directly affected by the altitude (Sherry & Wilson, 1998; Weineck, 1997). Of the biochemical variables are mainly used: hemoglobin, hematocrit, iron metabolism parameters in blood serum and blood oxygen saturation. Furthermore, variables characterizing acidosis after training such as lactate, pH, base excess (Suchý, 2012).

The significance of stay and training in high altitude for sports training has been confirmed by numbers of published papers. One of the first monographs on the topic was published by Jokl (1968) who summarized data from the first Olympic Games which took place in high altitude (Mexico, 1968). A synthesis of data gained throughout twenty years since the breakthrough Olympics in Mexico was published by Fuchs & Reiss (1990) and Marajo & Réga (1989). A monograph by Wilber (2004) introduces methodology and approaches on the issue of utilizing altitude, which results from his long term experience in researching the impact of altitude on human organism in USOC center in Colorado Springs (1850 m ASL). Millet & Schmitt (2011) summarize theoretical and methodological aspects of altitude training as well as results of their own research.

The meta-analysis of articles published by Bonetti & Hopkins (2009) on this topic in past 30 years showed that elite athletes increased their sea level athletic performance about 5.2% after staying and training in altitudes of about 2000m ASL compared with staying and training in lowland.

Adaptation to high altitude is a relatively long complex process. There is a general agreement that 21-day stay and training is an ideal period to get adapted to altitude successfully (Jokl, 1968; Marajo & Réga, 1989; Millet & Schmitt, 2011). The majority of analyses of classical three week stay and training in natural altitude (1800–2400 m ASL) have found positive effects on aerobic performance and changes in biochemical parameters of endurance athletes (Dovalil et al., 1999; Fuchs & Reiss, 1990; Jokl, 1968; Pupiš & Korčok, 2007; Suchý, 2009; Wilber, 2004). In past 20 years, artificial altitude (Rusko, 1996; Wilber, 2004) has been used to increase aerobic performance and blood count parameters; this issue is, however, not dealt with in this paper.

In our previous qualitative research with Czech coaches of various sports branches, we found out that many of them used stays shorter than classical 21 days in high altitude areas – usually from ten to twelve days. These shorter stays are convenient due to socioeconomic reasons and it is also evident from empiric experience of the addressed coaches that even short stays have a positive influence on the conditioning level of the endurance athletes (Suchý & Dovalil, 2009). Our analysis showed that the vast majority of relevant research revealed positive effects of a classical three week stay in natural high altitude areas (1800–2500 m ASL) on aerobic performances and changes in biochemical parameters of endurance athletes (Bonetti & Hopkins, 2009). However, there are only a limited number of relevant studies focusing on the issues concerning high altitude acclimatization in an approximately ten day period. Klausen et al. (1991) researched the influence of a seven day stay in altitude of 1700 m ASL and training in altitude of 2760 m ASL on selected blood count parameters with cross country skiers (n = 7). The majority of observed blood count parameters were higher during the stay and also after coming back to lowlands than as found out by check measurement before leaving for the stay. Svedenhag et al. (1991) were concerned with a two week altitude stay and training (2000 m ASL) with middle distance runners (n = 7) and found out that it had no impact on aerobic performance increase but a change in the circulatory regulation during submaximal exercise was observed. This paper was not designed to include blood analysis.

PURPOSE

The aim of our study was to monitor selected hematological parameters before and after a short-term altitude stay and training. The results of the research may be valid in verifying if a shortened ten day stay and training in 1850 m ASL is influential increasing observed blood count parameters immediately and in a ten days' time after coming to lowlands in comparison with check values measured before leaving for the stay. Another aim was to check the influence of altitude on morning resting HR. Morning resting HR is considered to be an easy indicator of acute changes in the inner state of the organism often used by coaches and athletes (Suchý, 2012; Wilber, 2004).

