Acute Mountain Sickness (AMS)

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Conflict of Interest Statement

Payed lectures, consultancies, clinical studies for

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May, 23rd, 2019

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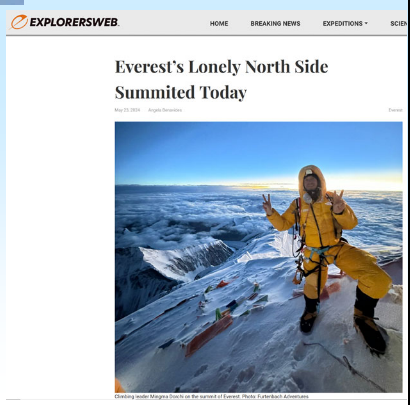

EXPLORERSWEB HOME BREAKING NEWS EXPEDITIONS SCIEN

Everest's Lonely North Side Summited Today

May 23, 2024 · Angela Benavides · Everest

Climbing leader Mingma Dorchi on the summit of Everest. Photo: Furtenbach Adventures

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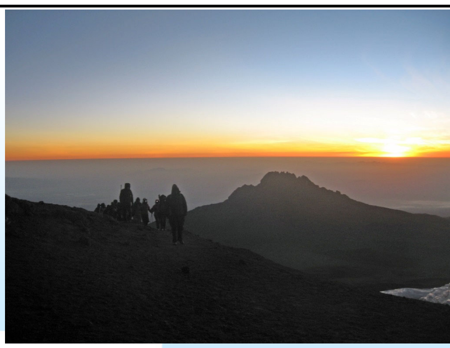
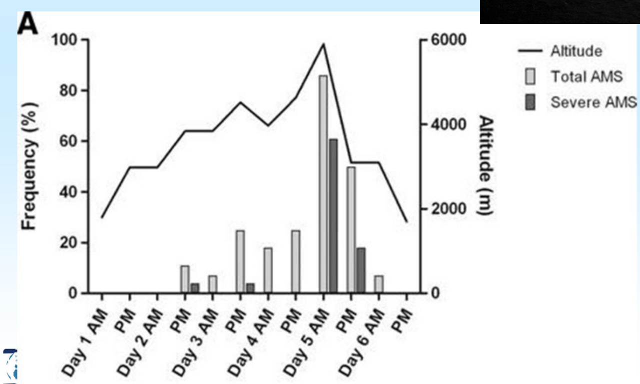
Kilimajaro:
>80% have AMS at summit day,
59% show severe forms!





Meyer et al HAMB 2012

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Why do we develop altitude sickness?

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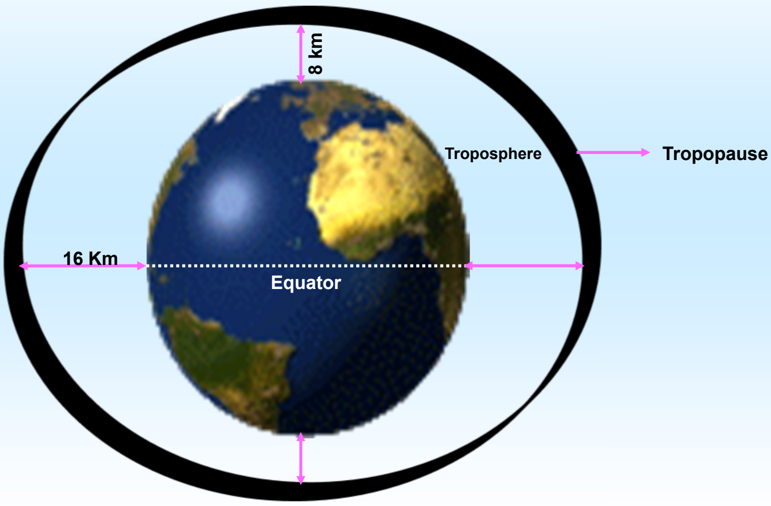
Air Pressure in the Troposhere



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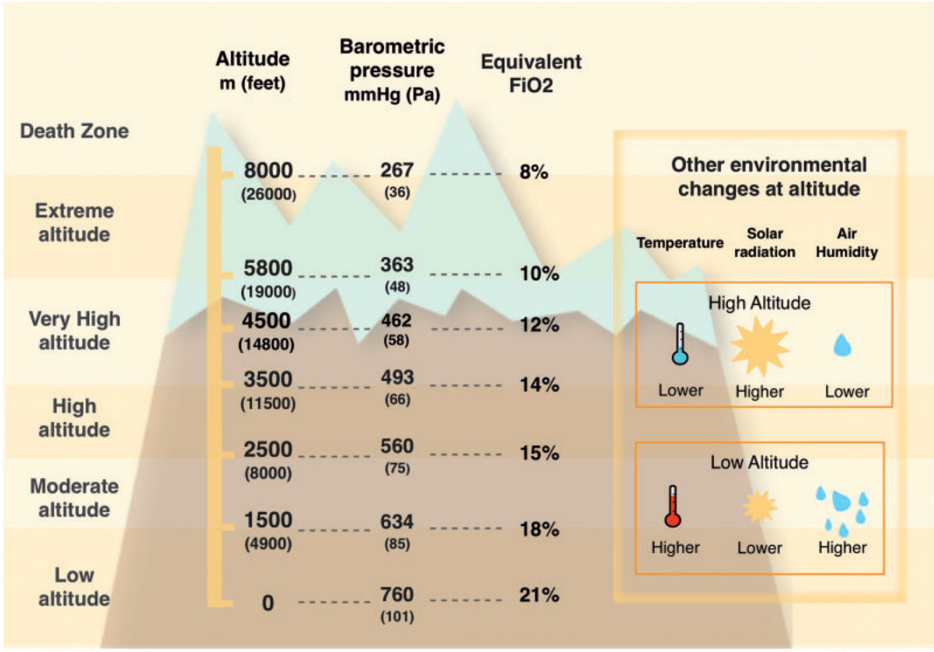

Quelle: Parati et al. Eur Heart J 2018;39:1546-1554

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Hypoxia: Early Physiological Adaptation

