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IMPROVEMENT IN ALTITUDE PERFORMANCE TEST AFTER FURTHER ACCLIMATIZATION

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Abstract

Introduction: The Altitude Performance Test is a measure designed to assess an individual's degree of acclimatization in order to reduce the risk of acute mountain sickness (AMS) during high altitude activities.

Objective: To investigate the hypothesis that test results will improve in a pre-acclimatized population after several days of further acclimatization.

Methods: The Altitude Performance Test consists of an uphill run at high altitude. The event is timed and performed with continuous oxygen saturation (SaO_2) monitoring. The individual's time and lowest SaO_2 measurement are recorded. This test was performed on the first day of arriving at Turin Hut (Mt. Blanc massif, Aosta Valley, Italy; elevation 3371 m), and after nine days at the same location. The 37 male participants of the German Army mountain guide course were all pre-acclimatized prior to arrival at Turin Hut. The sleeping altitude remained constant at 3371 m, and the daytime altitudes increased up to a maximum of 4808 m (Mt Blanc peak). The results of the first and second tests were compared using the Wilcoxon Signed Rank Test.

Results: Test results improved significantly after a further nine days of acclimatization (Time: -11 sec, $P \leq 0.001$; SaO_2: +5%-points, $P \leq 0.001$). This is remarkable because all soldiers were pre-acclimatized and, in general, showed only minor high altitude symptoms during the entire stay, even at the summit of Mt. Blanc.

Conclusions: This indicates that the acclimatization process is not finished after amelioration of altitude symptoms. The demonstrated improvement in physical performance could prove very important, particularly during rescue or military missions performed at high altitude. Therefore, it is recommended that the additional time necessary for improved acclimatization be scheduled.

Key words: *acute mountain sickness, pulse oximetry, oxygen saturation, acclimatization, exercise*

Introduction

The Altitude Performance Test was initially designed to choose the best acclimatized subjects from within a group of pre-acclimatized persons in order to build a task force with a low risk of developing AMS in case of time-critical missions at high altitude (*e.g.* rescue operations or military missions) [1]. The test itself utilizes the lowest SaO_2 found during an uphill run at high altitude, combined with the time needed to complete the run. It is performed at a "safe" altitude in order to assess an individual's ability to continue to ascend to higher altitudes. Since the Altitude Performance Test is able to measure an individual's degree of acclimatization, the test results should improve with increasing acclimatization. Therefore, the aim of this study was to investigate the hypothesis that test result will improve in a pre-acclimatized population after several days of further acclimatization.

Material and methods

Participants

We chose the German Army Mountain Guide Course as the subjects for our study because they provided a homogeneous group with regard to their gender, general health, physical fitness level, and degree of acclimatization. This assertion is supported by the fact that each student in the course required medical clearance prior to attending, and all were found to be healthy without significant co-morbidities. Additionally, each member had to qualify for the course by completing a demanding one-week entry test. Finally, pre-acclimatization was achieved via participation in two preceding modules of the Army Mountain Guide Course. This involved five weeks of rock climbing at 1500 m altitude, followed by one week mountain warfare course at altitudes ranging from 1800–2500 m. This course then concluded with 11 days of ice climbing training in the Ötztal Alps, and involved a sleeping altitude of 1925 m and daytime altitudes up to 3300 m (Fig. 1).

In addition to German soldiers, the study population consisted of members of the armed forces of the United States of America, Great Britain, and the Netherlands. In total, 37 non-smoking males participated. Their consent to participate in the study was obtained in accordance with the pertinent guidelines on the use of human subjects.