PROCEDURES

Participants

The study was conducted on a group (n = 10, men: 7, women: 3) of young (under 18) and junior (under 20 and 23) cross country skiers. All participants were members of the Youth Sports Center in Jilemnice (Czech Republic). All of them take regularly part in the contests of Czech Cross country cup and they are subjects to regular training (for the period of 7 ± 3.3 year on average). At the time of conducting the research, three participants were members of Czech junior national team. Characteristics of the probands are shown in Table 1. The skiers were in a good health condition during the research period and under regular medical supervision during the whole training year. Considering the fact that the research took place during a training period, the training process was aimed to an aerobic training, with high volumes and low intensity load, which took 27–32 hours per microcycle. During the training camp in altitude (1850 m ASL, Livigno, Italy), competitors practiced 29 to 33 hours in 9 training and two rest days. Within the framework of the training process, the skiers spent approximately 12 hours in an altitude of about 2200 m ASL. Detailed description of the training program is provided in Suchý (2012).

Table 1. Probands characteristics (n = 10)

Variables	Age (years)	Years of training (years)	Body fat (%)	Height (cm)	Weight (kg)
Average ± S.D.	18.7 ± 4.3	7 ± 3.3	9.4 ± 4.5	175.6 ± 4.7	67.5 ± 8.1

S.D. – standard deviation

Measures

To get input check data, selected values of blood count in observed persons were gathered after long-term stay in lowlands (500 m ASL) two days before leaving for altitude training session (T1). The same blood count parameters were gathered again two days after coming back from the ten-day altitude training session – 1850 m ASL (T2) so that they were not affected by possible dehydration after a ten hour journey from Livigno. The last test was carried out ten days after finishing the training session (T3); all participants spent the ten days in lowlands (500 m ASL).

Morning resting HR [beat.min^{-1}] was continuously checked by the participants themselves during the whole course of the research.

Procedures

All the participants were repeatedly tested for selected hematological parameters in the blood count, namely those which are important for assessment of the influence of high altitude on the human body:

- hemoglobin (g/l)
- red blood cell count (10^12/1)
- hematocrit (%)

The blood samples were taken in the morning on an empty stomach by a medical doctor who participated in our study and samples were analyzed and evaluated in the certified laboratory of Jilemnice Hospital.

Body fat values were obtained according to the model of Pařízková (1977).

The morning resting HR was monitored individually with the help of sport testers. Monitoring was carried out after the participants woke up, still lying in bed. Input values started to be gathered 24 days before their departure for the training camp and ended 26 days after their return, which is consistent with the theory of the performance peak within the 21st day in lowland after three-week stay and training in altitude (Dovalil, 1999). It meant 60 days of every day resting HR monitoring. The lowest value in one minute of measuring was recorded in a special record which was handed in after the research was finished.

Statistical analysis

Microsoft Excel 2007 was used for subsequent processing and analysis. With regard to the nature of the research (Hendl, 2004) and in accordance with similar published researches (Bonetti & Hopkins, 2009), we decided to judge statistical significance of differences at the level of significance $p < 0.05$ and $p < 0.01$. We monitored the substantive significance for the differences in the variables monitored using Cohen's d effect coefficient (Hendl, 2004) with the conventional parameter d as follows: $d > 0.8$ means large effect, $d > 0.5–0.8$ means medium effect, $d > 0.2–0.5$ means small effect, $d < 0.2$ very small effect.

The research was performed in accordance with World Medical Association declaration of Helsinki Ethical Principles for Medical Research Involving Human Subjects amended in October 2008 in Seoul. The Ethical committee of the Faculty of Physical Education and Sport, Charles University in Prague approved of the research design in August 23rd 2009. All the participants signed the informed consent.

RESULTS

Following the set methodology, we took blood samples of all observed athletes on afore determined dates (T1, T2, T3) which are summarized in Table 2 and Table 3.

Table 2. Selected blood count parameters of all participants (n = 10)

Variables/date	**T1**	**T2**	**T3**
	Red blood cells (10^12/1)		
Average ± S.D.	4.96 ± 0.15	5.12 ± 0.06	5.07 ± 0.17
	Hemoglobin (g/l)		
Average ± S.D.	145.2 ± 11.7	153.1 ± 10.97	148.3 ± 11.81
	Hematocrit (%)		
Average ± S.D.	43.8 ± 2.9	45.7 ± 3.0	44.5 ± 3.5

T1 – check measurement prior to altitude; T2 – immediately after return; T3 – ten days after returning from altitude

Table 3. Statistical significance and size effect of chosen blood count parameters changes