- Increase of Ventilation
  (up to 200 l / min*, Resp. Rate 80 /min*)
- Pulmonary Hypertension
- Reduction of Pulmonal Shunts
- Increase Carciac Output
- Splenic Contraction§
- Hb-Increase through
  - Erythropoetine-Increase$
  - Shifting of Oxygen Binding Curve

* West et al, 1983, J Apl Phy
§ Richardson et al, Eur J Appl Physiol 2007
$De Brujn et al. Eur J Appl Physiol 2008

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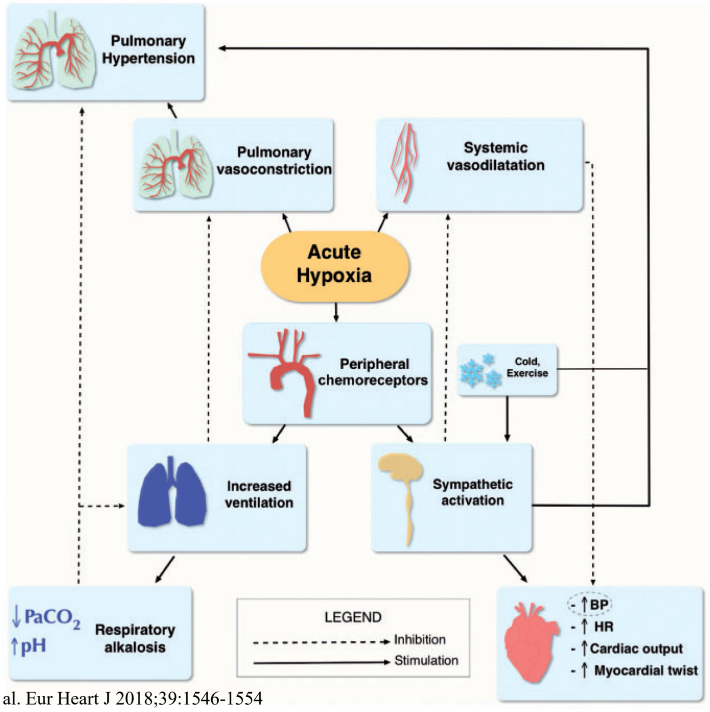
Physiological Reactions to Hypoxia



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Quelle: Parati et al. Eur Heart J 2018;39:1546-1554

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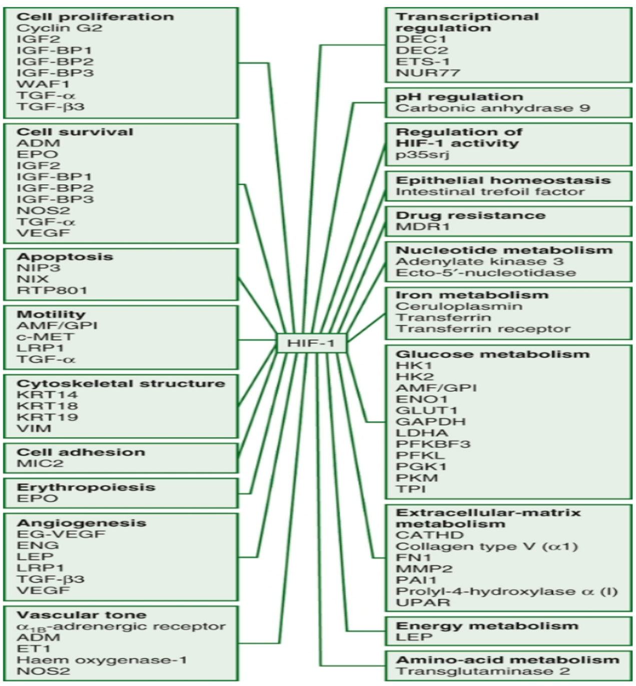
Effects of Hypoxia-inducible Factor (HIF) Released in the Carotid Bodies



Source: Auerbach Wilderness Medicine. Expert Consult 2017

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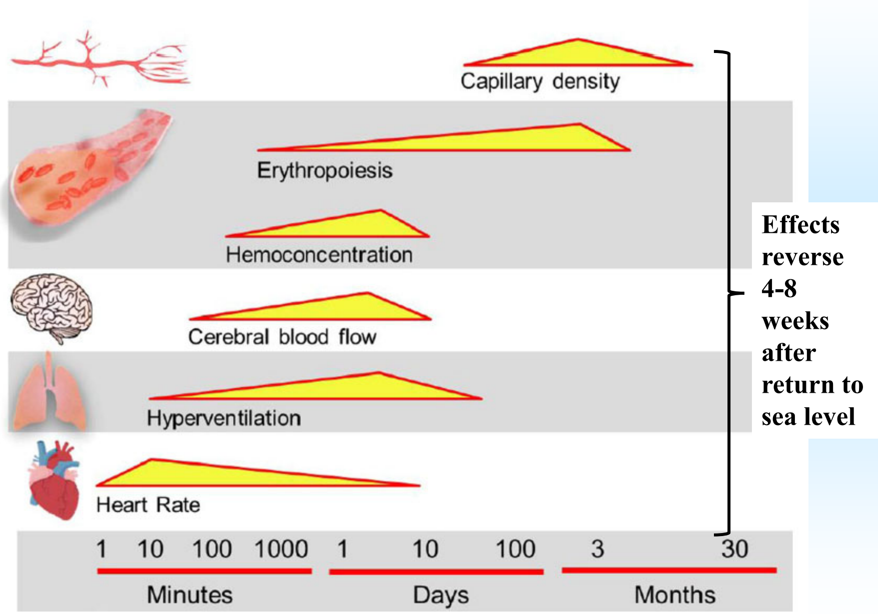
Reactions to Hypoxia - Timeline



