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Reduction of olfactory sensitivity during normobaric hypoxia

Tilman Huppertz [a,*], Jessica Freiherr [b], Bernhard Olzowy [c], Ulrich Kisser [d,e], Jutta Stephan [f], Gunther Fesl [g], Kathrin Haegler [g], Berend Feddersen [h], Rainald Fischer [i], Klaus Mees [d], Sven Becker [a,d]

[a] Department of Otorhinolaryngology, Head and Neck Surgery, University Medical Center, Johannes Gutenberg University, Mainz, Germany
[b] Diagnostic and Interventional Neuroradiology, Uniklinik RWTH Aachen, Germany
[c] Department of Otorhinolaryngology, Head and Neck Surgery, University of Rostock, Germany
[d] Department of Otorhinolaryngology, Head and Neck Surgery, Ludwig Maximilians University Munich, Germany
[e] Department of Otorhinolaryngology, Head and Neck Surgery, Martin-Luther-University Halle-Wittenberg, Germany
[f] Institute for Altitude Training – Altitude Balance, Munich, Germany
[g] Department of Neuroradiology, Ludwig Maximilians University Munich, Germany
[h] Department of Neurology, Ludwig Maximilians University Munich, Germany
[i] Pneumologische Praxis Pasing, Munich, Germany

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ABSTRACT

Objective: Acute mountain sickness (AMS) is caused by a low partial pressure of oxygen and may occur above 2500 m. The aim of this research was to evaluate olfactory and gustatory abilities of healthy subjects during baseline conditions and after seven hours of normobaric hypoxia.
Methods: Sixteen healthy subjects were assessed using the Sniffin' Sticks, as well as intensity and pleasantness ratings. Gustatory function was evaluated utilizing the Taste Strips. Experiments were carried out under baseline conditions (518 m altitude) followed by a second testing session after seven hours of normobaric hypoxia exposure (comparable to 4000 m altitude).
Results: During normobaric hypoxia olfactory sensitivity and intensity estimates were significantly reduced.
Conclusions: We conclude that normobaric hypoxia leads to a significant decrease of olfactory sensitivity and intensity ratings.

1. Introduction

Acute mountain sickness (AMS) is characterized by different symptoms that can affect non-acclimatized travelers shortly after ascending to high altitudes. The most important risk factors for the development of high-altitude illness are rate of ascent, altitude reached (especially the sleeping altitude), and individual susceptibility [1,2]. Mild symptoms of this condition can occur above 2500 m whereas invariable symptoms can be seen within some hours at a height of 4000 m and more. Primary symptoms are headaches, lack of appetite, nausea, vomiting, fatigue, and dizziness [1]. The reason for this phenomenon is a reduction of parterial pressure of oxygen. The proportion of oxygen in the air is constant at about 21% up to a height of approximately 12,000 m. On the other hand barometric pressure decreases exponentially with altitude and consequently partial oxygen pressure decreases. For example the barometric pressure at sea level (1013 hPa) is reduced by 50% at a height of approx. 5500 m (530 hPa), at extreme heights like the summit of the Mount Everest (8848 m) it is reduced by approximately two thirds (335 hPa) [3]. Under these hypoxic

* Corresponding author at: Department of Otorhinolaryngology, Head and Neck Surgery, University Medical Center of the Johannes Gutenberg University Mainz, Langenbeckstr. 1, 55131 Mainz, Germany.
E-mail address: Tilman.huppertz@unimedizin-mainz.de (T. Huppertz).

