THE INTERNATIONAL MOUNTAINEERING AND CLIMBING FEDERATION
UNION INTERNATIONALE DES ASSOCIATIONS D'ALPINISME

Office: Monbijoustrasse 61 • Postfach
CH-3000 Berne 23 • SWITZERLAND
Tel.: +41 (0)31 3701828 • Fax: +41 (0)31 3701838
e-mail: office@uiaa.ch

RECOMMENDATION
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Work in Hypoxic Conditions

Including work in low oxygen facilities and work at high altitude

Intended for Physicians, Occupational Health and Safety Advisors, Interested Non-medical Persons

Th. Küpper, J.S. Milledge, D. Hillebrandt, J. Kubalova, U. Hefti,
B. Basnayt, U. Gieseler, R. Pullan, V. Schöffl

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Content

1 Preamble

The actual update V2.15 includes some changes which “sharpen” the text to avoid misinterpretation. Figure 2 is presented in a more comprehensive form now. But the main reason for an update was the situation in many countries where persons who are not experienced in hypoxia were requested to establish procedures for medical surveillance of employees by occupational medicine. Often basic physiological facts – some of them well known since Paul Bert 1878 – were ignored and some of the procedures are simply “political”. This has caused trouble – local, national, and international in a global industry. UIAA MedCom as the world’s umbrella gremium for prevention in any kind of hypoxic environment has decided to add a procedure to this recommendation which takes into account the multidimensional risk evaluation of work in hypoxia. It also takes into account that there are many employees who work in hypoxia and also many physicians for occupational medicine who survey them. It would not be realistic to require a specialist in hypoxia for every employee. Therefore the procedures given in appendix 2 aim to set standards for daily routine situations. This enables the specialists for hypoxia to assist in those cases where there is no routine situation or where criteria are not fulfilled. Don’t exclude an employee permanently from work in hypoxia or at altitude without the contact to a specialist in this area before!

2 Introduction

Apart from “classical” hypoxia, which is almost an exclusive problem for mountaineers and, to lesser extent, for travelling business men, hypoxia is now also being used for fire prevention in storage areas, for altitude training in sport and for many other purposes. As a consequence more and more employees and other persons are exposed to hypoxia. Up to now there has been no consensus on how to provide occupational health and safety advice. Most regulations do not take into account the kind of exposure or other circumstances (e.g. whether the person is able to “escape” from hypoxia at any time). Regulations do not define the type or degree of different risks – if any – and therefore a more specialised analysis of the individual exposure is necessary to provide adequate advice for health and safety. As the world’s umbrella organization for activity in a low oxygen environment, the Medical Commission of the Union Internationale des Associations d’Alpinisme (UIAA) has a special responsibility to coordinate an international consensus on this topic. For easier use the paper is structured as follows:

- Differentiation between several types of exposure to hypoxic conditions and the consequences of each one
- Procedures of preventive medical care in Occupational Medicine and Safety for people working in the different hypoxic situations
- Comments on the differentiation and procedures

Although there are some minor physiological differences between simulated (isobaric) and “real” altitude (hypobaric hypoxia, altitude sojourn) [1], [2], these are not relevant for occupational safety and health. Therefore the term “altitude” includes in this paper the situation of “simulated altitude” (achieved by isobaric hypoxia) or “equivalent altitude” (a term, which is often used for aircraft cabin pressure).

Facilities with isobaric hypoxia can be left immediately and it is easy possible to survey employees working in such facilities much better (“controlled hypoxia”). Therefore a significant lower risk can be assumed in such facilities than during real altitude sojourns where it is neither possible to “escape” from hypoxia within a short time nor is it possible to perform a good survey of the health status of the person by independent (non-hypoxic) persons (“uncontrolled hypoxia”).

Note: This paper focuses on altitude related aspects of Occupational Medicine only! Other aspects of Occupational Medicine are excluded here and have to be taken into account for the individual activity at altitude. An example for this will be given in MedCom Recommendation No.23 for persons with high workload at high altitude, such as when working in alpine (helicopter) rescue organizations.

Note: There is a legal difference between athletes who may use hypoxia for training voluntarily and employees who do their job. For the latter a contact to a physician specialized in occupational medicine (here with special training in high altitude medicine) is state of the art and in many nations a must. However, athletes, although voluntarily in a hypoxic environment, should get some health care, too. At least they should have the chance to contact an altitude experienced physician in any case of problems or when exposed to extreme conditions (workload, hypoxia).

3 Types of occupational exposure to hypoxic conditions

With regard to the current discussion in several countries (Austria, G.B., Finland, Germany) it should be emphasised that (mild) hypoxia is not normally a risk. Five important factors must be taken into account for the differentiation and the risk profile of exposure to hypoxia:

- Altitude or equivalent altitude (% O_2), respectively
- Duration of exposure
- Altitude profile / acclimatization (intermittent hypoxia included)
- Workload in hypoxic condition
- Native Highlanders vs. native lowlanders

Individual risks caused by pre-existing conditions will be discussed later (see also ref [3]). With the five major points given above at least four kinds of exposure each with a completely different risk profile can be established (fig.1).

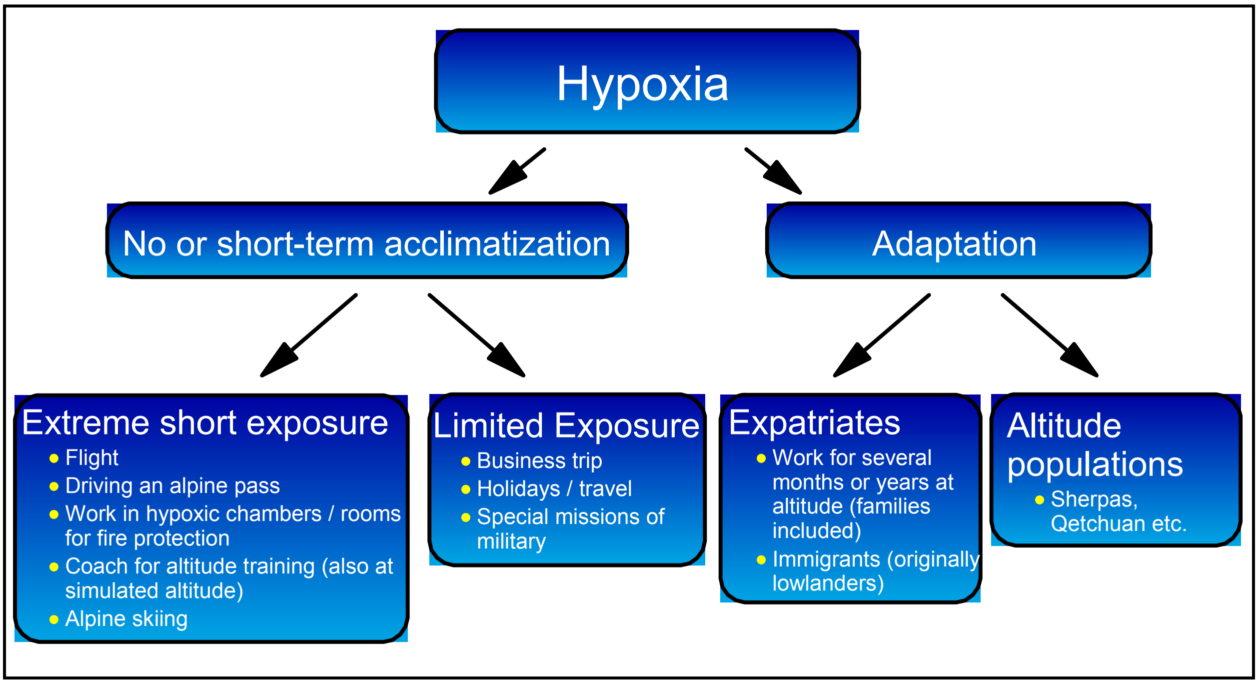

Figure 1: Different types of occupational exposure to hypoxic conditions (see also table 1

3.1 Extreme Short Exposure

Extreme short exposure normally takes place at altitudes between **1800m and 2500m**.and for a period for some **minutes to some hours**. With isobaric hypoxia of about 17.0-14.8% O_2 (+/- 0.2) in rooms equipped with hypoxia systems for fire prevention, expose employees to an altitude of about 1,700-2,600m (based on ICAO standard atmosphere, fig.2). This altitude is well within the range of the so-called “threshold altitude”, which is the altitude, where the body shows the first responses to hypoxia. Depending on the system observed, the threshold altitude varies between 1,500m (slight increase in pulse rate at rest) to 2,400m (increase of erythropoietin serum concentration) [4], [5]. In conclusion altitudes around the threshold do not cause any risk for healthy people by hypoxia. It also does not cause risks for people with chronic diseases of moderate severity [3]. Severely ill persons will be discussed later.

