A COMPARISON OF HEART RATES BETWEEN SIMULATED AND REAL ALTITUDE

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Abstract

The aim of the presents study is to make a comparison between heart rates measured at real altitude and at the simulated altitude (in hypoxic chamber), before and after the process of acclimatization. Six students (two women and four men) of Faculty of sport in Ljubljana participated in the study. They undergone eighteen day long acclimatization process on 2100 - 5642 m. Heart rates were measured in rest and during the step test before and after the acclimatization, at two locations: high altitude simulation chamber in Ljubljana and real altitude in Elbrus, Kavkaz, both at 2100 m. The results showed that heart rates were not significantly different between real altitude and simulated altitude. Acclimatization process caused a decrease of heart rates in both cases. From that we can conclude that it would be possible to train in hypoxic chamber and therefore shorten the acclimatization time in real very high mountains. Heart rate could be used as an objective parameter of the quality of the acclimatization. This should be proven in the future by research on bigger sample.

Keywords: mountaineering, hiking, acclimatization, heart rate.

Introduction

Hiking and climbing in high mountain ranges used to be exclusively the privilege of mountaineers. Nowadays, more and more tourists take part in trekking trips to high mountains. Simultaneously with the increased number of tourists, the numer of accidents at high altitudes above 3000 m also increases. The adoption to living at high altitudes is of utmost importance for the assurance of safety. Improper acclimatization in high altitudes can lead even to death (Balado, 1996). Such an unfortunate case happened in 2008, when four members of an Iranian expedition to Pik Lenin (7134 m) made an improper time schedule of the ascent (personal communication).

Acute Mountain Sickness (AMS)

AMS is common at high altitudes. At elevations over 3000 m, 75% of people will have mild symptoms. The occurrence of AMS is dependent upon the elevation, the rate of ascent, and individual susceptibility. Many people will experience mild AMS during the acclimatization process. Symptoms usually start 12-24 hours after arrival at altitude and begin to decrease in severity about the third day. The symptoms of Mild AMS are headache, dizziness, fatigue, shortness of breath, loss of appetite, nausea, disturbed sleep, and a general feeling of malaise. Symptoms tend to be worse at night and when respiratory drive is decreased. Mild AMS does not interfere with normal activity and symptoms generally subside within 2-4 days as the body acclimatizes. As long as symptoms are mild, and only a nuisance, ascent can continue at a moderate rate. When hiking, it is essential that you communicate any symptoms of illness immediately to others on your trip. AMS is considered to be a neurological problem caused by changes in the central nervous system. It is basically a mild form of High Altitude Cerebral Edema (Hacket & Roach, 2001)

Moderate AMS

Moderate AMS includes severe headache that is not relieved by medication, nausea and vomiting, increasing weakness and fatigue, shortness of breath, and decreased coordination (ataxia). Normal activity is difficult, although the person may still be able to walk on their own. At this stage, only advanced medications or descent can reverse the problem. Descending even a for 70-100 m may help and definite improvement will be seen in descents of 300-600 m. Twenty-four hours at the lower altitude will result in significant improvements. The person should remain at lower altitude until symptoms have subsided (up to 3 days). At this point, the person has become acclimatized to that altitude and can begin ascending again. The best test for moderate AMS is to have the person "walk a straight line" heel to toe. Just like a sobriety test, a person with ataxia will be unable to walk a straight line. This is a clear indication that immediate descent is required. It is important to get the person to descend before the ataxia reaches the point where they cannot walk on their own (which would necessitate a litter evacuation). (http://wildernessmedicinenewsletter.wordpress.com/2006/11/19/high-altitude-cerebral-edema-hace/)

Severe AMS

Severe AMS presents as an increase in the severity of the aforementioned symptoms, including shortness of breath at rest, inability to walk, decreasing mental status, and fluid buildup in the lungs. Severe AMS requires immediate descent to lower altitudes 600-1200 m.