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conditions impairment of different senses like audition, vision and balance were observed [4,5]. Beyond that, members of high altitude expeditions sometimes report a decrease of their olfactory and gustatory capabilities which was first described by Bert in 1878 [6]. Stepanek provided evidence for increased odor thresholds for vanillin in 14 out of 17 subjects under hypobaric conditions in comparison to normobaric conditions [7]. In line with these results, Kuehn et al. and Altundag et al. postulated a decrease of olfactory sensitivity under hypobaric conditions (comparable height approx. 2700 m) or at high altitude using the Sniffin' Sticks [8,9]. Reasons for the reduced olfactory sensitivity were seen in the expansion of gases under lower pressure leading to a lower amount of odor molecules in a certain gas volume. As neither suprathreshold olfactory discrimination nor cognitive functions were impaired, Kuehn et al. consider hypoxia as a reason for the threshold shift rather unlikely, however, they had not controlled for the effects of hypoxia [8].

In the current study we aimed to evaluate changes in olfactory and gustatory functioning after 7 h of induced normobaric hypoxia (comparable to a height of about 4000 m above sea level (a.s.l.)) and compare it with findings under normal conditions (Munich, 518 m a.s.l.).

2. Methods

2.1. Participants

Sixteen right-handed male subjects with a mean age of 22.9 years were included in the study. All participants were medically healthy: they had no history of cardiovascular, renal, or pulmonary diseases, neurological or psychiatric disorders, head trauma, or drug abuse. Non of them complaint about seasonal or perennial allergic rhinoconjunctivitis. The most recent exposure to high altitude above 2500 m had been terminated at least 4 months prior to the study. This study was performed according to the Declaration of Helsinki on Biomedical Studies Involving Human Subjects [10]. The study design was approved by the local ethical review board and included different examinations under normal and hypoxic conditions [11,12]. All subjects were informed about the procedures and aims of the study and provided written informed consent. The participants received a financial compensation for their participation in the study.

2.2. Experimental procedure

The study comprised two experimental sessions. During the first session olfactory and gustatory tests were conducted at the Department of Otorhinolaryngology, Head and Neck Surgery at Ludwig-Maximilians-University of Munich by means of the Sniffin' Sticks and Taste Strips test [13,14]. All participants underwent a physical examination including an anterior rhinoscopy followed by an endoscopic posterior rhinoscopy to exclude participants with profound septal deviation or a polyposis nasi. Baseline measurement was performed while participants were breathing normal air at room temperature (ca. 21% O_2, ca. 78% N_2, temperature between 21 to 23 °C, humidity between 30 to 50%) at an altitude of 518 m a.s.l.

During the second session olfactory and gustatory tests were conducted under normobaric hypoxic conditions at the Institute for altitude training, altitude balance, Munich, Germany. Hypoxia was induced in a chamber by means of a VPSA — S330 System (B-Cat High Altitude) without changing the atmospheric pressure level. The O_2 level was set to 13.0% ± 0.4% (comparable to a partial O_2 pressure at 4000 m a.s.l.) by accumulating N_2 to 86%, temperature and humidity were comparable to the baseline condition. The partial pressures of O_2 and N_2 during baseline and hypoxic conditions as well as at sea level are depicted in Table 1. All parameters were checked automatically every 5 min. Subjects spent a total of 8:29 h (SD = 24 min) under normobaric, hypoxic conditions. Hypoxic conditions were tolerated well by most of the participants. Two subjects complaint about nausea and had to vomit during their stay in the hypoxic chamber.

2.3. Sniffin' Sticks

Subjects were advised to not eat or drink anything except water one hour before the test. Olfactory function was evaluated using the Sniffin' Sticks test battery consisting of a threshold, a discrimination, and an identification test. For odor presentation,

Table 1
Partial pressures of O_2 and N_2 during experimental conditions as well as at sea level. Partial pressures are calculated due to Dalton's law describing the total pressure of a gas mixture as the sum of the partial pressures of the involved gases.

Partial pressures of O_2 and N_2					
	Atmospheric pressure hPa (mbar)		Percentage %		Partial pressure hPa (mbar)
Sea level					
O_2	1013	×	21	=	213
N_2	1013	×	78	=	790
Baseline condition					
O_2	962	×	21	=	202
N_2	962	×	78	=	750
Nomobaric hypoxic condition					
O_2	962	×	13	=	125
N_2	962	×	86	=	827

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