Burtscher et al. J Sci Sport Exercise 2022;4:331-345

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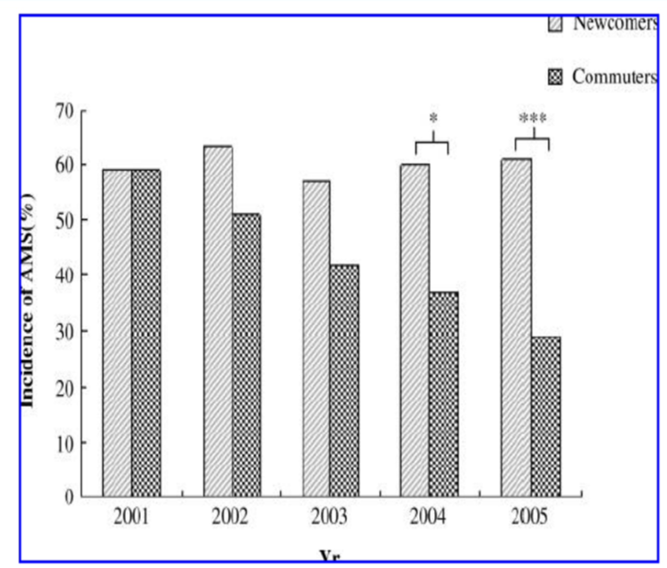
Memory of Acclimatisation Stays over Years



Wu et al, High Alt Med Biol 2009, 221-232

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Forms of Acute Mountain Sickness

Cerebral Manifestations

Acute Mountain Sickness (AMS)

High Altitude Cerbral Edema (HACE)

Pulmonal Manifectations

High Altitude Pulmonary Edema (HAPE)

High Altitude Lymph Edema (HALE)
High Altitude Retinal Hemorrhagies (HARH)

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AMS - Symptoms

- **Headache**
- Nausea
- Vomiting
- Fatigue
- Insomnia
- Loss of appetite
- Drowsiness

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Reasons for AMS and HACE

– Hypoxia

– Increase of cerebral blood flow

– Increased vascular permeability

– Cerebral Edema

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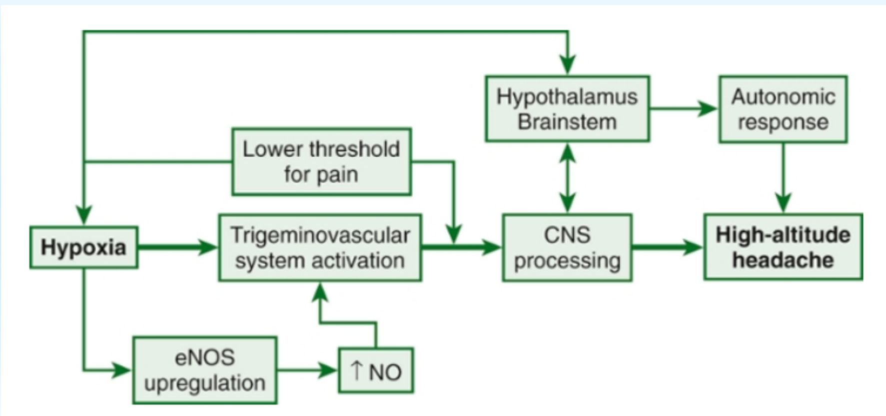
Pathophysiology of High Altitude Headache



Source: Auerbach Wilderness Medicine. Expert Consult 2017

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Who is at Risk for AMS ?

- *No Correlation* of AMS/HACE with
  - Fitness
  - Smoking
  - Diet
  - Sex (maybe more frequent in woman?)
  - Cerebral blood flow
- *Correlation with*
  - **SaO2 at arrival at altitude**
  - **Level of exercise**
  - **Age**

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HIGH ALTITUDE MEDICINE & BIOLOGY
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Special Reports

The 2018 Lake Louise Acute Mountain Sickness Score

Robert C. Roach,[1] Peter H. Hackett,[1] Oswald Oelz,[2] Peter Bärtsch,[3] Andrew M. Luks,[4] Martin J. MacInnis,[5] J. Kenneth Baillie,[6,7] and The Lake Louise AMS Score Consensus Committee

Abstract

Roach, Robert C., Peter H. Hackett, Oswald Oelz, Peter Bärtsch, Andrew M. Luks, Martin J. MacInnis, J. Kenneth Baillie, and The Lake Louise AMS Score Consensus Committee. The 2018 Lake Louise Acute Mountain Sickness Score. *High Alt Med Biol*. 19:4–6, 2018.— The Lake Louise Acute Mountain Sickness (AMS) scoring system has been a useful research tool since first published in 1991. Recent studies have shown that disturbed sleep at altitude, one of the five symptoms scored for AMS, is more likely due to altitude hypoxia per se, and is not closely related to AMS. To address this issue, and also to evaluate the Lake Louise AMS score in light of decades of experience, experts in high altitude research undertook to revise the score. We here present an international consensus statement resulting from online discussions and meetings at the International Society of Mountain Medicine World Congress in Bolzano, Italy, in May 2014 and at the International Hypoxia Symposium in Lake Louise, Canada, in February 2015. The consensus group has revised the score to eliminate disturbed sleep as a questionnaire item, and has updated instructions for use of the score.

Keywords: AMS; high altitude illness; history; Lake Louise; symptom scores

Committee members: Eric Achatz, United States; Edi Albert, Australia; Jon S. Andrews, United States; James D. Anholm, United States; Mohammad Zahid Ashraf, India; Paul Auerbach, United States; Buddha Basnyat, Nepal; Beth A. Beidleman, United States; R.R. Berendsen, The Netherlands; Marc Moritz Berger, Austria; Konrad E. Bloch, Switzerland; Hermann Brugger, Italy; Annalisa Cogo, Italy; Ricardo Gonzalez Costa, Argentina; Andrew Cumpstey, United Kingdom; Allen Cymerman, United States; Tadej Debevec, Slovenia; Catriona Duncan, United Kingdom; David Dubowitz, United States; Angela Fago, Denmark; Michael Furian, Switzerland; Matt Gaidica, United States; Prosenjit Ganguli, India; Michael P.W. Grocott, United Kingdom; Debra Hammer, Canada; David Hall, United Kingdom; David Hillebrandt, United Kingdom; Matthias Peter Hilty, Switzerland; Gigugu Himashree, India; Benjamin Honigman, United States; Ned Gilbert-Kawai, United Kingdom; Bengt Kayser, Switzerland; Linda Keyes, United States; Michael Koehle, Canada; Samantha Kohli, India; Arlena Kuenzel, United Kingdom; Benjamin D. Levine, United States; Mona Lichtblau, Switzerland; Jamie Macdonald, United Kingdom; Monika Brodmann Maeder, Italy; Marco Maggiorini, Switzerland; Daniel Martin, United Kingdom; Shigeru Masuyama, Japan; John McCall, Canada; Scott McIntosh, United States; Gregoire Millet, Switzerland; Fernando Moraga, Chile; Craig Mounsey, United Kingdom; Stephen R. Muza, United States; Samuel Oliver, United Kingdom; Qadar Pasha, India; Ryan Paterson, United States; Lara Phillips, United States; Aurélien Pichon, France; Philipp A. Pickerodt, Germany; Matiram Pun, Canada; Manjari Rain, India; Drummond Rennie, United States; Ge Ri-Li, P.R. China; Steven Roy, Canada; Samuel Verges, France; Tatiana Batalha Cunha dos Santos, Brazil; Robert B. Schoene, United States; Otto D. Schoch, Switzerland; Surinderpal Singh, India; Talant Sooronbaev, Kyrgyz Republic; Craig D. Steinback, Canada; Mike Stembridge, United Kingdom; Glenn Stewart, United States; Tsering Stobdan, United States; Giacomo Strapazzon, Italy; Andrew W. Subudhi, United States; Erik Swenson, United States; A. A. Roger Thompson, United Kingdom; Martha Tissot van Patot, United States; Rosie Twomey, Canada; Silvia Ulrich, Switzerland; Nicolas Voituron, France; Dale R. Wagner, United States; Shih-hao Wang, Taiwan; John B. West, United States; Matt Wilkes, United Kingdom; Gabriel Willmann, Germany; Michael Yaron, United States; Ken Zafren, United States.