There are two other severe forms of altitude illness, High Altitude Cerebral Edema (HACE) and High Altitude Pulmonary Edema (HAPE). Both of these happen less frequently, especially to those who are properly acclimatized. When they do occur, it is usually with people going too high too fast or going very high and staying there. The lack of oxygen results in leakage of fluid through the capillary walls into either the lungs or the brain. (http://wildernessmedicinenewsletter.wordpress.com/2006/11/19/high-altitude-cerebral-edema-hace/)

High Altitude Pulmonary Edema (HAPE)

High Altitude Pulmonary Edema results from fluid buildup in the lungs. The fluid in the lungs prevents effective oxygen exchange. As the condition becomes more severe, the level of oxygen in the bloodstream decreases, and this can lead to cyanosis, impaired cerebral function, and death. Symptoms include shortness of breath even at rest, "tightness in the chest," marked fatigue, a feeling of impending suffocation at night, weakness, and a persistent productive cough bringing up white, watery, or frothy fluid. Confusion and irrational behavior are signs that insufficient oxygen is reaching the brain. One of the methods for testing yourself for HAPE is to check your recovery time after exertion. If your heart and breathing rates normally slow down in X seconds after exercise, but at altitude your recovery time is much greater, it may mean fluid is building up in the lungs. In cases of HAPE, immediate descent is a necessary life-saving measure 600-1200 m. Anyone suffering from HAPE must be evacuated to a medical facility for proper follow-up treatment.

(http://wildernessmedicinenewsletter.wordpress.com/2006/11/19/high-altitude-cerebral-edema-hace/)

High Altitude Cerebral Edema (HACE)

HACE is the result of swelling of brain tissue from fluid leakage. Symptoms can include headache, loss of coordination (ataxia), weakness, and decreasing levels of consciousness including, disorientation, loss of memory, hallucinations, psychotic behavior, and coma. It generally occurs after a week or more at high altitude. Severe instances can lead to death if not treated quickly. Immediate descent is a necessary life-saving measure 600-1200 m. There are some medications that may be prescribed for treatment in the field, but these require that you have proper training in their use. Anyone suffering from HACE must be evacuated to a medical facility for proper follow-up treatment.

(http://wildernessmedicinenewsletter.wordpress.com/2006/11/19/high-altitude-cerebral-edema-hace/).

Acclimatization in real altitude

The major cause of altitude illnesses is going too high too fast. Given time, your body can adapt to the decrease in oxygen molecules at a specific altitude. This process is known as acclimatization and generally takes 1-3 days at that altitude. For example, if you hike to (3000 m), and spend several days at that altitude, your body acclimatizes to (3000 m). If you climb to (3500 m), your body has to acclimatize once again. A number of changes take place in the body to allow it to operate with decreased oxygen.

The depth of respiration increases

Pressure in pulmonary arteries is increased, "forcing" blood into portions of the lung which are normally not used during sea level breathing. The body produces more red blood cells to carry oxygen. The body produces more of a particular enzyme that facilitates the release of oxygen from hemoglobin to the body tissues.

Prevention of Altitude Illnesses

Prevention of altitude illnesses falls into two categories, proper acclimatization and preventive medications. Below are a few basic guidelines for proper acclimatization. If possible, don't fly or drive to high altitude. Start below 3000 m and walk up. If you do fly or drive, do not over-exert yourself or move higher for the first 24 hours. If you go above 3000 m, only increase your altitude by 300 m per day and for every 900 m of elevation gained, take a rest day. "Climb high and sleep low." This is the maxim used by climbers. You can climb more than 300 m in a day as long as you come back down and sleep at a lower altitude. If you begin to show symptoms of moderate altitude illness, don't go higher until symptoms decrease (" Don't go up until symptoms go down"). If symptoms increase, go down, down, down!

Keep in mind that different people will acclimatize at different rates. Make sure all of your party is properly acclimatized before going higher.