Variables / no. of the test	**Red blood cells (10^12/1)**		**Hemoglobin (g/l)**		**Hematocrit (%)**	
	d	P	d	P	d	P
T1 vs. T3	0.41	0.044	0.55	0.005	0.19	n.s.
T1 vs. T2	0.65	0.004	0.88	0.000	0.61	0.001
T2 vs. T3	0.25	n.s.	0.33	0.028	0.41	0.026

T1 – check measurement prior to altitude; T2 – immediately after return; T3 – ten days after returning from altitude); S.D. – standard deviation; d – size effect; n.s. – not significant

Average increase in observed blood count parameters found immediately after returning from the ten day altitude training session in comparison with the values taken before leaving for altitude camp (T1 vs. T2 measurements): red blood cells by 3.2% ($p < 0.05$), hemoglobin by 5.4% ($p < 0.05$), hematocrit by 4.3% ($p < 0.05$).

Significant increase (d) between T1 and T2 measurements was found in all parameters. Large effect (d) was observed with hemoglobin, while medium effect (d) occurred with red blood cells and hematocrit.

Ten days after returning from altitude camp, the increase in observed parameters was still visible in comparison with check measuring before leaving (T1 vs. T3): red blood cells by 3.3% ($p < 0.05$), hemoglobin by 2.1% ($p < 0.05$), hematocrit by 1.5% (n.s.). The increase in observed parameters between T1 and T3 measuring had medium effect (d) for hemoglobin. The increase in hematocrit and red blood cells had small effect (d).

The revealed positive influence of ten day altitude stay and training on observed parameters of blood count is in compliance with the results of Berglund (1992), Faulkner et al. (1967), Klausen et al. (1991), Suchý (2012), Svedenhag et al. (1991), who evaluated similar blood indicators in athletes after one to two week altitude stay and training.

Resting heart rate monitoring

Acute changes of the inner state of organism exposed to high altitude were longitudinally tracked by the sportsman themselves by means of the values of morning resting heart rate immediately after waking up (Figure 1).

3.7% of morning HR results are missing because in some cases some of the participants failed to record it. We did not use the heart rate parameters from the days on which the athletes travelled to and from the training camp.

Average values of morning resting HR in altitude were by 9.4% ($p < 0.01$) higher than within check measuring in lowlands before leaving for altitude camp. Gained results confirm that altitude brings increase in morning resting heart rate which culminates on the second day and subsequently decreases but always stays at a higher level than in lowlands.

After returning to lowlands, average values of morning resting HR were by 11.4% ($p < 0.01$) lower than during altitude stay. Gathered values are in compliance with estimations and they confirm that the reaction of organism to initial days spent in altitude results in increasing morning resting HR.

Average values of morning resting HR after returning from altitude camp were by 1.6 [beat.min^{-1}], i.e. 2.6% (n.s.), lower than before leaving; size effect (d) of this change was small as well. Even though the measuring has not proved statistical difference or size effect of HR decrease before leaving and after returning, we suppose that, from the point of view of sports training and the inner reaction of organism, average decrease by 1.6 [beat.min^{-1}] is an important change.

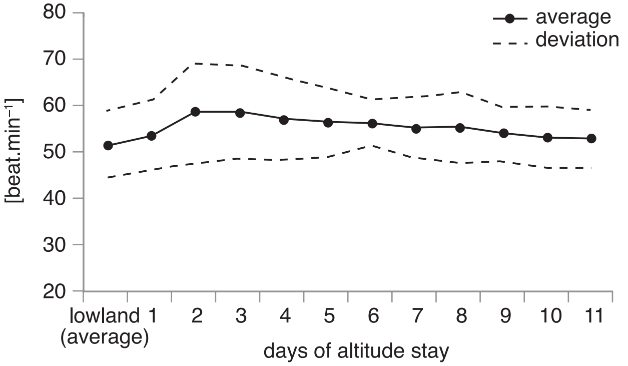

Figure 1. The average values of morning resting heart rate during each day of altitude stay

Table 4. Results of the morning rest HR measurements in lowland, in altitude and after return to lowland from altitude

Variables / measurements	Before altitude [beat.min^{-1}]	In altitude [beat.min^{-1}]	After altitude [beat.min^{-1}]
Average ± S.D.	51.6 ± 6.4	55.9 ± 7.0	50.2 ± 6.0