In some special circumstances there are some employees exposed to equivalent altitudes between 2,700m and 3,800m in rooms for fire protection. This situation is limited in the duration of exposure to a maximum of some hours, often for <60 min. As for any room equipped with hypoxia systems for fire protection these employees can leave immediately at any time if they do not feel well.

Some common activities expose people to even higher altitude, e.g. skiing to 3,800m (Europe) or >4,000m (U.S.A), or road traffic (nearly 3,000m (Europe), >4,000m (U.S.A, & Tibet), >5,000m (South America). Here the main problem may be the change of pressure, especially for children or persons suffering from an infection of the upper airways.

Group	Typical (equivalent) altitude	Typical duration of exposure	Typical Risk
Extreme short exposure (aircrafts, cable cars, skiing, road traffic, fire protection rooms)	1,800 – 2,600m	minutes to hours	Pressure changes (persons with infection of the upper airways) No risk by hypoxia for any person who does not have severe cardiopulmonary illness or severe anaemia
	2,600 – 3,800m		No risk for healthy persons
	3,800 – 5,500m		No risk for healthy persons, if exposure does not exceed 30 min. (Tab.2)
Limited exposure	2,000 – 3,000m	days to weeks	Acute mountain sickness (AMS) if the unacclimatized person sleeps at this altitude Beside AMS there is normally no risk to any person who does not have severe cardiopulmonary illness or severe anaemia (HAPE is extremely rare at this altitude)
Expatriates	3,000 – 4,500m	years	high altitude pulmonary hypertension insufficiency of the right ventricle chronic mountain sickness (CMS, "Monge's Disease") Subacute Infantile Mountain Sickness (SIMS)
Altitude populations	>3,000m.	several generations	CMS (see above) Re-entry pulmonary oedema

Table 1: Characteristics of the types of exposure

The longest exposure of this type ("extreme short exposure") is long distance flights which can be classed as "limited exposure cases". There are data that some airlines operate even higher cabin altitude than the limit of 2,400m given by ICAO, especially when using modern aircraft [6]. Normally the exposure time does not exceed a few hours. 5 Billion aircraft passengers annually prove that this regulation is safe. Up to 3,000m (and even higher) there is no risk to develop any altitude disease during this period [7], [8], [9], [10]. The main problem for this group may be the acute change of pressure, especially in the case if a person suffers from a common cold. Normally everybody – including pregnant women [11], [12] and children [13] – will feel well at these altitudes. Exceptions are people with severe pre-existing diseases (see specific paragraph below and table 3).

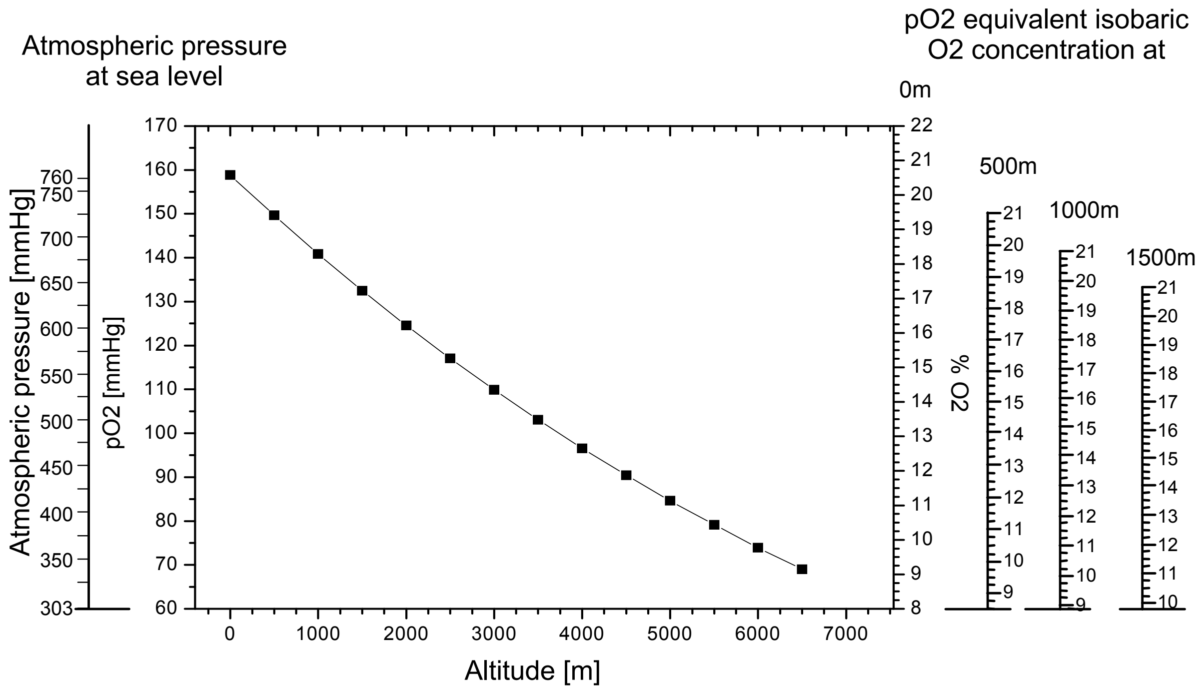

Figure 2: Atmospheric pressure, pO_2 and isobaric $\%O_2$ in relation to altitude. Graphs according to ICAO standard atmosphere as given by [14] (see also table 2). For fire protection oxygen concentration between 14.8 and 17% is used in most cases [15], [16]. The three Y-scales at the right end should be used, if the hypoxic system should be used at locations which are located significantly above sea level (for details see text).

For some special situations which are available by recent technologies UIAA MedCom was asked for recommendations concerning exposure of healthy people for a limited duration at corresponding altitudes of more than 2,700m rsp. less than 14.8% O_2. with or without workload (sports / exercising). If such exercise should be done within the range of 2,700 to 4,000m data suggest that there is no increased risk for the athletes. The subjective estimation of workload or exhaustion works well in hypoxia [17]. The exposure of non-acclimatized athletes should be limited to a maximum of 3 hours. For any exposure of non-acclimatized persons higher than 4,000m for exercise purposes a physician should be on scene and the exposure should be limited to 2 hours or less as advised by the physician. A pure "passive" exposure (no workload) to a maximum of 5,000m and for a maximum of 2 hours is considered to be safe. For safety reasons SaO_2 should be monitored.

Altitudes of more than 4,000m may be of interest for some purposes, e.g. pre-acclimatization. If the altitude profile follows well established strategies for acclimatization (e.g. [18]) there is no risk for healthy persons up to 5000m. A longer exposure compared to those mentioned above should be preferred (e.g. overnight stay / sleeping). For safety reasons (in contrast to the “exercise exposure” mentioned above AMS cannot be excluded for sure here) a physician trained in altitude medicine should be on call when exposure exceeds 4,000m. He / she should be on scene when exposure exceeds 5,500m.

Note: If a system for isobaric hypoxia should be used for any circumstances at altitudes which are significantly above sea level, the additional reduction of pO_2 by this altitude must be taken into account. This problem is addressed by the three Y-scales at the right end of figure 2. For practical reasons (it is unlikely that a hypoxic system will be used at an altitude significantly above 1500m) these scales are limited to 1500m. To get an idea of the pO_2 or the equivalent altitude of the respective system, the figure may be used in two ways:

1. Use $\%O_2$-scale to get the equivalent altitude. Add the altitude above sea level, at which the hypoxic chamber is used. From this altitude at the x-axis go back to the graph and get the real pO_2 at the chamber’s altitude or the $\%O_2$ which would correspond to the same physiological conditions if this chamber would be used at sea level.
2. Use the Y-scale marked “500m”, “1000m”, or “1500m” (the one which is closest to the altitude of your location) and read the graph as usual. This is less exact but will give you a good estimation of the physiological conditions of the hypoxic environment.