Stay properly hydrated. Acclimatization is often accompanied by fluid loss, so you need to drink lots of fluids to remain properly hydrated (at least 3-4 quarts per day). Urine output should be copious and clear. Take it easy; don't over-exert yourself when you first get up to altitude. Light activity during the day is better than sleeping because respiration decreases during sleep, exacerbating the symptoms. Avoid tobacco and alcohol and other depressant drugs including, barbiturates, tranquilizers, and sleeping pills. These depressants further decrease the respiratory drive during sleep resulting in a worsening of the symptoms. Eat a high carbohydrate diet (more than 70% of your calories from carbohydrates) while at altitude. The acclimatization process is inhibited by dehydration, over-exertion, and alcohol and other depressant drugs. (http://wildernessmedicinenewsletter.wordpress.com/2006/11/19/high-altitude-cerebral-edema-hace/)

Acclimatization in simulation altitude

Climbing Mount Everest needs an acclimatization period of 3 to 4 weeks between 3000 and 6000 m. In order to reduce this period of time spent in dangerous conditions, an experience of pre-acclimatization was performed with 5 elite alpinists (4 male, 1 female), aged 30 +/- 4 yrs (mean +/- SD), before their attempt to climb Mount Everest. Subjects first remained one week on Mont-Blanc (between 4350 and 4807 m), then spent a total of 38 hours in a hypobaric chamber (in 4 consecutive days) from 5000 to 8500 m standard altitude. Then, they flew to Kathmandu and reached 7800 m five days only after leaving the base camp. The pre-acclimatization period showed a 12% increase in hemoglobin concentration, and no change in ventilatory response to hypoxia. Arterial oxygen saturation at submaximal exercise in hypoxia (FIO2 = 0.115) increased from 75 +/- 4 to 82 +/- 3%, probably because of an efficient ventilatory acclimatization. On Mount Everest, the speed of ascent was very high (5600 m of altitude gain in 6 days), knowing that in conventional expeditions, 12 to 32 days are generally necessary to reach, safe, the same altitude. In conclusion, pre-acclimatization seems to have triggered efficient mechanisms which allowed climbers to save 1 to 3 weeks of time in mountain conditions (Richalet at al., 1992).

Lundby and van Hall (2001) have measured maximal heart rate during a graded maximal bicycle exercise test to exhaustion in five healthy climbers before and during an expedition to Mt. Everest. Maximal heart rates at sea level were 186 (177-204) beats/min at sea level and 170 (169-182) beats/min with acute hypoxia. After 1, 4 and 6 weeks of acclimatization to 5400 m, maximal heart rates were 155 (135-182), 158 (144-182), and 155 (140-183) beats/min, respectively. Heart rates of two of the climbers were measured during their attempt to reach the summit of Mt. Everest without the use of supplemental oxygen. The peak heart rates at 8750 m for the two climbers were 142 and 144 beats/min, which were similar to their maximal heart rates during exhaustive bicycle exercise at 5400 m, the values being 144 and 148 beats/min, respectively. The peak heart rates at 8750 m are in agreement with other field studies, but considerably higher than values reported from hypobaric chamber studies.

The physiological responses to short-term intermittent exposure to hypoxia in a hypobaric chamber were evaluated in the study of Casas at al., (2000). The exposure to hypoxia was compatible with normal daily activity. The ability of the hypoxia program to induce hematological and ventilatory adaptations leading to altitude acclimation and to improve physical performance capacity was tested. Six members of a high-altitude expedition were exposed to intermittent hypoxia and low-intensity exercise (in cycle-ergometer) in the INEFC-UB hypobaric chamber over 17 d, 3-5 h x d(-1), at simulated altitude of