Table 5. Statistical significance morning rest HR measurements in lowland, in altitude and after return to lowland from altitude

Variables / no. of the test	p
T test ⌀ before vs. after	0.002
T test ⌀ before vs. altitude	0.042
T test ⌀ altitude vs. after	0.016

DISCUSSION

The results of the measuring confirmed that shortened ten day altitude stay and training is influential in increasing the observed blood count parameters immediately after returning from altitude camp (T2) in comparison with check values before leaving (T1). Likewise, ten days after coming back to lowlands (T3), observed values were higher than before leaving (T1). On the basis of this observation, we assume that it is possible to induce that a ten day stay and training in high altitude may positively affect the increase in performance. It is clear, that also the other functional systems are necessary for the final use of oxygen in the body and thus better athletic performance. But improvement in hematological parameters, which is assumption for better transportation function of blood, is only one of the conditions for aerobic performance improvement. Our results are for instance in compliance with the findings of Klausen et al. (1991) who found significant increase in erythrocytes after seven days spent in altitude of 1700 m ASL; but the training load with cross country skiers was carried out in altitude of 2700 m ASL. Friedman et al. (1999) found significant increase in both erythrocytes and hematocrit. Similar results were presented by Strzala et al. (2011) or Wilber (2004).

The information value of the results would be greater if the observed parameters could be checked also during altitude stay. More frequent sample taking after returning to lowlands (not only on the second and tenth days) would make the information more accurate. The same range of hematological parameters measurements as morning resting HR measurements wasn't possible for technical and organizational reasons.

The results of (not only) the observed blood count parameters are significantly affected by current hydration of the organism. We attempted to reduce this negative influence by checking liquid and energy intake and body weight of the observed skiers. In the course of the research, all observed skiers kept the same weight. Twelve hours spent on the bus on the way from and to Livigno (where the training session took place) influenced hydration negatively. For this reason, we did not take blood immediately, but two days after coming back to lowlands.

A theoretical possibility to increase the information value of the results was including a bigger number of athletes into the research. This possibility was considered as early as within preparations of the research design but with respect to socio-economic and organizational aspects; we were not able to secure a bigger number of probands. However, meta-analysis by Bonetti & Hopkins (2009) shows that a similarly small number of persons (most often from 5 to 15) are used in this kind of research, which means the same number of probands as we used in our research. We have also considered presentation of individual data for each person, but given the scope of this article and gender difference we have rejected it.

On the basis of the feedback on the research design, we suppose that it would be interesting to increase supply of iron to the athletes (e.g. with food supplements). Chapman & Levin (2000) or Stray-Gundersen et al. (2001) state that there is a possible relationship between higher values of hematocrit and bigger iron supplements during the course of altitude stay. On the contrary, Friedmann et al. (1999) state that the influence of iron supplements on the increase in the amount of hemoglobin in high altitude cannot be proved.

As is well known, high altitude also affects morning resting heart rate. The higher average values of morning resting HR of our group correspond to other results (Dovalil et al., 1999; Jokl, 1968; Friedmann & Burtsch, 1997; Chapman et al., 1998; Wilber, 2004). The highest values were observed from the 2nd to the 6th day of the stay, while papers usually refer the time period between the 2nd and 4th days as crisis days, and recommend diminishing training volume.

Morning HR could be affected during the first days of altitude by fatigue after a long journey and shorter rest on the first day. After the stay in altitude camp, the level of HR was relatively quickly adjusted little bit lower compare to original values. But it is a matter of suitable reacclimatization process during the first several days after returning to lowlands (Chapman et al., 1998; Dovalil et al., 1999). We suppose that the lower value of HR after altitude stay is a consequence of cumulative effect of the unusual environmental stimulus during a ten day stay in a high altitude area and proper training in altitude and before the camp (Wilber, 2004).

Average values of morning resting heart rate may be influenced by different times and methodology of individual measuring by individual research participants (e.g. the time period between waking up and measuring or the position of the body at the time of measuring). With respect to the bigger number of research days, we consider the consequences of this error relatively insignificant.