Both, athletes who perform hypoxia training and those who acclimatize, should be advised to leave the hypoxic environment if they should experience any symptoms for any reason. They may re-enter when the symptoms have recovered completely. If they should arise again the person should leave the hypoxic environment and contact a physician who is specialized in altitude medicine before any other exposure.

Within the “extreme short exposure group” there is one small subgroup of subjects who are a special case: Persons who coach people, normally mountaineers, who pre-acclimatize for extreme altitude expeditions or employees who pre-acclimatize for work at high altitude. This is increasingly used, often in facilities which offer isobaric hypoxia. This may expose participants to an altitude of 5,300m or more. In most cases this exposure is limited for some minutes to up to half an hour. With the special advantage of isobaric hypoxia these persons can easily escape to normal atmospheric conditions at any time if they feel unwell. People with some pre-existing conditions may suffer from severe problems at this altitude while healthy persons should tolerate this exposure well: The duration of exposure is too short to develop acute mountain sickness (AMS) and it is also well below the limits of the period after which significant neurological risks may arise. In aviation medicine this period is called “time of useful consciousness” (table 2). Neither are relevant for this group.

Altitude	$\%O_2$, isobaric conditions	Atmospheric pressure		pO_2		Time of useful consciousness
[m]		[mmHg]	[hPa]	[mmHg]	[hPa]	
0	20.9	760.0	1013.2	158.8	211.7	No limitation
500	19.7	716.0	954.6	149.6	199.5	
1000	18.5	673.8	898.3	140.8	187.7	
1500	17.4	634.0	845.3	132.5	176.7	
2000	16.4	596.0	794.6	124.6	166.1	
2500	15.4	560.0	746.6	117.0	156.0	
3000	14.5	525.8	701.0	109.9	146.5	
3500	13.6	493.0	657.3	103.0	137.3	
4000	12.7	462.0	616.0	96.6	128.8	
4500	11.9	432.6	576.8	90.4	120.5	
5000	11.1	404.8	539.7	84.6	112.8	
5500	10.4	378.6	504.8	79.1	105.5	>30 min.
6000	9.7	353.6	471.4	73.9	98.5	
6500	9.1	330.0	440.0	69.0	92.0	
7000	8.5	307.8	410.4	64.3	87.7	3-5 min.
10500	5.0	183.0	244.0	38.2	50.9	ca. 1 min.
12900	3.4	123.5	164.7	25.8	34.4	15-30 sec.

Table 2: Atmospheric conditions (altitude, pressure, pO_2 and the corresponding % O_2 in isobaric hypoxia) according to ICAO standard atmosphere [14] and the time of useful consciousness for unacclimatized persons [19], [16]. There is no limitation of the time of useful consciousness up to 5000m or 11.1% O_2, respectively, which means, that persons exposed to hypoxia can leave the hypoxic environment..

With increasing altitude the maximal workload decreases by 10% to 15% per 1,000m of altitude (beginning at 1,500m above sea level) with highly trained persons loosing most power (figure 3). Since most work performed at altitude is of limited load on the human body (estimated 0.5 – 1.0 W/kg body weight) this effect is not limiting most of the previously described activities at altitude. During very demanding or exhausting work at >3,000m O_2 diffusion becomes a more and more limiting factor and persons doing intense work cannot stabilize their SaO_2 at a level which can be expected for the respective altitude. As a result their SaO_2 will decrease. Working conditions like these are exclusively for healthy people, and even then the limited (decreased) workload must be taken into account when the required activity and the resources are planned (figure 3).

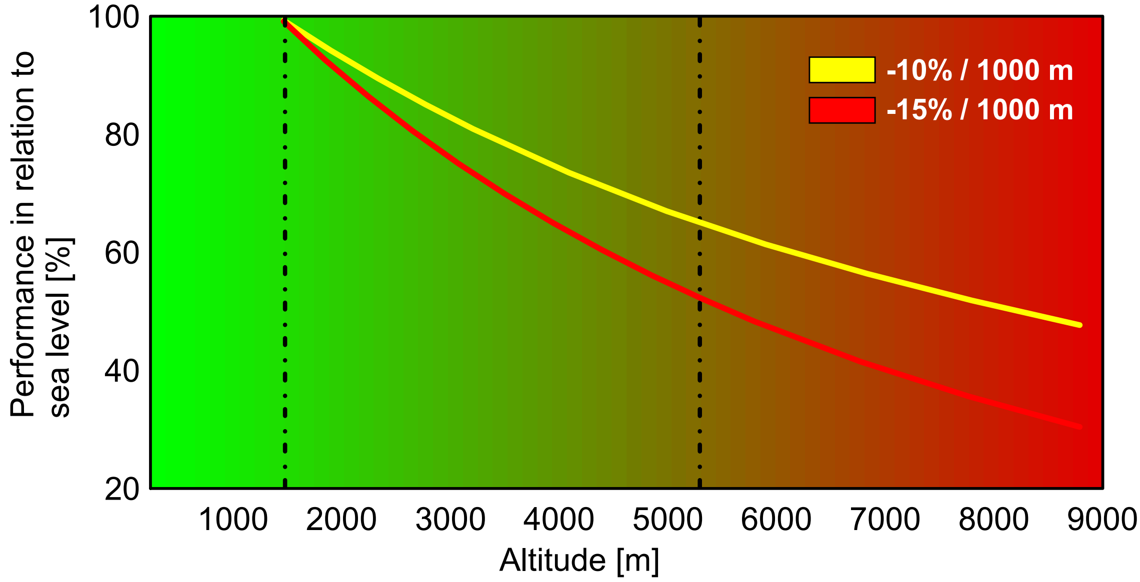

Figure 3: Decrease in maximal workload at altitude: -10% per 1000m (low fitness) and up to -15% per 1000m for highly trained persons [20], [21], [22], [23], [24]. 1,500m: "threshold altitude"; 5,300m: limit of complete acclimatization / permanent stay

3.2 Limited Exposure

The typical exposure of the **Limited Exposure Group** is **2,000 to 3,000m** for some **days or weeks**. At some places these people will be exposed to even higher conditions of 4.000 – 5.000m, e.g. at Colorado or South America. Examples of locations for business men or normal travellers (not mountaineers) are given in figure 4. In contrast to the "Extreme Short Exposure Group" the combination of altitude and duration of exposure is potentially able to cause altitude disease (acute mountain sickness, AMS) in non-acclimatized persons. An increase of the pulse rate for about 12-14% should be expected at 2,500-3,000m (e.g. [25], [15], [26]). A comparable increase of minute ventilation and breathing frequency will occur [27], [26]. Oxygen saturation will decrease only for about 6-8% of the saturation measured at sea level and be stable at 90-94% [28], [29], [26]. A slight decrease of aerobic performance (without significant effect on performance at work) must be expected at 3,000m (figure 3), but no significant effect on psychomotoric functions [30], [31]. There are some data which indicate a slight impairment in the coordination of complex movements, especially when they have to be performed very quickly.