4000 m to 5500 m. Following this hypoxia exposure program, significant increases were found in packed cell volume (41 to 44.6%; $p<0.05$), red blood cells count (4.607 to 4.968 10(6) cells x microL(-1); $p<0.05$), and hemoglobin concentration (14.8 to 16.4 g x dL(-1); $p<0.05$), thus implying an increase in the blood oxygen transport capacity. Significant differences in exercise blood lactate kinetics and heart rate were also observed. The lactate vs. exercise load curve shifted to the right and heart rate decreased, thus indicating an improvement of aerobic endurance. These results were associated with a significant increase in the ventilatory anaerobic threshold ($p<0.05$). Significant increases ($p<0.05$) in pulmonary ventilation, tidal volume, respiratory frequency, O_2 uptake, CO_2 output and ventilatory equivalents to oxygen (VE/Vo2) and carbon dioxide (VE/co2) were observed at the ventilatory threshold and within the transitional zone of the curves. We conclude that short-term intermittent exposure to moderate hypoxia, in combination with low-intensity exercise in a hypobaric chamber, is sufficient to improve aerobic capacity and to induce altitude acclimation.

With regard to different opinions of scientists we wanted to identify heart frequency in standstill and in active state at a real altitude and simulated altitude.

Methods

Sample of subjects

Our sample of subjects consisted of two female students (height 166 ± 9.8, mass 62.5 ± 2.1, age 25 ± 1.4) and four male students (height 179.5 ± 8.38, mass 76 ± 6.6, age 25.5 ± 3.6) of the Faculty of Sports, all participants in the Elbrus 2007 expedition, organised by the Department for Mountaineering, Sport Rock Climbing and Activities in Nature of the Faculty of Sports. They participated voluntarily in our research.

Sample of variables

The monitored variable was heart rate (HR) before (in standstill) and in active state (step test).

Description of the test

The subjects performed step test. They were stepping on and off a 41.3 cm high bench for three minutes. In this period the female subjects performed 22 cycles and male subjects performed 24 cycles. One cycle was: right leg up, left leg up, right leg down, and left leg down. At the middle of the test, after a minute and a half, they changed the starting leg. The subjects performed two measurements in Ljubljana in an altitude room at the Jožef Stefan Institute at a simulated altitude of 2100 m. One measurement was made before the expedition and the second after the return. The expedition lasted for three weeks. During the expedition they were mostly living at altitudes between 2000 and 5642 m. They performed two measurements at an altitude of 2100 m in the former Russian research centre at the feet of Elbrus. The first measurement was performed after the first day at high altitude, and the second after 18 days.

The test protocol included HR monitoring during:

- 10 min of standstill (sitting on a chair),
- 3 min stepping on a bench.

Before that, all subjects waited for the beginning of measurement sitting on a chair. Their HR was monitored all this time by means of Suunto-t6 measuring devices.

The differences in HR between a real and simulated altitude, as well as before and after acclimatization were tested with t-test for dependent samples of the SPSS 15.00 for Windows.

Data processing methods

The measurement devices measured HR each two seconds during all test protocols. At the end of the measurements we transferred data to a PC computer, ordered them and prepared graphical presentations in MS_Excel programme. The differences in HR between a real and simulated altitude, as well as before and after acclimatization were tested with t-test for dependent samples of the SPSS 15.00 for Windows.

Results and discussion

Real altitude-Elbrus

Average heart rate (HR) decreased after 18 days of acclimatiozation at altitudes between 2000 and 5642 m with regard to HR after the first day of acclimatization. HR measured at an real altitude of 2100 m in standstill as well as during step test decreased (Figure 1). Average values of HR in standstill were 78.14 beats/min on the first day of acclimatization and 63.68 beats/min on the 18th day of acclimatization. The difference between them is 14.46 beats/min and is also statistically significant (p=0,004). Average HR during the step test was also higher on the first day (146.65 beats/min) then on the 18th day of acclimatization (132.33 beats/min). The difference between is 14.32 beats/min and is statistically significant (p=0.000).