3-5 points:	mild AMS
6-9 points:	moderate AMS
10-12 points:	severe AMS

Assessment not earlier than 6 hours after reaching altitude

TABLE 1. 2018 LAKE LOUISE ACUTE MOUNTAIN SICKNESS SCORE

Headache
0—None at all
1—A mild headache
2—Moderate headache
3—Severe headache, incapacitating
Gastrointestinal symptoms
0—Good appetite
1—Poor appetite or nausea
2—Moderate nausea or vomiting
3—Severe nausea and vomiting, incapacitating
Fatigue and/or weakness
0—Not tired or weak
1—Mild fatigue/weakness
2—Moderate fatigue/weakness
3—Severe fatigue/weakness, incapacitating
Dizziness/light-headedness
0—No dizziness/light-headedness
1—Mild dizziness/light-headedness
2—Moderate dizziness/light-headedness
3—Severe dizziness/light-headedness, incapacitating
AMS Clinical Functional Score
Overall, if you had AMS symptoms, how did they affect your activities?
0—Not at all
1—Symptoms present, but did not force any change in activity or itinerary
2—My symptoms forced me to stop the ascent or to go down on my own power
3—Had to be evacuated to a lower altitude

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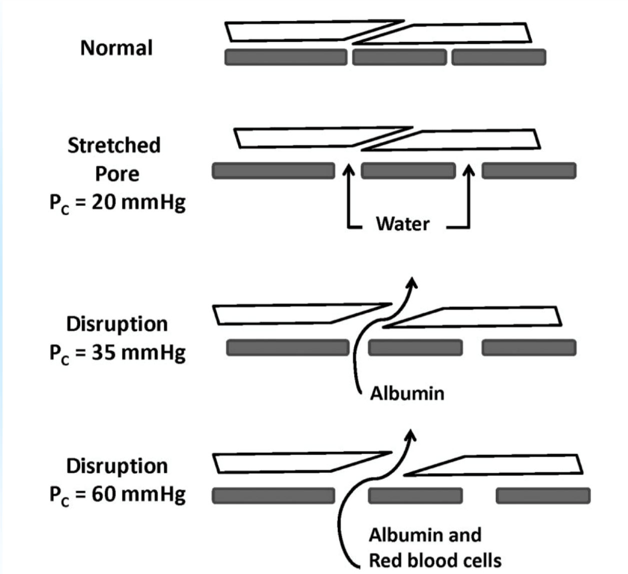
HAPE and HACE

High Altitude Pulmonary Edema (HAPE)

Symptoms

- Resting **dyspnoea** / orthopnoea
- Sudden drop in performance
- Fine- to coarse-bubbling rales
- Severe cough with foamy reddish sputum
- Severe cyanosis
- Fever (!), Cave DDX pneumonia/infection
- AMS not a necessary preliminary stage (negative in 20-25%)
- Rapid re-ascent possible after symptoms disappear

Disruption of alveo-capillary barrier



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Swenson E, Maggiorini M, Mongovin S, et al. Pathogenesis of high-altitude pulmonary edema, inflammation is not an etiologic factor. JAMA 2002;287:2228–35.

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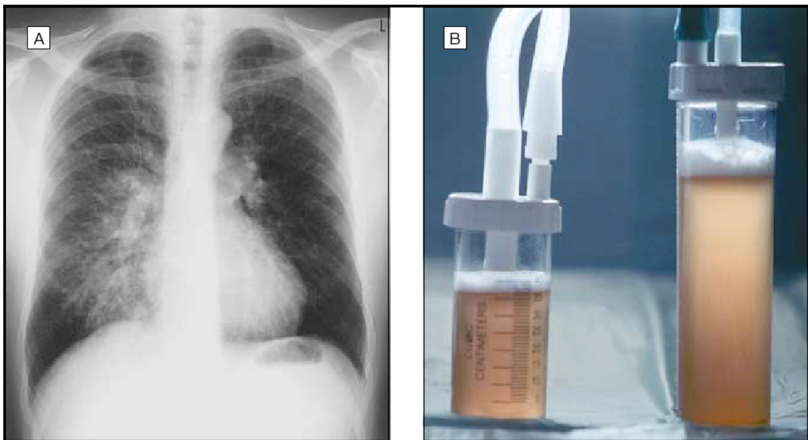

Bärtsch JAMA 2002, 287, 2332

Table 1. Arterial Blood Gas Measurements and Chest Radiograph Scores at Low and High Altitude on Bronchoalveolar Lavage*