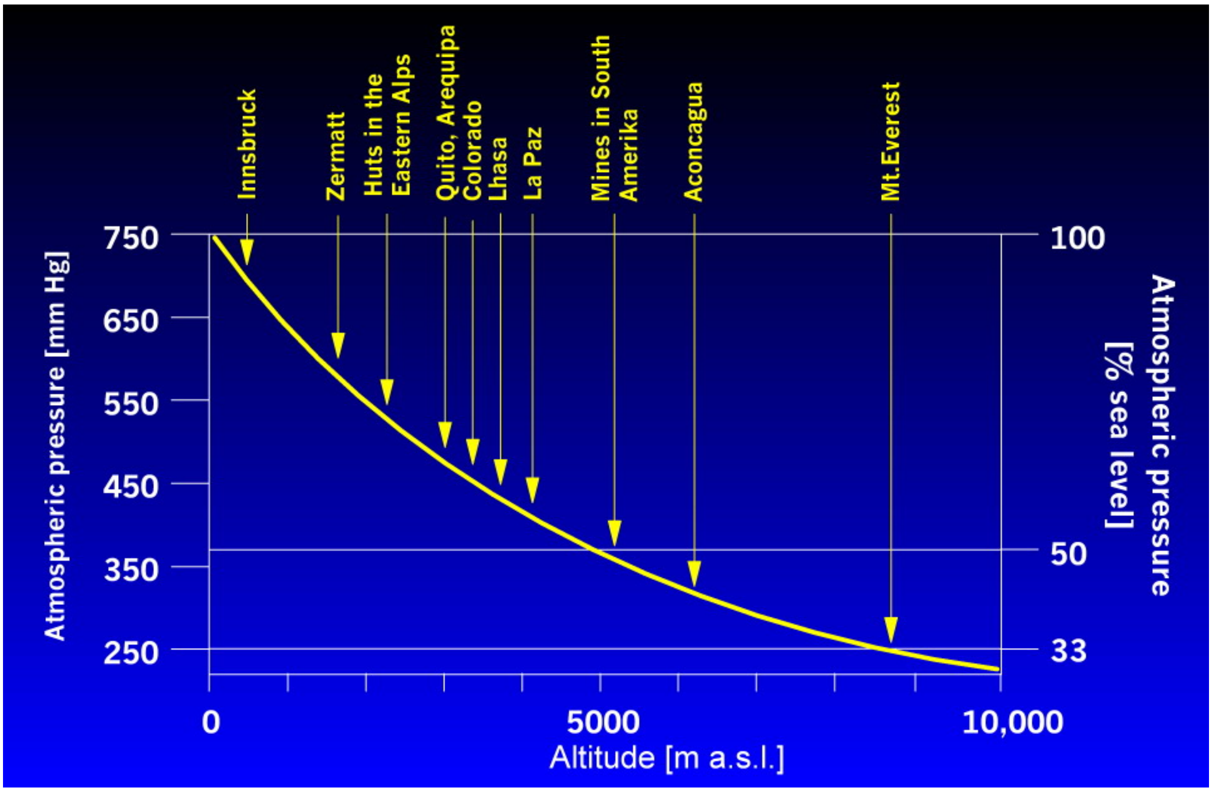

Figure 4: Examples for destinations of business men or normal travellers. Note: Some places are higher than the highest mountains in the European Alps

The main risk for the limited exposure group is the development of altitude diseases, most often AMS. High altitude pulmonary oedema (HAPE) is extremely rare at this altitude (1:4,000 nights of non-acclimatized persons at 3,000m [32]) as it normally occurs above 4,000m. A significantly increased risk exists for any person who has a rapid ascent profile, e.g. business men arriving by aircraft. If the arrival destination is around 4,500m the risk for HAPE with severe symptoms increases to 1:600 [32] (signs for HAPE in X-ray up to 31.7% [33]) and 30 – 57% will suffer from AMS [34], [35], [7], [36], [37]. On the other hand, these data indicate that some hours or even a night at 3,000m is relatively safe, at least for healthy people. Some people with pre-existing diseases may be at specific risk [3]. Nevertheless any strategy for occupational safety and health for the "limited exposure group" has to focus on AMS.

Note: In contrast to the belief of most Westerners many porters in the Himalayans are not true Sherpas anymore, and are instead immigrants or expatriate lowlanders! They may suffer from the same altitude-related risks as any other visitor [38].

Note: Persons who suffered from a stroke in their history, who got radiation therapy of neck or head, with large foramen ovale, or single pulmonary artery may be at increased risk when exposed to altitude, even if they do not have symptoms at low altitude (several case reports in literature, no systematic data). There are no data which support a general unability of these persons to be exposed to hypoxia or altitude, but these persons should be monitored closely during the first "test-"exposure, which should take place where it is easy to "escape". Technical and medical surveyed rooms with isobaric hypoxia provide the optimum of safety for such testing.

3.3 Expatriates and Immigrants

Expatriates in this paper are defined as persons who migrate as lowlanders to high altitude regions, normally **above 3,000m**. Some of them are living higher than 4,500m. The duration may be for several months but is frequently for **years**. Normally this group will not suffer from acute altitude diseases (after the first few days at altitude) and they fully acclimatize.

The definition also includes immigrants. In many cases the employees are attended by their families. As a consequence, pregnancy may be a problem [11] and more often children of different ages will be exposed to high altitude. After a while they may suffer from specific diseases of the cardiopulmonary system: high altitude pulmonary hypertension (HAPH) (formerly called sub-acute mountain sickness) with acute bouts of high blood pressure in the pulmonary vessels [39] and high altitude heart disease. For details see [13].

After some months at high altitude adults may develop the symptoms of HAPH, caused by chronic pulmonary hypertension. These patients suffer from signs of insufficiency of the right ventricle (peripheral oedema, dyspnoea, cough, and angina pectoris). After years at altitude chronic mountain sickness (CMS, “Monge’s Disease”) may arise (headache, poor concentration, dizziness, reduced work capacity, cyanosis, clubbed / drumstick fingers, polycythaemia and high haemoglobin concentration) [40], [41], [42], [43], [44], [45], [46].

3.4 Altitude Populations

Altitude populations are defined as populations living for several **generations** (some for more than 30,000 years) at altitude **>3,000m**. These people show long-term and genetic adaptations. Most health problems are not altitude-related, but caused by socioeconomic factors (e.g. chronic bronchitis, Kangri carcinoma (skin cancer in cicatrice caused by multiple burning either by carrying a small oven heated with charcoal (kang) under the coat or by sleeping around a fire and burning the belly when the person turns around during sleep) etc.). While altitude-related health disorders are very uncommon in Tibetians and occupational medicine is not yet established in Ethiopia, South American highlanders – many of them working in mines at altitudes above 5000m – have been studied and are of special interest here. Some of them may develop CMS (see above). Another specific problem is re-entry pulmonary oedema where highlanders and also expatriates or immigrants who visit friends or relatives near sea level are of special risk when they return to their high altitude home after a stay of a week or two at low altitude. The symptoms are the same that for HAPE.

Note: In contrast to the belief of most Westerners, many porters in the Himalayans are not of true Sherpas anymore, and are immigrant or expatriate lowlanders! They may suffer from the same altitude-related risks as any other visitor [38]. Prefer to co-operate with agencies which follow the rules of the International Porters Protection Group (IPPG, see appendix 4).

4 Aspects of occupational safety and health

With the systematic structure given above, recommendations to provide specific advice and procedures for occupational medicine will be given here to facilitate personnel selection and offer health and safety guidance for employees going to altitude. An overview is given by the flowchart in appendix 1. For any standard situation the facilitated flow charts as given in appendix 2 may be used. Workload can be estimated according to table 3 or to [47].

In contrast to any other occupational exposure where less exposure normally means less risk, employees at altitude benefit if they are exposed as often as possible to hypoxia because a partial adaptation can be expected (although scientific data about intermittent hypoxia are limited).

All persons working at altitude or in hypoxic conditions should be advised to drink enough to keep their fluid balance stable.

Note: In contrast to common thinking, it is not the heart which carries the greatest risk for people at altitude. While the myocardium is able to handle astonishing levels of hypoxia, the lung may be the limiting factor in the case of a pre-existing disease.

4.1 Extreme Short Exposure

As mentioned above the situation for this group may be best illustrated by the situation inside an aircraft's cabin (this excludes very high workload subjects and coaching of athletes who acclimatize to extreme altitudes, see below). In this well studied situation there are the following minimal requirements given by aviation medicine (values for sea level in adults) [48]:

- Vital capacity 3 l
- FEV1 70%
- SaO_2 85%
- pO_2art. 70 mmHg

Haemoglobin should be >10g/dl and erythrocyte count >3 Million/µl [48]. Both are relative contraindications in the case of a chronically anaemic fully compensated patient who may be completely adapted.

For exposure up to 2,700m (equivalent to about 15.0-14.8% O_2) a check-up by Occupational Medicine – if any – should include the following topics:

- Person's history:
  - Any indicators for cardiopulmonary diseases or for significant limitations of maximum workload? (Sports?)
  - Any significant disease or operations in the last year?
  - Any problems during altitude sojourns in the past?
  - High or extreme workload at altitude expected?

If the person performs any aerobic endurance sport regularly and without problems, there is no doubt – without any other medical investigation – that there is no risk if this person is exposed within the conditions as described for the “extreme short exposure group” up to 2,700m or about 15.0-14.8% O_2.

- Laboratory or technical investigations are only required in cases which are not completely clear after checking the patient’s history:
  - Significant anaemia: blood status
    - Note: Exclude sickle cell anaemia if the person belongs to a group where this is endemic
  - Pulmonary hypertension: echocardiography
  - Pulmonary disease: spirometry and ergometry
  - Cardiac disease: ergometry, stress echocardiography

If employees are exposed to equivalent altitudes of 2,700 – 3,800m as mentioned in section 2.1, the medical procedure should additionally include blood count, ergometry and spirometry (as VO_2max is the limiting factor at high altitude this may be combined as spiroergometry).

