An analysis of commercially recommended profiles for normobaric preacclimatization

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Abstract

Introduction: Normobaric hypoxic training (NHT) for preacclimatization at home has found its way into commercial expedition mountaineering. Portable NH-generators produce a normobaric hypoxic gas mixture that can be inhaled using breathing masks at rest or during exercise or it can be pumped into lightweight tents for sleeping. These devices can be rented from commercial companies.

Materials and methods: Prior to an expedition to Manaslu (8163 m) NHT was used for preacclimatization over a period of 10 days. Our regimen involved a greater increase in sleeping altitude (10 nights to reach 5400 m) than recommended by the rental company (30 nights to reach 3900 m).

Results: No incidents occurred during NHT. Our regimen induced sufficient acclimatization to Manaslu Base Camp (4900 m), as evidenced by the fact that none of the expedition members suffered from AMS although they reached base camp within 2 days from Kathmandu – by helicopter flight to 3500 m and a one day walk the next day. Eight days after leaving Kathmandu, camp III was reached at 6850 m.

Conclusions: At natural altitudes above 2500 m an increase of sleeping altitude should not exceed 300-500 m per day. Below 2500 m, there are no restrictions. It is therefore unclear why the company recommends such a slow increase in sleeping altitude. In our opinion, it is not necessary for healthy persons to start with a sleeping altitude below 2500 m. In contrast to natural altitudes, NH exposure can be instantly stopped if symptoms occur. Therefore, it seems safe to expose healthy persons to more liberal normobarichypoxic conditions.

Keywords: acute mountain sickness (AMS), high attitude, acclimatization, normobaric hypoxia, trekking, expedition mountaineering

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Introduction

The number of tourists travelling to high altitude all over the world is estimated to reach 100 million a year [1]. Over the past 10 years, climbing of 8000 m peaks has become increasingly popular even by technically unskilled climbers on commercial expeditions [2]. Climbing peaks above 8000 m normally requires acclimatization on site for several weeks [3, 4].

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Therefore it seems very attractive to use normobaric hypoxia (NH) for preacclimatization at home in order to reduce time on the mountain. This strategy has been used by professional athletes for years [5-7] and normobaric hypoxic training (NHT) has now found its way into commercial expedition mountaineering [8, 9]. Some expedition providers expect their participants to acclimatize at home in NH [10]. For this purpose portable NH-generators are used that produce a normobaric hypoxic gas mixture that can be inhaled using breathing masks at rest or during exercise or it can be pumped into lightweight tents for sleeping. These devices can be rented from commercial companies. In the commercial setting one can be of divided opinion about the necessity of the application of NH, in the military sector or also during occupational stays at high altitude there are regularly situations which require a profound preacclimatization [11-13]. During military operations at high altitude, achieving and maintaining solid acclimatization is a major problem, because it is always challenging to follow usual acclimatization recommendations. Therefore, one of the objectives of the military training expedition to Manaslu (8163 m) was to investigate if it is possible to reduce the time required to reach the base camp at 4900 m considerably by using NHT. For this purpose, NHT was carried out prior to the expedition and the appropriate equipment was rented from a civilian company. However, a much more ambitious NHT protocol was performed than recommended by the rental company.

The aim of this study was to proof if a significantly shortened NHT regimen allows a rapid ascent to high and extreme altitude and whether this is practicable during normal working routine.

Material and Methods

Seven healthy soldiers preacclimatized over 10 days using Hypoxico Everst Summit II generators with corresponding hypoxia tents before an expedition to Manaslu. All (age median: 44 yrs.; min: 34 yrs.; max: 47 yrs.) were well trained army mountain guides and physically exceptionally fit and non-smokers. All train regularly in the European Alps (even in the months prior to the expedition to Manaslu) and have experience in expedition climbing as well. But none of them had any experience with NH for preacclimatization.

The NHT regimen was applied during daily working routine. Therefore, they performed NHT every night and supplemented this with additional NH exposures of 1-1.5 h during the day (Tab. 1). This regimen involved a much greater increase in sleeping altitude than recommended by the rental company (Tab. 1). Immediately after finishing NHT the expedition members flew to Kathmandu (1400 m) where they had to spend 3 days for organizational reasons before Samergaun (3530 m) was reached by helicopter flight (Fig. 1). The next day they walked to the base camp (4900 m), but spent the night again at 3530 m before they finally moved to the base camp the day after. Eight days after leaving Kathmandu they reached camp III at 6800 m (Fig. 1).