	Mean (SD)				
	490 m		4559 m		
	Resistant (n = 6)	Susceptible (n = 10)	Resistant (n = 6)	Susceptible Well (n = 7)	Susceptible Ill (n = 3)
Pa_{O_2}, mm Hg	88 (4)	92 (3)	40 (2)†	33 (2)‡	29 (2)§
Sa_{O_2}, %	97 (1)	97 (1)	78 (2)†	66 (2)‡	57 (3)§
Pa_{CO_2}, mm Hg	38 (2)	37 (2)	28 (2)†	29 (2)†	29 (3)†
Chest radiograph score‖	0	0	0	1.5 (4.2)	12.7 (1.2)¶

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High Altitude Cerebral Edema HACE

- Symptoms:
  - Severe headache
  - **Ataxia**
  - Visual Disturbances
  - Hallucination
  - Nausea
  - Vomiting
  - Unreasonable behaviour
  - Loss of consciousness to coma

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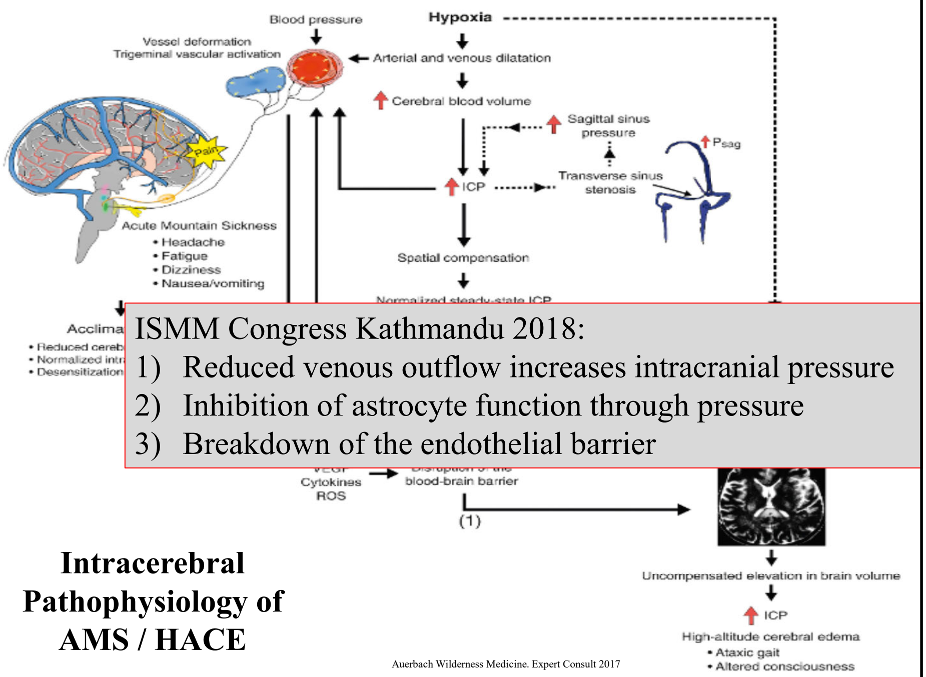

ISMM Congress Kathmandu 2018:
1) Reduced venous outflow increases intracranial pressure
2) Inhibition of astrocyte function through pressure
3) Breakdown of the endothelial barrier

Intracerebral Pathophysiology of AMS / HACE

Auerbach Wilderness Medicine. Expert Consult 2017

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HACE

- Severe hypoxia at high altitude leads directly to HACE
- Hypoxia at medium altitude initially leads to HAPE, then to HACE
- Remission after descent often delayed (>14 days), re-ascent not advisable
- Often residual damage (e.g. microhaemorrhages in the corpus callosum (bars) visible on MRI up to 50 months after HACE)

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High Altidude Lymph Edema (HALE)

- Frequent phenomenon, women >>men
- Increase with AMS
- Mainly feet, hands, face
- Warning signs for HAPE and HACE!

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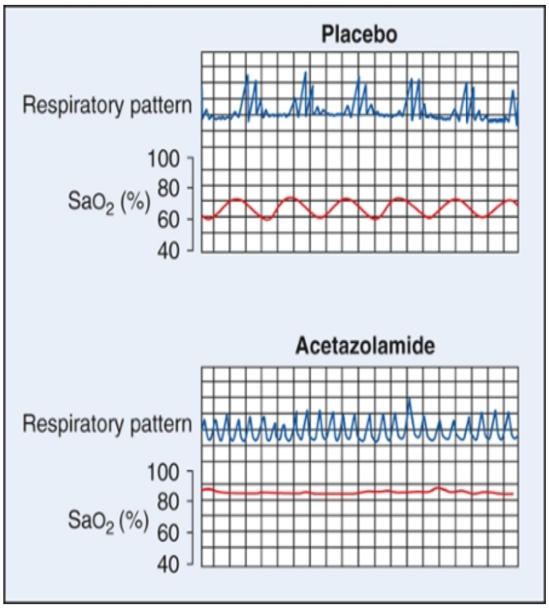
Sleep Disturbances

- Cheyne-Stokes respiration starts early
- Leads to poorer oxygenation
- Remedy with acetazolamide and benzodiazepines



Source: Auerbach Wilderness Medicine. Expert Consult 2017

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High Altitude Cough

- Almost universal problem above 5500m
- Lack of oxygen triggers coughing
- Main cause inhalation of dry, cold air through the mouth:
  leads to dehydration of the mucous membranes, viscous mucus in the airways, eventually coughing, also tendency to infection
- Massive coughing irritation up to rib fractures
- Prevention:
  breathing through balaclava, noscapine drops,
  inhaled β-mimetics, steroids,
  antihistamines (ketotifen)

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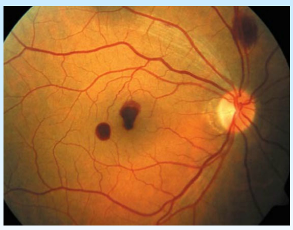
High Altitude Retinopathy (HAR)

- Often an incidental finding, rarely visual disturbances, visual field defects
- More common in older climbers, often delayed
- Caused by increased blood flow in retinal vessels
- Good regression
- Incidence of HAR around 60%
- 28 soldiers up to 4120m:
  81.5% central retinal vein occlusion,
  18.7% lateral branch occlusion, all reversible
  (Mukhtar et al. 2017)



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Thrombosis

- Fibrinolysis tends to increase at high altitudes
- But still tendency to thrombosis due to dehydration, inactivity, polycythaemia
- Increased fibrin production with HAPE
- Risks with hereditary tendency to thrombosis (e.g. factor V Leiden) unknown