Employees who go to >3,800m should be checked as detailed above for 2,700-3,800m. Since hypoxic chambers are increasingly available (e.g. rooms or training centres for hypoxia training) these employees should be exposed to hypoxia once before their first departure to high altitude or before they enter hypoxic rooms for the first time. The exposure must take into account the kind, the expected duration, and especially the (equivalent) altitude (pO_2) of the exposure during work: For a task to be performed in a controlled environment (hypoxic rooms) for a limited duration, an acute exposure for 1-2 hours at the (equivalent) altitude where the work will be performed later should be sufficient. During exposure the person should be monitored for SaO_2, pulse rate, and altitude-related symptoms by persons with adequate skills in altitude medicine. Persons with cardiopulmonary diseases >NYHA/CCS I, anaemic or pregnant persons should not be chosen for work at high altitude or hypoxia which corresponds to >3,800m [3], [49], [11].

For a normal work day it is not necessary to include additional pauses, if the real or equivalent altitude does not exceed 2,700m (rsp. 14.8% O_2 in isobaric conditions), as there is no risk for altitude-related disorders. If possible, and the work lasts all day in hypoxic rooms (e.g fire protection), the person should be advised to leave the hypoxic area for a lunch break. If non-acclimatized persons are exposed to equivalent altitudes of 2,700 – 3,800m as mentioned above, they should be advised to make a pause in normoxia for at least 15 min. after every 2 hours of exposure. If they are exposed to >3,800m, this pause should be extended to 30 min. Non-acclimatized workers should avoid exposure to >4,500m or stay only a short time there (<30 min.).

Any employee should be advised to leave hypoxic areas if he / she does not feel well. To retreat to a normoxic area as soon as possible is the most important therapy in such a situation. As altitude-related diseases never start suddenly so any employee who heeds advice, which must be given to him prior to entering / ascending, will have plenty of time to escape from the hypoxia (see also table 2). It is not necessary to have a stand-by “rescue team” for this “extreme short duration group”.

If the symptoms recover completely after ¼ - ½ hour, the person can re-enter, if necessary. If the subject does not recover within ½ hour he / she should be advised to consult a physician who is a specialist in altitude medicine before the next exposure.

The employees should be advised to use a decongestant spray if they ascend quickly to altitude (hypobaric hypoxia) while suffering from upper airways infection (e.g. xylometazoline spray). Special care must be given to accompanying children in such situations [13].

Maximum workload need not be investigated for all employees: If the work which has to be performed at altitude is not very hard (e.g. paperwork (businessmen), supervision etc.) and the altitude does not exceed 2,700m, it is enough to know that the person is able to climb one flight of stairs or to walk 80-100m horizontal without shortage of breathing [49]. More detailed and according to NYHA / CCS stages [50], [51], [52] (for stages see also appendix 3):

- NYHA / CCS I (no symptoms): No limitations at altitude
- NYHA / CCS II (symptoms during moderate workload): No limitations at altitude for activities of minor workload
- NYHA III-IV (symptoms during minimal workload or at rest): Contraindication for altitude. Diagnoses and situations which are a permanent or temporary contraindication are given in table 2. We also refer to the recommendations given in [3] and [53].

Diagnosis	**Period for which altitude / hypoxia should be avoided**
Stroke	At least 3 months [48], for details see [53]
Myocardial infarction	6 weeks, if no complications
	10 weeks (or more) in the case of complications (e.g. significant arrhythmia)
Aorto-coronary bypass operation	2-3 weeks
PTCA	3 days
Stent	3-10 days
Pace maker implantation	After a check for correct function is o.k.
Acute broncho-pulmonary infections	No exposure until recovery
Asthma (stress induced)	No exposure, if not sufficiently treated

Table 3: Permanent or temporary contraindications for altitude sojourns of the “extreme short exposure group” as defined above (according to the recommendations for aircraft travellers) [48]

At altitudes which are normally visited for extreme short duration (1,500-3,000m) the maximal workload is only marginal impaired (fig.3). Therefore the recommendations given for demanding work (e.g. self containing breathing apparatuses) can be used without modification, if such work has to be done at 2,000-3,000m. Above that there is a 10% reduction per 1,000m above 1,500m which should be added to the minimal requirements, e.g.:

> If a minimal requirement for a certain work at sea level is 2 W/kg body weight and this work shall be done at 4,000m, the estimation is as follows: (4000-1500)/1000=2.5; 2.5*10%=25%; 2W/kg+25% = 2.5 W/kg. At sea level this employee must be able to provide at least 2.5 W/kg to be able to do the respective work at 4,000m.

Data about the workload necessary for several tasks at sea level are available from medical literature, e.g. [47]. An example for a protocol for a medical check for crew members of alpine helicopter rescue services is given as an example for employees at altitude exposed to high workload in UIAA MedCom Recommendation No.23. Tables 4 and 5 give summarized information about the topic. Independent from these factors employees should be advised to minimize their workload as much as possible.

Risk category	Oxygen in inspired air			Specific risk	Precautions
	$\%O_2$ [%]	corr. Altitude [m]	pO_2 [mmHg]		
Class 1	≥17	0 - 1,600	159 - 130	No risk	Advise employees
Class 2	16.9 - 14.8	1,600 - 2,700	130 - 110	No risk for a full days shift if severe diseases of the lungs or heart and severe anaemia is excluded	Exclude severe diseases (Self reporting: minimum requirements climbing 2 floors without dyspnoea, see also table 5) Advise employees
Class 3	14.7 - 13.0	2,700 - 3,800	110 - 99	No risk, if diseases are excluded as mentioned for Class 2, the workload is limited (see table 3) and the duration of exposure does not exceed 4 hours/day or 2x2 hours/day with high workload	Exclude severe diseases (Physician for Occupational Medicine; self-reporting not sufficient!) Check workload level (see comment below and table 5) Advise employees
Class 4	13.0-10.4	3,800-5,500	99-79	Risk of AMS or other disorders (e.g. limited coordination of movement) may occur for non-acclimatized persons	Special precautions necessary, see comment below
Class 5	<10.4	>5,500	<79	Risk of acute hypoxia, dizziness, mental or other disorders (e.g. limited coordination of movement) may occur within 30 min. for non-acclimatized persons	Special precautions necessary, see comment below

Table 4: Risk classification of hypoxia and actions for safety precaution

Persons who are exposed to extreme altitude e.g. while training expedition members must have a cardiopulmonary (especially pulmonary!) capacity well within in the normal range. This may include also well treated asthmatic patients. Above 4,500m employees should be observed for safety by a “rescue person” who is outside the isobaric hypoxia but in permanent contact to the person(s) inside. For optimum supervision rooms for isobaric hypoxia should be constructed with a big window to the next room. Above 4,500m safety may be further increased if an oxygen bottle and a mask is available. Above 4,500m a specialist high altitude physician should be on call. Above 5,000m he/she should be on scene.

In contrast to others of the “extreme short exposure group” employees working in such conditions need to be educated about symptoms and management of acute hypoxia. Again: if they work regularly in such conditions (e.g. every day 2-3x for 15-60 min., or even more) a benefit by partial acclimatization can be expected (although data are scarce).

Conditions	**Minimal fitness**
Class 1: all kind of work	Same as at sea level
Class 2: inspection, supervision (or similar)	75 W
Class 2: moderate work	125 W
Class 2: hard work (e.g. moving heavy loads)	>200 W
Class 3: inspection, supervision (or similar)	100 W
Class 3: moderate work	150 W
Class 3: hard work (e.g. moving heavy loads)	>200 W
Class 4: inspection, supervision (or similar)	125 W
Class 4: moderate work	>200 W
Class 4: hard work (e.g. moving heavy loads)	Perfect trained and well acclimatized persons only!