Table 1. Comparison between the recommendations of the rental company for NH-devices and the NHT performed before an expedition to Manaslu (8163 m). NHT at rest was applied over 1.5 hours in a sitting position using the breathing mask

NH rental company recommendations		Manaslu (8163 m) applied program			
Night	**Sleeping altitude**	**Night / day**	**Sleeping altitude**	**Rest at altitude (1.5 h)**	**Exercise at altitude**
1-3	2000 m	1	2800 m	5400 m	
4	2300 m	2	2800 m		
5-6	2500 m	3	3400 m	5400 m	
7-8	2700 m	4	3700 m	5400 m	
9-10	3000 m	5	3900 m	5400 m	
11-13	3200 m	6	4100 m		
14-19	3500 m	7	4400 m	5800 m	
20-25	3700 m	8	4800 m	6400 m	4800 m*
26-30	3900 m	9	4800 m	6500 m	
		10	5400 m	6500 m	4800 m*

* Exercise (bicycle ergometer) at an altitude equivalent to 4800 m: 1 h at 110 W on day 8 and 10.

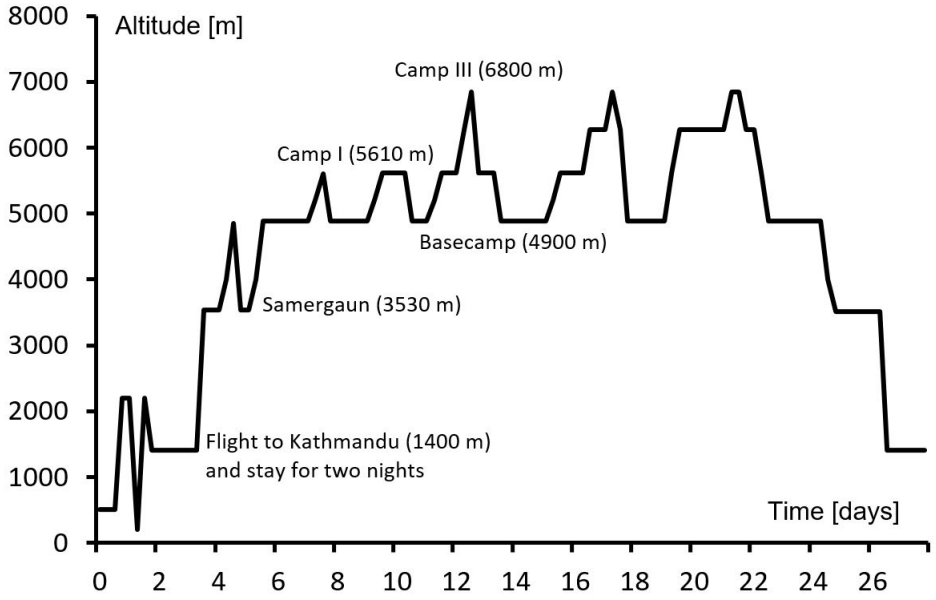

Figure 1. Altitude profile of the expedition

NH is induced by lowering the percentage of oxygen in the inspired air (FiO_2) [14]. The technical principle is well developed as NH is widely used in fire protection, since at 15% oxygen (at sea level, equivalent to 2700 m) an open fire is almost impossible and at 13% (at sea level, equivalent to 3850 m) even explosive substances such as gasoline do not burn [15-17]. The oxygen content (pO_2) of the normobaric gas mixture of the NH-generator can be adjusted according to the desired equivalent altitude. The oxygen reduced gas can be inhaled using breathing masks at rest or during exercise or it can be pumped into lightweight tents for sleeping.

The whole expedition and the 10 days of NHT were observed and accompanied by a physician who is very experienced in high altitude medicine. Acute mountain sickness (AMS) was defined by the presence of headache and another symptom. There was no prophylactic use of Acetazolamide, Dexamethasone or any other drugs.

Results

The initial altitude gain made during the expedition was 3500 m within 2.5 days. Although the expedition began very promisingly, the summit could not be reached due to permanently strong winds. At high camp III, the ascent route reaches the ridge and the expedition would have been exposed to the storm for over 1.5 days. The expedition members spent 4 hours in camp III in good health but as the updated weather forecast did not promise any improvement, they aborted. During the whole Expedition none of the expedition members suffered from AMS.