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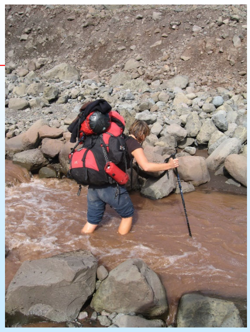
Immunosuppression



- Poor wound healing, poor response to antibiotics
- Improvement on descent
- Suppression of T-lymphocyte function in animal experiments
- B-lymphocytes not restricted - higher susceptibility to bacterial infections
- Probably caused by high levels of stress hormones, possibly also due to high UV exposure

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Diarrhea and ARI

- Diarrhea rate at Denali 34%, in Nepal 80%
- Variable pathogens
- Reduced hygiene
- No water for hand washing

- URTI triggered by
  - Cold air
  - Lack of oxygen
  - High altitude cough

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High-Altitude Deterioration

- Starts at approx. 5500m, very visible from 8000m
- Weight loss through loss of appetite and limited resorption (fat -49%, protein -33%, carbohydrates -24%)
- Performance weakness, fatigue
- Organic psycho-syndrome in 35% of mountaineers above 7000m
- Alitude psychosis?

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Hormones at High Altitude: Stress and Sex

Swiss Himlung Himal Expedition 2013:
24 subjects, >1000 blood samples, >6000 hormone measurements

- Stress hormones inhibited up to 5,000m, normalisation through acclimatisation
- Stress hormones massively increased from 5,000m, no adaptation
- Testosterone and oestrogen decrease steadily with altitude

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Source: von Wolff M, Interview in Die Alpen 4/2017

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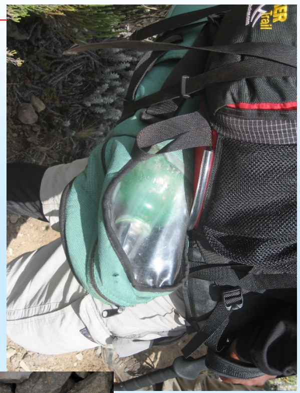
Moutain Sickness – Emergency Medication

- Oxygen
- Pressure Bag
- Ibuprofen
- Acetazolamide
- Nifedipine
- Dexamethasone



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Pressure Bag (Gamow, Certec, DEBEL)

Real Altitude [m]	Simulated Altitude
4000	1650
5000	2450
6000	3100
7000	3850
8000	4500

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AMS Therapy

- Mild symptoms:
  – Rest day at the same level
  – Fluids!
  – Symptomatic therapy (Ibuprofen)
- Severe symptoms:
  – Descent to the last campsite, never alone
  – Oxygen administration / hyperbaric chamber
  – Symptomatic therapy
  – Acetazolamide 125-250 mg 3 x daily
  – Dexamethasone 4 - 8 mg p.o. (up to 3 x daily)
- Consider DDx

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Therapy of Severe High Altitude Disease

Sequence of Measures in Severe Manifestations:

- **Decrease Altitude „descent – descent – descent !!“**
- Oxygen
- Drug Therapy
- Pressure Bag

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HAPE - Therapy

- **Descent at least 1000m**
- Oxygen
- Pressure Bag Roach et al. 1993
- **Decrease PA-pressure**
  - **Nifedipine** (Oelz et al. 1989) 20 mg ret. +
  - **Salmetarol (Salbumatol)** 125 µg 2x/die (Sartori et al, NEJM 2002)
  - **Sildenafil 50mg** (ISMM World Congress 2018)
  - Phentolamin (Hackett et al. 1992)
  - Acetazolamide (Teppema et al 2007)
  - Sildenafil, Tadalafil (Olschewski 2004, Richalet 2004, Bärtsch, 2006)

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HACE - Therapy

- Immediate, if possible passive descent
- Oxygen administration
- Dexamethasone orally/iv/im, at least 4 mg,
  preferably 8 mg every 6 h
- Acetazolamide
  (protects endothelial barrier, reduces cerebrospinal fluid production)
- Hyperbaric chamber

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Drugs for Prophylaxis of AMS

- Acetazolamide
- Prednisone
- Nifedipine
- Sildenafil
- Tadalafil
- Salmeterol (Spray)
- ASS
- Ibuprofen

- Intake of betablockers reduces altitude adaptation!
- Lots of fluid!

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Acetazolamide

- Characteristics
  - Diuretic - enough fluid!
  - Sulfonamide - Allergies?
  - Dosage for prophylaxis 2 x ½ tablet (=125 mg) per day, if necessary only 2 x ¼ tablet/day
  - Start: individually / 1 day before ascent > 2500m
  - End: usually from the start of the descent
- Side effects
  - Frequent: paraesthesia, change in taste, urge to urinate
  - Rare: Fatigue, dizziness, calf cramps
  - Sy overdose: tachycardia and -pnoea, Kussmaul respiration (acidosis), hypotension, muscle cramps
  - DDX AMS (!), but SO2 remains good

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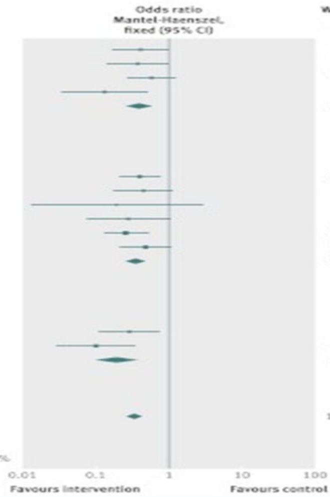
Meta-analysis: efficacy of acetacolamide prophylaxis

