

# The lung at high altitude

## Il polmone in alta quota

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The lung is the interface between the environment and the metabolic mechanisms of the body, and plays a pivotal role in exposure to high altitude. In fact, high altitude is a challenge for the human body due to the progressive reduction of barometric pressure and subsequent reduction of oxygen pressure, leading to a series of important physiologic responses that enable individuals to tolerate hypoxia and secure the oxygen supply to tissues. These compensatory responses are known as the acclimatization process. Most of the adaptations are observed from 2000 m a.s.l. and they become progressively more evident with increasing altitude, from near sea level through to moderate and extreme altitude.

A new classification of altitude levels based on the effects on performance and well-being has been recently proposed [1]: the decrease in partial pressure of oxygen reduces maximal oxygen uptake and impairs "aerobic" performance by reducing maximal aerobic power. Submaximal exercise performance is also impaired at altitude. When the acclimatization is not adequate, hypoxia triggers maladaptive responses that lead to various forms of high altitude illness or acute mountain sickness (AMS), characterized by headache plus gastrointestinal symptoms (anorexia, nausea) and sleep disturbances. AMS is present in 10-30% of subjects at altitudes between 2500 and 3000 m a.s.l. and is usually due to a fast ascent. It is well defined by the short phrase: "Too fast, too high". Less frequent, but much more serious, consequences are high-altitude cerebral edema (HACE), and high-altitude pulmonary edema (HAPE).

The lung response to acute altitude exposure is mainly hyperventilation which, together with elevated heart rate, aims at achieving an adequate supply of oxygen to the tissues. At rest, ventilation increases by firstly increasing the tidal volume, at least up to 3500 m. Above this altitude, also the breathing rate significantly increases. Besides the compensatory response, other mechanisms affect

lung physiology during hypoxic exposure: the increase of pulmonary artery pressure and endothelial permeability which can explain the extravascular lung fluid accumulation described in many papers [2]. It must be underlined that the interstitial fluid accumulation which affects a large part of climbers at high altitude should be considered a para-physiological mechanism and does not predict subsequent pulmonary edema [3].

The role of the lung in the acute exposure to altitude was first described by Angelo Mosso, physiologist at the University of Torino, at the end of the 19<sup>th</sup> century. He very well pointed out the changes in ventilation and the reduction of lung volumes consistent with the extravascular fluid accumulation in the pulmonary interstitium [4].

However, mountain climate is characterized not only by the progressive reduction of barometric and inspiratory oxygen pressure, but also by other changes that can variably affect respiratory function and bronchial hyperresponsiveness: progressive reduction of air density, humidity, temperature, aeroallergens, and outdoor pollution. The lower density of air reduces respiratory resistances and increases inspiratory and expiratory flows; this fact explains the improvement of some parameters of the forced exhalation curve observed at altitude. The reduced temperature and the reduced humidity cause hyperventilation of dry and cold air, especially during exercise; this fact could induce an asthma attack, especially in subjects suffering from exercise induced bronchospasm. The reduction or even the absence of some aeroallergens (i.e. dermatophagoides) and outdoor pollution reduces the airway inflammation. Mountain climate can therefore variably affect the respiratory system.

An increasing number of people travel each year to high altitude for leisure, sport and even work purposes. Because of the critical role played by the respiratory system in the adaptive and maladaptive responses, patients with underlying lung disease may

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be at increased risk for complications in this environment and warrant careful evaluation before a sojourn to higher altitudes. Given the high prevalence of chronic respiratory diseases such as asthma and COPD in the general population, it is to be expected that many patients will ask their physicians about the safety of travel to altitude. This fact highlights the importance for physicians to have a good understanding of the high-altitude environment, the compensatory mechanisms of the body and high altitude illness. Advice for respiratory patients must be founded on an adequate knowledge of the altitude environment and the underlying disease. Is the patient at risk of an asthma attack? Can the patient adequately increase the ventilation? Has the patient

a gas exchange defect impairing the oxygen supply at altitude? The severity of the disease and the altitude to which the patient will go are critical points, but the first rule is that the disease must be in a stable state.

The physician, after a careful examination of the patient, must take into account the level of hypoxia (i.e. the altitude), the duration of exposure to hypoxic conditions, and the exercise intensity [5,6]. Heinrich Matthys in his paper in this issue [7] describes all these points, and provides physicians with valuable recommendations for management of respiratory patients prior to and during a sojourn at high altitude.

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