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BRIEF REPORT

# Residence at Moderate Versus Low Altitude Is Effective at Maintaining Higher Oxygen Saturation During Exercise and Reducing Acute Mountain Sickness Following Fast Ascent to 4559 m

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**Objective.**—To continuously monitor oxygen saturation ($SpO_2$) by pulse oximeter and assess the development of acute mountain sickness (AMS) using the Lake Louise Score (LLS) during ascent from 1154 to 4559 m in 2 groups of subjects: 10 moderate-altitude residents (MAR; $\geq$1000–$\leq$2500 m) and 34 low-altitude residents (LAR). MAR are reported to have a lower incidence of AMS during ascent to higher altitudes compared with LAR. Whether this is related to higher $SpO_2$ is still open to debate.

**Methods.**—Seventy subjects were recruited; 24-hour $SpO_2$ monitoring with finger pulse oximetry was performed. All subjects rode a cable car from 1154 to 3275 m and then climbed to 3647 m, where 60 subjects (LAR) overnighted. The second day, 34/60 LAR reached the highest altitude. Ten subjects who lived permanently at 1100 to 1400 m (MAR) climbed directly to 4559 m without an overnight stop.

**Results.**—One LAR was excluded from the analysis because he performed a preacclimatization. We compared data of 10 MAR with data of 33 LAR who reached 4559 m. Two MAR had an LLS of 3, and 8 scored $<$3. Six LAR had an LLS of 3 to 4, 8 scored $\geq$5, and 19 scored $<$3. $SpO_2$ monitoring showed higher mean $SpO_2$ in MAR during ascent above 3600 m compared with LAR (MAR, 79$\pm$4% vs LAR, 76$\pm$5%; analysis of variance, $P = .03$).

**Conclusions.**—The results of this preliminary study suggest that residence at moderate altitude allows maintenance of higher $SpO_2$ and reduces risk of developing AMS during rapid ascent to higher altitude.

*Keywords:* acclimatization, acute mountain sickness, exercise, oxygen saturation

## Introduction

Progressive exposure to high altitude is characterized by progressive hypoxemia, which worsens with exercise. Travel to elevations above 2500 m is associated with the risk of developing acute mountain sickness (AMS) or other more severe high-altitude diseases.[1] AMS is assessed by the Lake Louise Acute Mountain Sickness Scoring System (LLS), a well-validated questionnaire for field evaluation of AMS. An LLS score $\geq$3 is diagnostic of altitude sickness.[1] The best way to prevent AMS is to undertake an adequately slow ascent to high elevation, which allows time for acclimatization. Other nonpharmacologic prophylactic measures for AMS are repeated exposures to hypoxia in the time preceding a high-altitude excursion or spending up to 6 to 7 days at approximately 2200 to 3000 m.[2,3] In an article regarding the development of AMS at the Regina Margherita Hut, pre-exposure is defined as having spent more than 4 days above 3000 m during the 2 months preceding the climb.[4]

Likewise, individuals who usually reside at moderate altitude ($\geq$1000–$\leq$2500 m) achieve more rapid acclimatization to higher altitude and have reduced

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incidences and severity of AMS compared with those who usually reside at low altitude.[5,6] The few studies that have addressed this topic reported higher oxygen saturation measured by pulse oximeter ($SpO_2$), above 4000 m in moderate-altitude residents (MAR) compared with low-altitude residents (LAR).[5,6] In these studies, $SpO_2$ was measured at rest for only a few minutes, and no data during exercise were available. Only 1 study[7] reported a comparison between endurance performance and $SpO_2$ during exercise in MAR and LAR in a well-controlled laboratory setting at 4300 m. This study reported that MAR were able to exercise at a higher intensity and maintained higher exercise $SpO_2$ compared with LAR. However, these results were obtained at the third day of residence at altitude,[7] when the first changes involved in acclimatization have already occurred, especially the ventilatory acclimatization that contributes to increased $SpO_2$.

No study has continuously monitored $SpO_2$ during progressive high-altitude ascent from moderate to high altitude in MAR compared with LAR, particularly during exercise that induces physiologic responses that may exacerbate the development of AMS.

We had the opportunity to monitor $SpO_2$ and LLS during the entire ascent from Alagna (1154 m) to the Regina Margherita Hut (4559 m) in both MAR and LAR. In a previous article, we reported data among LAR.[8] Now we report data of $SpO_2$ monitoring and LLS in MAR compared with LAR.

## Methods

### RECRUITMENT

We designed a 4-week study on Mt. Rosa at the beginning of the climbing season, aiming to monitor $SpO_2$ for 24 hours and assess the development of AMS in climbers during the ascent to the Regina Margherita Hut (4559 m). The study purpose was explained in flyers posted in the Alpine Guide office and at the cable car base. Seventy subjects intending to climb to the Regina Margherita Hut were successively enrolled and provided informed consent. All subjects were asked about anthropometric data, altitude of residence, occupation, habitual physical activity, medical history, and previous AMS events. We defined "moderate altitude residents" as subjects who have resided at an altitude between 1000 and 2500 m for at least 12 months. Subjects taking drugs for AMS prophylaxis were excluded from the study. The study complied with the principles of the Declaration of Helsinki and was approved by the Ethics and Research Committee of the Medical School of the University of Ferrara, Italy.

### STUDY DESIGN

All 70 subjects were equipped with a 24-hour data memory pulse oximeter with a finger sensor (Pulsox-300i, Konica Minolta, Osaka, Japan) to monitor $SpO_2$ and heart rate (HR). The pulse oximeter was removed on arrival at the Regina Margherita Hut.

Subjects were asked to complete 2 questionnaires:

1. The Lake Louise Questionnaire for the assessment of AMS while in Alagna, at the Gnifetti Hut (on arrival, in the evening, and on the following morning), and on arrival at the Regina Margherita Hut. On the same sheet, the subjects also recorded the starting and arrival time and any exposure to altitude in the previous 2 months.
2. The Baecke questionnaire[9] for the measurement of habitual physical activity. This is a self-administered questionnaire separated into 3 dimensions: work, sports, and leisure activity. Each activity is scored in a range from 1 to 5.

On the first day, subjects rode a cable car from 1154 to 3275 m. They then climbed to the Gnifetti Hut (3647 m), where 60 subjects (all LAR) stayed overnight. On the second day, only 34/60 subjects climbed to the Regina Margherita Hut (4559 m). Twenty-six subjects ceased further climbing due to bad weather (11), poor health (7), or because the ascent was too demanding (8). Ten of the 70 subjects (3 females), permanently residing in Alagna and surrounding area (1100–1400 m, MAR), intended to climb directly from 3275 m to 4559 m. These subjects were excluded from the previous article.[8]

### DATA COLLECTION AND ANALYSIS

Data were stored at 1-second intervals and processed by DS-5 Minolta software.

For the analysis, we divided the data into 4 frames: at rest at 1154 and 3275 m, during the ascent to the Gnifetti Hut, and during the ascent to the Regina Margherita Hut. The mean values of HR, $SpO_2$, and time spent under different $SpO_2$ values (90%, 85%, and 80%) were evaluated. Exercise was identified by the time recorded by the subjects in the information and LLS sheet and confirmed by the HR.

### STATISTICAL ANALYSIS

Statistical analysis was performed using a statistical software package (GraphPad Prism 5; GraphPad Software, San Diego, CA). Data are presented as mean $\pm$ standard deviation where appropriate. Demographic data were analyzed with the unpaired Student's t test.