Table 5: Minimal fitness for several conditions of work in hypoxia (Watts to be performed for at least 3 minutes, treatmill or cycle ergometry; data according to [20]; minimal fitness includes a safety margin)

4.2 Limited Exposure

As this group goes to comparable altitude as the latter, the minimal requirements of the cardio-pulmonary system and the exclusion criteria (table 2) are the same. Special attention should be paid to persons who might be suspected for obstructive sleep apnoea, as this is often combined with pulmonary hypertension. The later will increase significantly at altitude. As mentioned in chapter 2 there is another risk for this group which cannot (yet) be predicted by any medical investigation: AMS. Here preventive occupational medicine includes detailed advice about the symptoms of AMS and how to treat them [18]. If possible discussion with the manager who is responsible for the employee and advice for an adequate ascent profile should be given. This may include an extra day on arrival and an overnight stay at intermediate altitude. If an immediate ascent and overnight stay >2,500m cannot be avoided prophylaxis with drugs may be considered (acetazolamide 125 mg bid, [18]).

It should be mentioned here that some facilities where people work at high altitude provide oxygen enriched rooms (e.g. some mines or telescopes in the Andes). Every additional 1% of oxygen corresponds to a “reduction” of 300m of altitude without increasing the risk of fire. With this technology some facilities provide an interior environment which corresponds to 3,000m, which is well tolerated.

If the person will be exposed without having the chance to escape from hypoxia (e.g. business trips to the Andes (South America)), an ascent profile according to international recommendations (e.g. [18] should be an integral part of the strategy when the respective work is planned. If the place of work is situated higher than 3,800m the person should sleep at least one night under controlled conditions (hypobaric room at a training centre with physicians experienced in altitude medicine) at the respective equivalent altitude before his / hers first departure to such places. Depending on the final altitude this may include several nights in hypobaric conditions to realize an altitude profile and acclimatization according to the “Gold Standard” as recommended [18].

Any employee should be advised to contact an experienced high altitude physician immediately in the event that he / she does not feel well at high altitude and cannot descend. Painkillers, nifedipine, dexamethasone and acetazolamide with education and information on how to contact the physician to manage an emergency should be given to him / her before departure for any destination above 3,800m. Below 3,800m a standard painkiller (not aspirin!) should be sufficient.

4.3 Expatriates and Immigrants

For their travel to the destination this group should be informed about AMS as described in 2.2. Before they leave, they should get a more detailed medical examination, especially with electrocardiography and echocardiography included. This aims at two topics: i. to exclude pulmonary hypertension, and ii. to get initial values for a comparison with later controls. HAPH, the main risk for this group, causes a hypertrophy and dilatation of the right ventricle, a pulmonary hypertension, and sometimes a pericardial effusion. In many places where these expatriates work there will be no possibility for echocardiography. Then the follow up investigation may be performed during a holiday trip home. A control echocardiography should be performed at least once a year or if symptoms should arise. Note that accompanying children need special attention [13]. If any pathologies which indicate increased pulmonary pressure or right ventricle hypertrophy or dilatation are found at echocardiography the patients should be advised to leave their high altitude residency as soon as possible.

4.4 Altitude Populations

As mentioned above, altitude related problems are rare in this group. Employees descending from altitude for holidays of for other reasons for more than a week should be advised, as described in 2.2, to avoid re-entry HAPE. They should also be educated about First Aid if a HAPE should occur.

South American highlanders should be surveyed by occupational medicine for CMS. As a minimum these checks should include an analysis of haematocrit, haemoglobin, and erythrocyte cell count and should be performed annually. If symptoms arise which suggest CMS additional echocardiography should be performed, if possible.

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Members of UIAA MedCom

C. Angelini (Italy), B. Basnyat (Nepal), J. Bogg (Sweden), A.R. Chioconi (Argentina), S. Ferrandis (Spain), U. Gieseler (Germany), U. Hefti (Switzerland), D. Hillebrandt (U.K.), J. Holmgren (Sweden), M. Horii (Japan), D. Jean (France), A. Koukoutsi (Greece), J. Kubalova (Czech Republic), T. Küpper (Germany), H. Meijer (Netherlands), J. Milledge (U.K.), A. Morrison (U.K.), H. Mosaedian (Iran), S. Omori (Japan), I. Rotman (Czech Republic), V. Schöffl (Germany), J. Shahbazi (Iran), J. Windsor (U.K.)

Guest Author

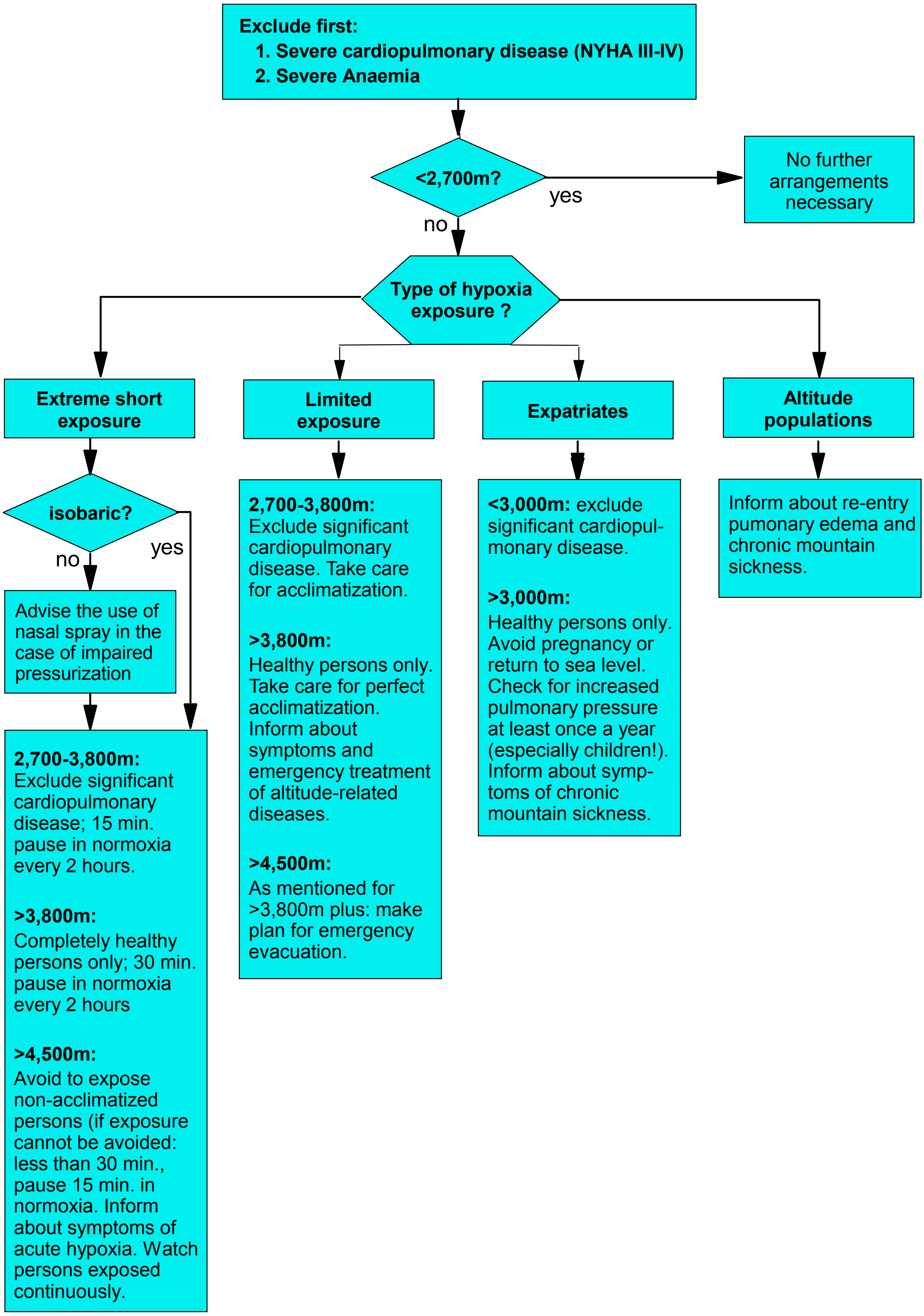
R. Pullan (Altitude Centre, London, U.K.)

History of this recommendation paper

The version presented here was approved by written consent in lieu of a live meeting in August 2009, updated and approved by written consent in April 2010.