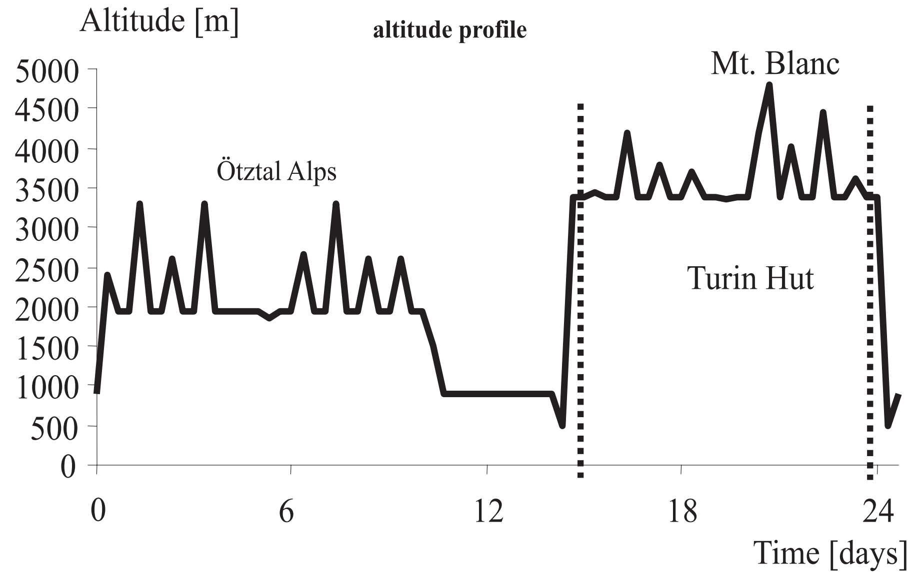

Fig. 1. *Altitude profile of the German Army Mountain Guide Course during the stay in the Ötztal Alps and on the Turin Hut with subsequent ascent of Mont Blanc (4808 m). Prior to this altitude exposure and not shown the subjects spent 6 weeks between 1500–2500 m. Dotted lines: Days of the Performance Test*

After a three-day break (altitude below 950 m) following the ice climbing training, all Mountain Guide Course members travelled by cable railway to the Turin Hut, a refuge in the Mt. Blanc Massif (Aosta Valley, Italy). The Turin Hut is at an elevation of 3371 m, and all course participants slept at this altitude throughout their stay. During the day altitudes of up to 4187 m were reached, and on the seventh day Mont Blanc was climbed to its summit (elevation 4808 m) (Fig. 1).

Fig. 2. *The covered stairs at the Turin hut. The participant will arrive at the finish line within some seconds*

The Performance Test was conducted on the first day of arrival at the Turin Hut, and then again after nine days at the same location. The test entails the use of a stairway that is 90 m length and involves a 46 m rise in elevation. The stairway is covered and can still be used during poor weather conditions (Fig. 2). On the test days (day 1 and day 9) the ambient air pressure was 680 mbar and 673 mbar respectively, and the temperature was 5°C and 1°C respectively.

In conducting the test, each individual was instructed to run up the stairs as fast as possible. At the top of the stairs the oxygen saturation sensor of the pulse oximeter (Nellcor® N-20) was placed on the individual's index finger. The participant then waited in a standing position until his pulse frequency stabilized. The corresponding oxygen saturation was noted down (SaO_2). At this point the individual slowly descended the stairs to the bottom, and then immediately ascended the stairs as fast as possible. The time required to complete the ascent was measured with a stopwatch. After crossing the finish line the test participant remained in a standing position. The examiner at the top of the stairs recorded the lowest oxygen saturation ($SaO_{2\ Perf}$) displayed by the monitor within a two minute period of completing the stairway ascent [1].

Altitude Symptomatology Screening

At the summit of Mt. Blanc each individual's high-altitude symptoatology was quantified utilizing a standardized questionnaire used by the German Army which has been previously described and vali-

Person: ………………………………………………………………………………

Location: ………………………………………………… altitude:……………..m/ft

SaO_2: ………..%; pressure: …………. mbar; date: ………………….