Prior to the expedition nighttime NHT exposures could be well integrated into daily life. Daytime NHT had to be subordinated to daily working routine, otherwise additional exposures could have been performed, especially during physical activity. NHT during physical activity is demanding and requires a high level of motivation because of the breathing mask. At higher intensities, the reservoir bag and the amount of air generated by the NH-generator are not sufficient for high breathing volumes.

During NHT at rest, disturbances of color vision were observed several times, which were immediately reversible after termination of NHT. At night only minor sleep disturbances occurred, a relevant part of which was noise-related (NH-generator) and disappeared after using ear plugs. Apart from this, no serious incidents were observed during NHT.

Discussion

Altitudes between 3000 and 5000 m are of great military importance, therefore some parts of the German Armed Forces regularly train at high altitude [13]. As base camps are typically located between 4000 and 5000 m, they are suitable to test corresponding preacclimatization regimens. The applied NHT regimen induced sufficient acclimatization to Manaslu Base Camp (4900 m), as evidenced by the fact that none of the expedition members suffered AMS although the rapid ascent by helicopter flight and subsequent 1-day walk to the base camp. This altitude gain (3500 m in 2.5 days) is considerably higher than the usual recommendations for acclimatization of 300-500

meters of altitude per day [3, 18-20]. This, as well as the very rapid ascent to camp III would not have been possible symptom-free without NHT.

The abortion of the ascent was solely due to the weather conditions and not due to the acclimatization protocol. The applied NHT regime was not designed for acclimatization to summit altitude at all. This would require a much more time-consuming NHT, as the actual promoted rapid ascent expeditions demonstrate [21].

Preacclimatization in NH is usually not performed continuously over 24 hours per day but as intermittent hypoxic exposure [22]. NH is simple to use and can be used almost anywhere [14, 22]. That is why NH has been used by elite athletes for years in order to optimize performance [23, 24], as well as for preacclimatization for professional mountaineers [5-7] and the military [10, 22, 25]. For practical reasons acclimatization should be done during the normal everyday working life. This can only be achieved by using NH, because hypobaric hypoxic chambers are expensive, complex to operate and not widespread [6, 26].

Significant acclimatization effects can be obtained by exposure times of a few hours per day [27, 28]. The longer the exposure time the more pronounced is the acclimatization effect [29, 30]. In general, the higher the planned altitude, the greater the required hypoxic dose must be. The hypoxic dose of NHT is determined by the degree of hypoxia (= FiO_2), the duration of each session, the number of sessions and the timing of the sessions, whether NHT is used during sleep at night, at rest during the day or during exercise [22, 30, 31]. This results in a large number of possible NHT protocols [22, 25]. It is currently unclear which preacclimatization strategy is most effective [10, 22, 32].

Since AMS does not play a role in NHT, likely due to its latency of 4-36 hours [18-20], many recommendations for the implementation of NHT may be too conservative [26, 33]. Table 1 shows the recommendations of a company that rents NH-devices compared to the NHT regimen followed to prepare for the expedition to Manaslu. At natural altitudes above 2500 m an increase of sleeping altitude should not exceed 300-500 m per day. Below 2500 m, there are no restrictions [3, 18-20, 34]. It is therefore unclear why the company recommends such a slow increase in sleeping altitude. In our opinion, it is not necessary for healthy persons to start with a sleeping altitude below 2500 m. In contrast to natural altitudes exposure, NH can be instantly stopped if symptoms occur. Therefore,it seems safe to expose healthy persons to more liberal hypoxic conditions. This is supported by the fact that no serious incidences occurred during the ambitious NHT regimen of this expedition.

However, we also see the safeguarding problem of a commercial rental company since not only healthy, very experienced and physically extraordinary fit persons (as in our case) rent NH equipment. In addition, there is a possible conflict of interest in order to rent the equipment for as long as possible. The presented data demonstrates what is feasible under optimal conditions.

Conclusion

We think that NHT will be widely used in the future. The most effective regimen of preacclimatization in NH, the duration of each session and the optimal FiO_2 are still unclear and require further study. The decisive factor is that NHT can be integrated into the normal working routine. We think that the regimen which can be integrated best into the daily routine will prevail in practice. Most people are likely to use NHT primarily during sleep with additional hypoxic exposures over the day, at rest or during exercise. Concerning the altitude profile for preacclimatization this study shows, that the recommendations of commercial companies are far too conservative.

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