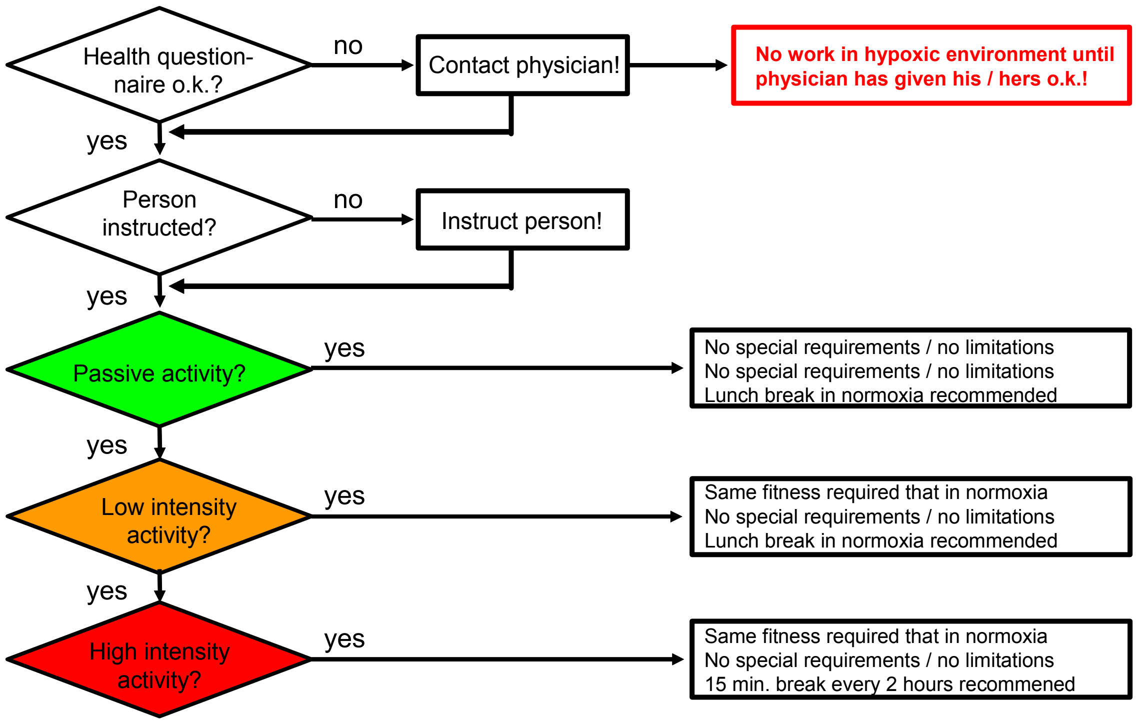
An update was finished and approved at the annual meeting at Whistler / Canada in July 2012 and again updated and approved by written consent in February 2014. The actual update 2.15 was approved at the annual meeting at Kalymnos in May 2015. Here it was also decided to erase the occupational aspects of alpine helicopter rescue operations here and to include them into an independent recommendation (No.23).

Appendix 1: Flowchart how to manage occupational health and safety for work in hypoxia

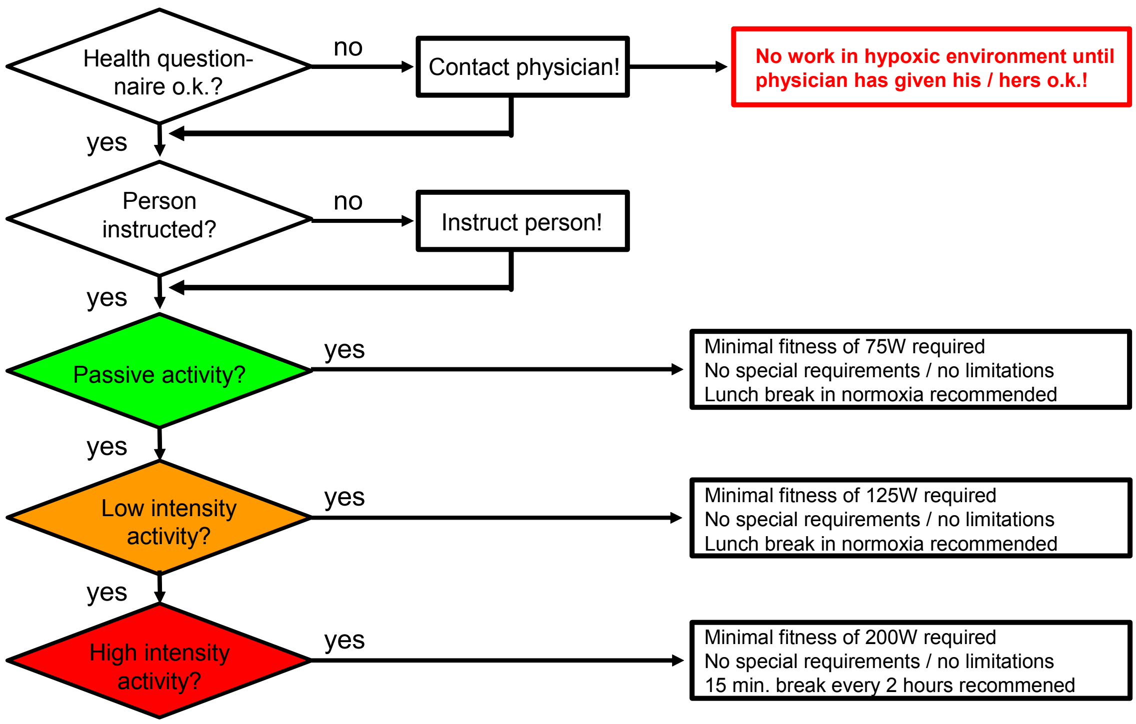


Appendix 2: Simplified Flowcharts for Occupational Health and Safety according to risk groups

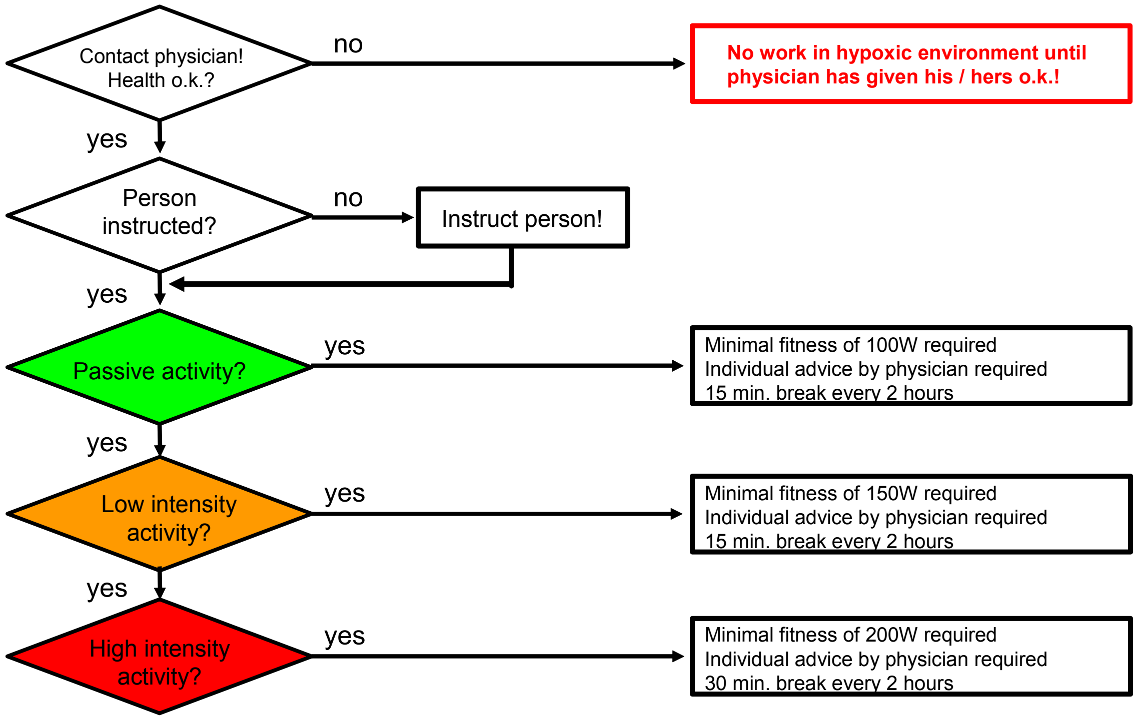
Appendix 2.1: Class 1 (≥17%; 0-1700m)