pulse: ………../min

	non	mild	moderate	severe
1. I feel sick	0	1	2	3
2. I feel weak / tired	0	1	2	3
3. I couldn't sleep well	0	1	2	3
4. Headache	0	1	2	3
5. Shortness of breath/Dyspnea	0	1	2	3
6. Irregular/Periodic Breathing	0	1	2	3
7. Change in mental status (irritable, nervous, uncertain, euphoric, confused...)	0	1	2	3
8. Pulse at rest:	$\leq 79 \Rightarrow 0$	$80\text{-}99 \Rightarrow 1$	$100\text{-}119 \Rightarrow 2$	$>120 \Rightarrow 3$
9. Appetite:	good $\Rightarrow$ 0	none $\Rightarrow$ 1	nausea $\Rightarrow$ 2	vomiting $\Rightarrow$ 3
10. Urine:	frequent: 0;	1;	2;	rare/concentrated: 3

Something else:

Fig. 3. *The high-altitude symptoms test generally used in the German Army*

dated [2,3]. This questionnaire is very similar to the Lake Louise Score) [4] and contains 10 symptoms with four possible degrees of severity: 0 = Not at All; 1 = Light; 2 = Moderate; 3 = Severe (Fig. 3). The sum of all the severity indices on the questionnaire is called the Individual Score (I.S.). The I.S. describes the degree to which an individual suffers from AMS. An I.S. of greater 15 indicates a high risk of high altitude pulmonary edema or high altitude cerebral edema [3].

Statistical analysis

The results for run time and $SaO_{2\,Perf}$ are expressed as median value and the range (minimum and maximum value). The results of the first and the second tests were compared using the Wilcoxon Signed Rank Test. A *P*-value of less than 0.05 was considered statistically significant.

Results

Even in our group of well acclimatized, asymptomatic subjects, the Altitude Performance Test results improved significantly after a further nine days of acclimatization (Test 1: 61 sec (Range: 38–97 sec); Test 2: 50 sec (Range 36–86 sec); Time: -11 sec, $P \leq 0.001$; SaO_2: +3%-points, $P \leq 0.001$) (Fig. 4). In total 33 subjects (89%) completed the run in less time on the second test as compared to the initial one. Only 4 (11%) had a slower time during the second test. In terms of $SaO_{2\,Perf}$ 26 subjects (70%) demonstrated improvement, 4 (11%) remained the same, and 7 (19%) worsened. However, keeping in mind that run time and $SaO_{2\,Perf}$ should have a disconcordant relationship, it is necessary to look at both parameters together. Twenty-six subjects (70%) demonstrated improvement in both time and $SaO_{2\,Perf}$. Six subjects (16%) had

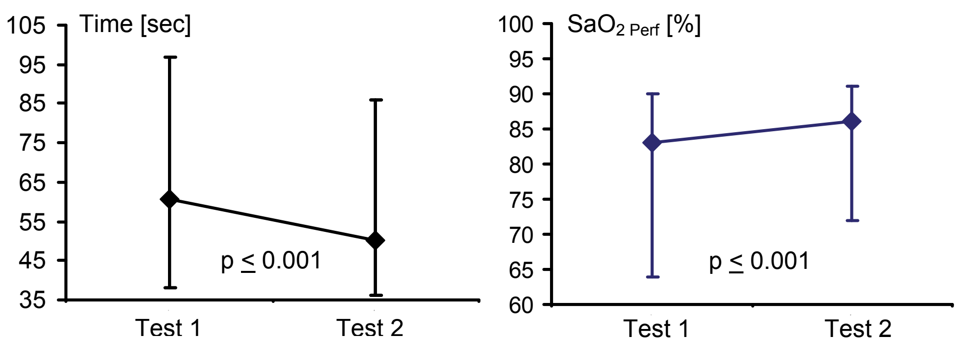

Fig. 4. *Change of Time and $SaO_{2\,Perf}$ after further acclimatization: median, minimum and maximum*

a faster run time and a decreased $SaO_{2\ Perf}$, while four subjects (11%) had a slower run time and a higher $SaO_{2\ Perf}$. Only one subject (3%) had both a slower run time and a lower $SaO_{2\ Perf}$. Of note, this soldier had recently recovered from a cold, and this may explain his findings. The staff physician did not regard his symptoms as being related to hypobaric hypoxia, but this cannot be definitely excluded.