Study or subgroup	No of events/total: Intervention	No of events/total: Control	Weight (%)	Odds ratio Mantel-Haenszel, fixed (95% CI)
250 mg acetazolamide				
Basnyat 2003[5]	9/74	20/81	8.3	0.42 (0.18 to 1.00)
Basnyat 2006[15]	14/58	13/29	6.5	0.39 (0.15 to 1.01)
Gertsch 2010[25]	18/97	18/65	8.7	0.59 (0.28 to 1.26)
Van Patot 2008[26]	7/22	17/22	5.8	0.14 (0.04 to 0.52)
Subtotal (95% CI)	48/251	68/197	29.4	0.41 (0.26 to 0.64)
Test for heterogeneity: χ^2=3.53, df=3, P=0.32, I^2=15%				
Test for overall effect: z=3.88, P<0.001				
500 mg acetazolamide				
Basnyat 2008[22]	18/174	36/165	16.5	0.41 (0.22 to 0.76)
Basnyat 2011[23]	10/95	13/64	6.9	0.46 (0.19 to 1.13)
Burki 1992[28]	3/6	5/6	1.2	0.20 (0.01 to 2.91)
Chow 2005[24]	6/20	12/20	4.2	0.29 (0.08 to 1.06)
Gertsch 2004[13]	14/118	40/119	17.5	0.27 (0.14 to 0.52)
Hackett 1976[27]	17/71	19/49	8.5	0.50 (0.23 to 1.10)
Subtotal (95% CI)	68/484	125/423	54.8	0.37 (0.26 to 0.52)
Test for heterogeneity: χ^2=2.17, df=5, P=0.83, I^2=0%				
Test for overall effect: z=5.68, P<0.001				
750 mg acetazolamide				
Basnyat 2006[15]	14/68	14/30	7.7	0.30 (0.12 to 0.75)
Larson 1982[29]	5/29	20/30	8.1	0.10 (0.03 to 0.36)
Subtotal (95% CI)	19/97	34/60	15.8	0.20 (0.10 to 0.41)
Test for heterogeneity: χ^2=1.78, df=1, P=0.18, I^2=44%				
Test for overall effect: z=4.39, P<0.001				
Total (95% CI)	135/832	227/680	100.0	0.36 (0.28 to 0.46)
Test for heterogeneity: χ^2=10.20, df=11, P=0.51, I^2=0%				
Test for overall effect: z=7.97, P<0.001				
Test for subgroup differences: χ^2=2.98, df=2, P=0.22, I^2=33%				



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Low EV et al. BMJ 2012;345:e6779.

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Self Medication in Trekking Tourists at Thorong-La

Journal of Wilderness Medicine 2, 110–117 (1991)

ORIGINAL ARTICLE

Acute mountain sickness in western tourists around the Thorong pass (5400 m) in Nepal

B. KAYSER*

Himalayan Rescue Association, Nepal

1986: 1% acetazolamide

HIGH ALTITUDE MEDICINE & BIOLOGY
Volume 5, Number 4, 2004
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Awareness, Prevalence, Medication Use, and Risk Factors of Acute Mountain Sickness in Tourists Trekking around the Annapurnas in Nepal: A 12-Year Follow-up

SAMUEL GAILLARD,[1] PASCALE DELLASANTA,[1] LOUIS LOUTAN,[1] and BENGT KAYSER[2]

1998: 12% acetazolamide

2010: 44% acetazolamide

WILDERNESS & ENVIRONMENTAL MEDICINE, 25, 152–159 (2014)

ORIGINAL RESEARCH

Risk Determinants of Acute Mountain Sickness in Trekkers in the Nepali Himalaya: a 24-Year Follow-Up

Marion McDevitt, DO, MPH; Scott E. McIntosh, MD, MPH; George Rodway, PhD, APRN; Jitsupa Peelay, MS; Doug L. Adams, MStat; Bengt Kayser, MD, PhD

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Alternatives to Acetazolamide

- **Dexamethasone**
  - 4 mg every 12 hours
  - Limited to 5 days
  - For rapid ascents – rescue missions
- **Nifedipine**
  - 20 mg every 8 hours, especially for persons at risk of AMS complications
- Salmeterol
  - 125 µg every 12 hours, additionally to Nifedipine
- Tadalafil
  - 10 mg every 12 hours

Not effective

- Gingko- and Coca-Preparations

Bates M et al. High Alt Med Biol 2011;12:207-14.
Luks AM et al. Wilderness Environm Med 2010:21:146-55.
Maggiorini M. Prog Cardiovasc Dis 2010;52:500-6.
Maggiorini M et al. Ann Intern Med 2006;145:497-506.
Chow T et al. Arch Intern Med 2005;165:296-301.

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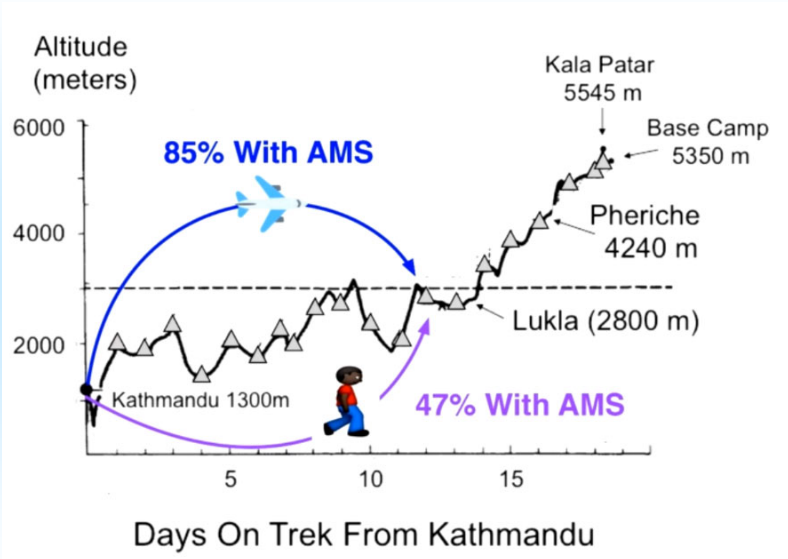
We know since a long time that speed of ascent makes a big difference



Hackett et al. Lancet 1976. 2(7996): 1149

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Acclimatisation to Altitude

„dont go too high too fast"
„dont go up until symptoms go down"
„climb high - sleep low"

- No anaerobic efforts
- Sleep as low as possible
- Daily sleep elevation gain 300 - 500m
- One additional rest day every 1000m