It would be more suitable to use variability of morning heart rates which has bigger information value (Melanson, 2000) or orthostatic reflex. We were considering both the tests during the preparations of the research design but abandoned them. The reason for this was the fact that the skiers recorded the morning values individually and they might not pay sufficient attention to a more complicated test, which might negatively affect the data.

A comparison of the influence of high altitude on the values of hematological and physiological parameters in men and women might bring interesting findings. In measurements carried out by us, women reached lower values of all hematological indicators and higher morning HR in comparison with observed men. This finding corresponds to commonly present physiological differences (Millet & Schmitt, 2011). Intersexual differences are not dealt with in the chapters on results in greater detail because the data were gathered on a small sample and the representation of men and women was not proportional either. Within data analysis of observed men and women, we were trying to find whether there are researches which focus on this issue. The majority of papers present only overall data for both sexes.

Aerobic tests (Suchý, 2012) were performed as a part of this research, but regarding to the range of this article are not included.

CONCLUSION

The changes in selected hematological parameters of monitored cross country skiers confirm the positive effects of a ten day stay and training in high altitude areas (1850 m ASL).

The values of mean morning resting HR proved that altitude is considerably significant in increasing the values of morning resting HR in comparison with lowland values. The changes of average values of morning resting HR in high altitudes which have been found out unambiguously prove that monitoring morning HR is a necessary part of the training process.

Altitude stay had an effect on average decrease in values of morning resting HR in lowlands (if compared to check measuring) which were not factually or statistically significant. Nevertheless, decrease by 1.6 [beat.min^{-1}] (i.e. 2.6%) is in our opinion important from the point of view of sports training.

On the basis of the results and their comparisons with references in literature, it can be concluded that it is desirable to make use of a ten day altitude stay and training with the aim to increase fitness during subsequent stay in lowlands, above all in endurance sports.

This study was financed from the institutional support for the development of research organizations and supported by The Ministry of Education, Youth and Sports Czech Republic (MSM0021620864), PRVOUK P38 and specific research (267 602).

No additional funding was received from any other organization. The authors have no conflicts of interest to report. Special thanks to Michael Allen for language corrections.

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ZMĚNY VYBRANÝCH HEMATOLOGICKÝCH PARAMETRŮ A RANNÍ KLIDOVÉ SRDEČNÍ FREKVENCE V PRŮBĚHU DESETIDENNÍHO TRÉNINKU A POBYTU VE VYŠŠÍ NADMOŘSKÉ VÝŠCE

JIŘÍ SUCHÝ, JAN PERNICA, PAVEL KORVAS

SOUHRN

Článek popisuje vliv desetidenního tréninku a pobytu ve vyšší nadmořské výšce (1850 m n. m.) na vybrané parametry krevního obrazu a ranní klidové srdeční frekvence. U skupiny mladých běžců na lyžích ($n = 10$, věk: $18{,}7 \pm 4{,}8$) byly realizovány celkem tři odběry krve: dva dny před soustředěním ve výšce, dva dny a deset dnů po návratu do nížiny. Dva dny po návratu byly signifikantně ($p < 0{,}05$) zvýšeny parametry hemoglobinu (o 5,4 %), červených krvinek (o 3,2 %) i hematokritu (o 4,3 %) v porovnání s kontrolním měřením v nížině. Deset dnů po návratu ze soustředění ve výšce byly signifikantně ($p < 0{,}05$) zvýšeny parametry červených krvinek a hemoglobinu v porovnání s parametry před soustředěním. Hematokrit byl také zvýšený, ale nikoliv signifikantně ($p > 0{,}05$). Průměrné hodnoty ranní klidové srdeční frekvence byly během soustředění ve výšce vyšší než před odjezdem v nížině ($p < 0{,}01$). Po návratu do nížiny byly průměrné hodnoty ranní klidové srdeční frekvence o 2,6 % nižší než před odjezdem do výšky, ale změna nebyla statisticky významná ($p > 0{,}05$).

Námi realizovaný výzkum u skupiny mladých běžců na lyžích prokázal pozitivní efekt desetidenního pobytu a tréninku ve vyšší nadmořské výšce (1850 m n. m.) na sledované krevní parametry a ranní klidovou srdeční frekvenci v nížině po návratu.

Klíčová slova: vyšší nadmořská výška, krevní obraz, ranní srdeční frekvence, sportovní trénink

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