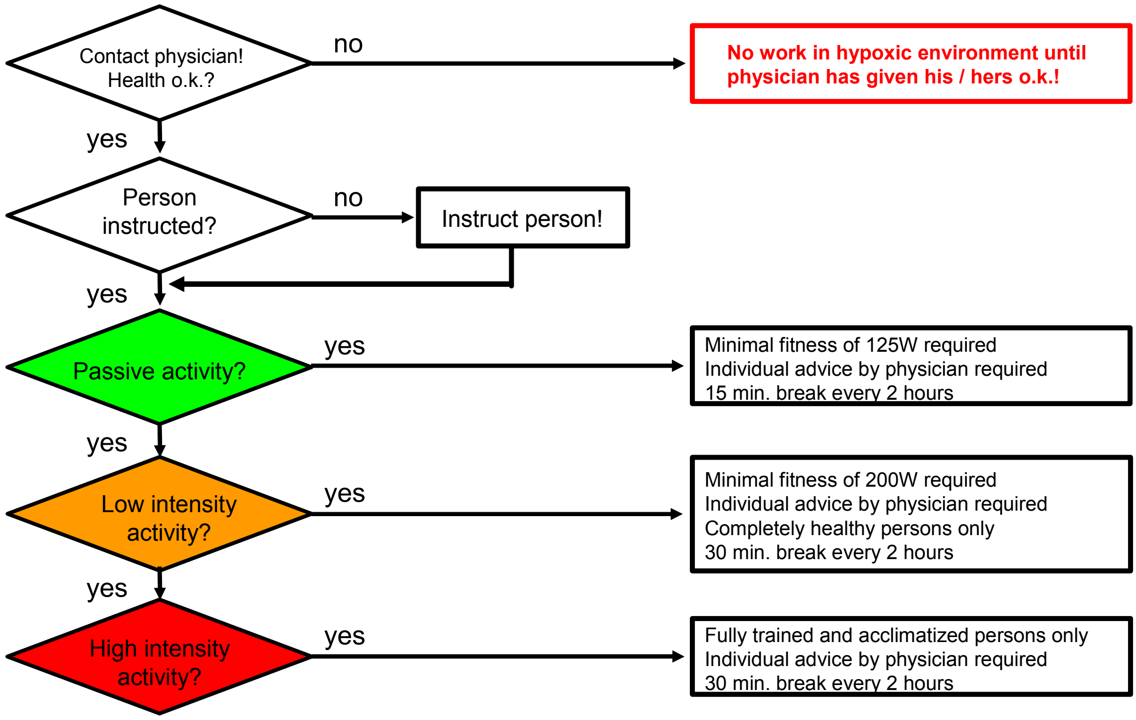
Appendix 2.2: Class 2 (16.9 – 14.8%; 1700 – 2800m)



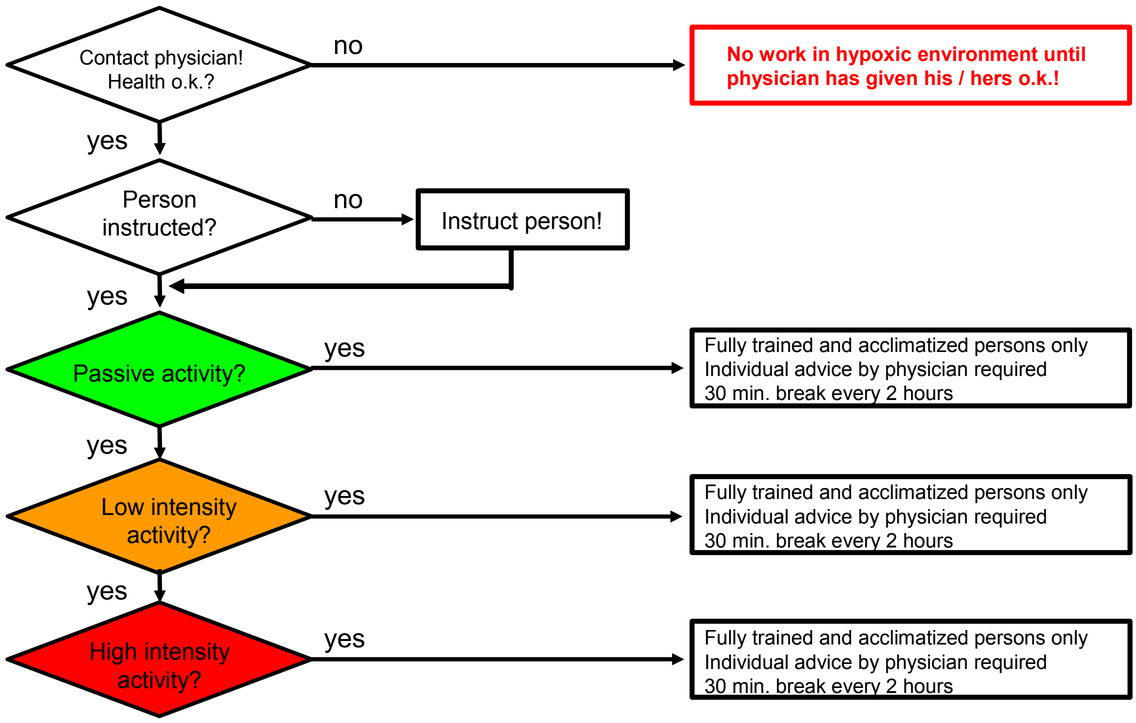
Appendx 2.3: Class 3 (14.7 – 13.0%; 2800 – 3800m)



Appendix 2.4: Class 4 (12.9 – 10.7%; 3800 – 5300m)



Appendix 2.5: Class 5 (<10.7%; >5300m)



Appendix 3: New York Heart Association Heart Failure Classification (revised version 1994) [51]

Functional Capacity	**Objective Assessment**
Class I. Patients with cardiac disease but without resulting limitation of physical activity. Ordinary physical activity does not cause undue fatigue, palpitation, dyspnoea, or anginal pain.	**A.** No objective evidence of cardiovascular disease.
Class II. Patients with cardiac disease resulting in slight limitation of physical activity. They are comfortable at rest. Ordinary physical activity results in fatigue, palpitation, dyspnoea, or anginal pain.	**B.** Objective evidence of minimal cardiovascular disease.
Class III. Patients with cardiac disease resulting in marked limitation of physical activity. They are comfortable at rest. Less than ordinary activity causes fatigue, palpitations, dyspnoea, or anginal pain.	**C.** Objective evidence of moderately severe cardiovascular disease.
Class IV. Patients with cardiac disease resulting in inability to carry on any physical activity without discomfort. Symptoms of heart failure or the anginal syndrome may be present even at rest. If any physical activity is undertaken, discomfort is increased.	**D.** Objective evidence of severe cardiovascular disease

Appendix 4: Guidelines of the International Porter Protection Group (IPPG)

1. Trekking ethics

1. Clothing that is appropriate for season and altitudes encountered must be provided to porters for protection from cold, rain and snow. This may mean: windproof jacket and trousers, fleece jacket, long johns, suitable footwear (leather boots in snow), socks, hat, gloves and sunglasses.
2. Above the tree line porters should have a dedicated shelter, either a room in a lodge or a tent (the trekkers' mess tent is no good as it is not available till late evening), a sleeping pad and a blanket (or sleeping bag). They should be provided with food and warm drinks, or cooking equipment and fuel.
3. Porters should be provided with the same standard of medical care as you would expect for yourself, and life insurance.
4. Porters should not be paid off because of illness/injury without the leader or the trekkers assessing their condition carefully. The person in charge of the porters (sirdar) must let their trek leader or the trekkers know if a sick porter is about to be paid off. Failure to do this has resulted in many deaths. Sick/injured porters should never be sent down alone, but with someone who speaks their language and understands their problem, along with a letter describing their complaint. Sufficient funds should be provided to cover cost of rescue and treatment.
5. No porter should be asked to carry a load that is too heavy for their physical abilities (maximum: 20 kg on Kilimanjaro, 25 kg in Peru and Pakistan, 30 kg in Nepal). Weight limits may need to be adjusted for altitude, trail and weather conditions; experience is needed to make this decision.

2. Questions to ask trekking companies:

1. Does the company you are thinking of trekking with follow IPPG's five guidelines on porter safety?
2. What is their policy on equipment and health care for porters?
3. What do they do to ensure the trekking staff is properly trained to look after porters' welfare?
4. What is their policy on training and monitoring porter care by its ground operator in Nepal?
5. Do they ask about treatment of porters in their post trek questionnaire to clients?

From: www.ippg.net, accession date Aug. 3rd, 2008