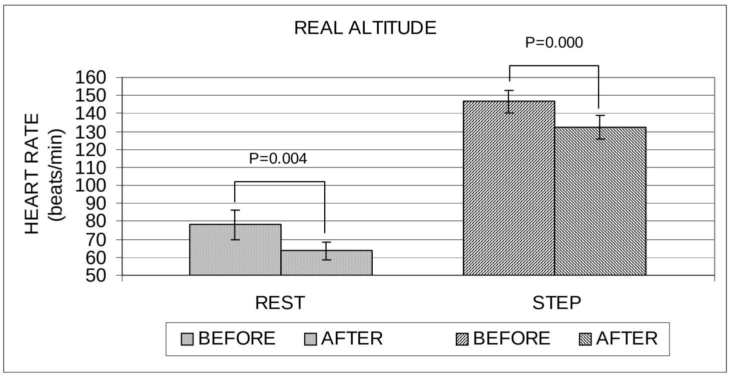

Figure 1. Average values of HR, standard deviation and statistically significant in rest and during step test at 2100 m (research station under Elbrus). First and 18th day of acclimatisation.

Simulated altitude-Ljubljana

The differences in average HR before and after the expedition measured in Ljubljana in a hypoxic chamber were somewhat lower than at a real altitude. The values in standstill before the expedition were 75.95 and after the expedition 67.44 beats/min. The difference was 8.51 beats/min, but was not statistically significant (Figure 2). Average values of HR in an active state were 139.60 beats/min before the expedition and 128.42 beats/min after the expedition. The difference between them is 11.18 beats/min and is statistically significant (p=0.014).

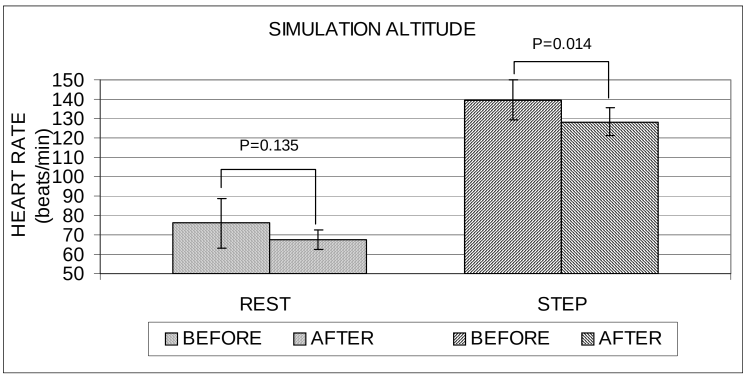

Figure 2. Average values of HR, standard deviation and statistically significant in rest and during step test at 2100 m in Ljubljana in a hypoxic chamber before and after the expedition.

Similar results were obtained by the researchers who monitored HR at high altitudes in Peru (Debevec et al., 2007).

It can be concluded that longer period of staying at higher altitudes can also result in better and thorough acclimatization if HR is taken as a reference. Decrease in HR during a long period at higher altitude could be caused by two major factors. The first of them is progressive increase of the impact of parasympathetic nervous system during acclimatization (Cornaolo et al., 2004, Boushel et al, 2001), while the second factor is changed hormone chart of kateholamines with decreased contents of adrenaline and gradual increase of noradrenaline (Mazzeo et al., 1995, Boushel et al., 2001). If we ignore the fact that HR can be influenced by many factors, or if we effectively control those factors, HR is, apart from one's own feeling, an important indicator of acclimatization, such as, for example, the kinetics of intraocular pressure.

The discovery of Pavlidis (2006) and Sait (1994) showed that physiologic indicators can be used as indicators of acclimatization rate. The results of their research (Pavlidis et al., 2006) showed that monitoring the kinetics of intraocular pressure indicates the state of acute mountain sickness and prevent its complications.

Comparison between simulated and real altitude (before acclimatization)

Lower average HR values were obtained in standstill as well as during step test before the expedition. The differences were so small that they were not statistically significant (Figure 3). Somewhat higher values were obtained at the feet of Elbrus, which can be a result of an exhausting three-day travel from Ljubljana to Elbrus.