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Pre-Acclimatisation

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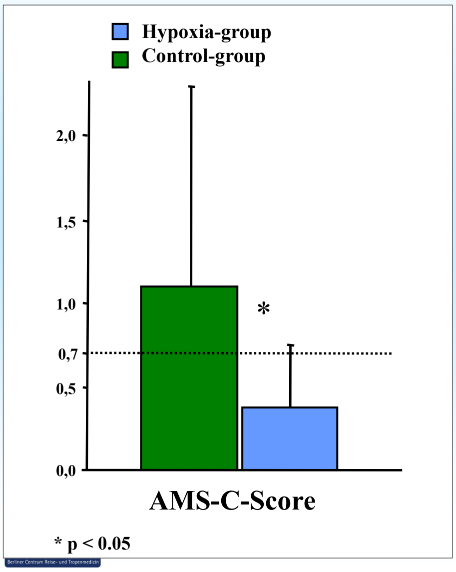
Sleeping in Moderate Hypoxia at Home for Prevention of Acute Mountain Sickness (AMS): A Placebo-Controlled, Randomized Double-Blind Study



AMS Definition:
AMS-C-Score > 0.7

	AMS +	AMS -
Control (< 800 m)	52%	48%
Hypoxia (> 2200 m)	14%	86%

Chi²-test, $p = 0.022$

Dehnert, Wilderness Med 2014

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Review

Review

Rapid ascents of Mt Everest: normobaric hypoxic preacclimatization

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The study was presented at the seventh Sport Orthopaedic Winter Symposium on the Feldberg Freiburg, Germany on 15 February 2020.
The study was presented as scientific lecture required as part of the habilitation procedure of the University of Ulm, Germany on 22 February 2019.
The opinions expressed in this article are those of the authors and do not necessarily reflect the views of the German Armed Forces.

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Abstract

Background: Acclimatization to high altitude is time consuming. An expedition to Mt Everest (8848 m) requires roughly 8 weeks. Therefore it seems very attractive to reach the summit within 3 weeks from home, which is currently promised by some expedition tour operators. These rapid ascent expeditions are based on two main components, normobaric hypoxic training (NHT) prior to the expedition and the use of high flow supplemental oxygen ($HFSO_2$). We attempted to assess the relative importance of these two elements.
Methods: We evaluated the effect of NHT on the basis of the available information of these rapid ascent expeditions and our experiences made during an expedition to Manaslu (8163 m) where we used NHT for preacclimatization. To evaluate the effect of an increased O_2 flow rate we calculated its effect at various activity levels at altitudes of 8000 m and above.
Results: So far rapid ascents to Mt Everest have been successful. The participants carried out 8 weeks of NHT, reaching sleeping altitudes = 7100 m and spent at least 300 h in NH. At rest a flow rate of 2 l O_2/min is sufficient to keep the partial pressure of inspired oxygen (PIO_2) close to 50 mm Hg even at the summit. For ativities of ~80% of the maximum rate of oxygen consumption (VO_{2max}) at the summit 6 l O_2/min are required to maintain a PIO_2 above 50 mm Hg.
Discussion: NHT for preacclimatization seems to be the decisive element of the offered rapid ascent expeditions. An increased O_2 flow rate of 8 l/min is not mandatory for climbing Mt Everest.
Conclusions: Preacclimatization using normobaric hypoxica (NH) is far more important than the use of $HFSO_2$. 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.

Key words: Mount Everest, pre-acclimatization, normobaric hypoxia, AMS, high altitude, artificial altitude, supplemental oxygen

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REVIEW ARTICLE

Hypoxia Conditioning for High-Altitude Pre-acclimatization

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Abstract

Purpose Main purposes of pre-acclimatization by hypoxia conditioning (HC) are the prevention of high-altitude illnesses and maintenance of aerobic exercise performance. However, robust evidence for those effects or evidence-based guidelines for exposure strategies, including recommendations to ensure safety, are largely lacking. Therefore, we summarize the current knowledge on the physiology of acclimatization to hypoxia and HC with the aim to derive implications for pre-acclimatization strategies before going on high-altitude treks and expeditions.
Methods Based on the literature search and personal experience, core studies and important observations have been selected in order to present a balanced view on the current knowledge of high-altitude illnesses and the acclimatization process, specifically focusing on pre-acclimatization strategies by HC.
Results and Conclusions It may be concluded that in certain cases even short periods (e.g., 7 h) of pre-acclimatization by HC are effective, but longer periods (e.g., > 60 h) are needed to elicit more robust effects. About 300 h of HC (intermittently applied) may be the optimal preparation for extreme altitude sojourns, although every additional hour spent in hypoxia may confer further benefits. The inclusion of hypobaric exposures (i.e., real altitude) in pre-acclimatization protocols could further increase their efficacy. The level of simulated altitude is progressively increased or individually adjusted ideally. HC should not be terminated earlier than 1–2 weeks before altitude sojourn. Medical monitoring of the pre-acclimatization program is strongly recommended.

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Oxygen Systems:

Poisk, TopOut and Summit Oxygen

- ✓ Constant Flow max. 2-8 l/h
- ✓ No On-Demand
- ✓ Regulator usually in backpack
- ✓ Problems with icing

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Kathmandu: Oxygen Bottles of an Everest-Expedition

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Five Golden Rules of the Himalayan Rescue Association

1. Everbody can get AMS,
   but nobody has to die from it !
2. Any health disorder at altitude must be
   considered altitude sickness until
   proven otherwise
3. No further ascent with symptoms of AMS
4. Descent immediately, if symptoms increase
5. A person with AMS must never be left alone

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How to Travel Safe at High Altitude

1. Don´t go
2. If you absolutely have to go: go slow
3. Consider pre-acclimatisation
4. Sleep low
5. Check yourself and your partner
6. Drink a lot
7. Don´t get diarrhea or ARI
8. Carry emergency medication
9. Consider prophylactic medication
10. Consider oxygen
11. Stay only briefly at high altitude
12. Descent immediately if sick
13. Despite all of this: try to enjoy yourself!

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Africa: Kilimanjaro 5895m

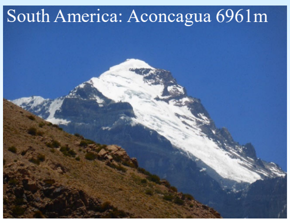
Asia: Everest 8850m

Europe: Elbrus 5642m

Oceania: Carstensz Pyramid 4884m

North America: Denali 6190m

Antarctica: Vinson 4892m



South America: Aconcagua 6961m

Questions?

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