During the initial test we found a substantial decrease in $SaO_{2\ Perf}$ (83%; Range 64–90%) as compared to the pre-exercise SaO_2 (92%; Range: 88–97%). Similarly, during the second test we also found a considerable decrease in the $SaO_{2\ Perf}$ (86%; Range 72–91%) as compared to the pre-exercise SaO_2 (95%; Range 91–98%). However, the diminished range of the SaO_2 data proved to be of interest. During the initial test there was a 9%-point difference between the maximum and minimum SaO_2 pre-exercise, but this jumped to a 26%-point difference during exercise. Alternatively, during the second test there was a 7%-point difference between the maximum and minimum SaO_2 pre-exercise, but only a 19%-point difference during exercise. Finally, the participant with the lowest initial $SaO_{2\ Perf}$ (64%) also had the lowest $SaO_{2\ Perf}$ at the second test (72%). However, his improvement of 8%-points was substantial in relation to the oxygen dissociation curve, and was the second best improvement demonstrated within the group.

Discussion

In a previous work we have demonstrated that individual's Altitude Performance Test results (run time and $SaO_{2\ Perf}$) correlate well with their degree of altitude symptomatology at the summit of Mt. Blanc [1]. In this study we observed an improvement in Altitude Performance Test result after further acclimatization. Combined, these data lend strong support to the notion that the Altitude Performance Test is able to measure an individual's degree of acclimatization. Additionally, the increasing range of SaO_2 within the group during exercise indicates that the measurement of SaO_2 during physical exercise may provide a procedure to detect insufficient acclimatization.

These conclusions are supported by other authors. Saito et al. showed that exercise (10 knee bends) induces an acute reduction in the degree of SaO_2 that was then ameliorated as the individuals in his study became acclimatized to the high altitude [5]. Roach et al. demonstrated that a workload of 50 % of the altitude-specific maximum workload decreases SaO_2 significantly by more than 5 percent points [6]. He concluded that this simple test could be a convenient means of estimating the levels of high-altitude acclimatization among healthy subjects. In our case, the workload during the uphill run is of maximal intensity, but our study subjects were already well acclimatized. Although the test scenarios are different, when these data are consolidated the general conclusion is the same: the measurement of SaO_2 during physical exercise seems to be more sensitive with regard to an individual's degree of acclimatization than the same measurement at rest. Due to the fact that the uphill run in the Altitude Performance Test involves anaerobic exercise, it is also necessary for us to comment on the findings of Burtscher et al. [7]. In their study they could not show an improvement in anaerobic performance (30 sec of cycling) after acclimatization. However, in contrast to our study, they did an acute exposure to 3200 m at which time they performed their first exercise test. Their follow-up test was then performed three days later at the same altitude. Our subjects, on the other hand, had been well pre-acclimatized prior to performing the Altitude Performance Test. Additionally; the time required for our uphill run was substantially longer than the 30 sec of cycling. (Test 1: 61 sec (Range: 38–97 sec); Test 2: 50 sec (Range 36–86 sec)). These differences may certainly explain the disparity between our findings and those of Burtscher's group.

In summary, our results are remarkable because all of our subjects were pre-acclimatized, and in general, displayed only minor high altitude symptoms during their stay at the Turin Hut, including the ascent to the summit of Mt. Blanc. This clearly indicates that the acclimatization process is not complete after amelioration of high altitude symptoms. This finding may be of particular importance to individuals who have to stay at high altitude for a long period or under conditions in which time is critical (*e.g.* rescue operations and military missions). In these situations, the improvement in physical performance gained by additional acclimatization could be crucial. Therefore, the necessary time and resources should be dedicated to ensure successful completion of an improved acclimatization process. In order to accomplish this successfully and practically, it will likely require the implementation of new methods of pre-acclimatization, such as intermittent hypoxia [8-10].

Declaration of interest

There are no conflicts of interest.

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