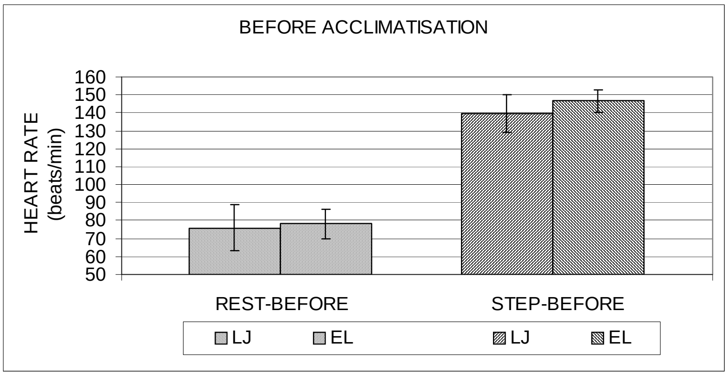

Figure 3. Average values of HR and standard deviation in rest and during step test at 2100 m in a hypoxic chamber-Ljubljana and at a real altitude-Elbrus before acclimatization.

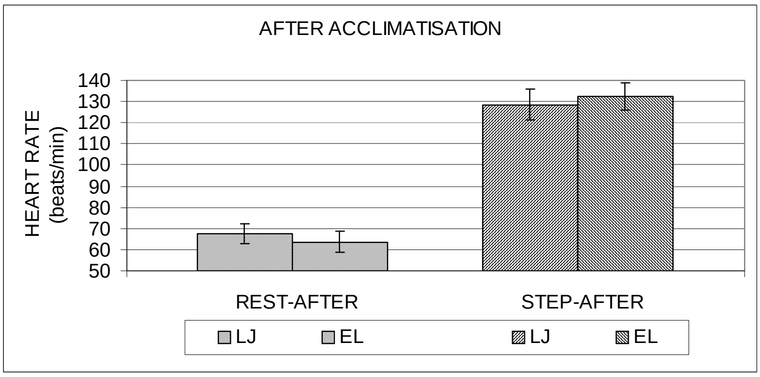

Figure 4. Average values of HR and standard deviation in rest and during step test at 2100 m in a hypoxic chamber-Ljubljana and at a real altitude-Elbrus after acclimatization.

Comparison between simulated and real altitude (after acclimatization)

Higher average HR in Ljubljana was expected due a difference of one week between the measurements at the feet of Elbrus and in Ljubljana, which could cause declimatuzation to already have taken effect. This, however, did not happen. The average HR in standstill as well as during step test was not statistically significantly different (Figure 4).

The results of the comparison between HR measured at simulated and real altitudes proved an altitude room to be a successful pre-acclimatization tool before traveling to high altitudes above 3000 m. Richalet at all, (1992) showed the possibility of shortening the acclimatization period with pre-acclimatization in an altitude room. According to them pre-acclimatization seems to have triggered efficient mechanisms which allowed climbers to save 1 to 3 weeks of time in mountain conditions. Simmilar opinion was expressed by Casas at all., (2000). According to them, short-term intermittent exposure to moderate hypoxia, in combination with low-intensity exercise in a hypobaric chamber, is sufficient to improve aerobic capacity and to induce altitude acclimatization.

Conclussions

With the results obtained during HR monitoring in standstill as well as in an active state at real altitude and in an altitude room before and after acclimatization our main goal was achieved. We are getting closer to the establishment of HR as an indicator of acclimatization. For the people who stay at high altitudes this means easier and more adequate decission about the time of further ascent. It will lower the possibility of altitude sickness and even prevent death, which sometimes appear when the rules of acclimatization are neglected. An altitude room could serve as a form of standard pre-acclimatization for top mountaineers as well as other people who travel to high altitudes above 3000 m.

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