OCCASIONAL COMMUNICATION

THE CHACALTAYA HIGH ALTITUDE LABORATORY

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INTRODUCTION

Human function at altitude is one of the least understood aspects of physiology. A better understanding of the human response to hypobaric hypoxia may aid the treatment and prevention of dangerous high altitude illnesses and in addition may hasten the development of new therapies for sea-level pathologies such as chronic obstructive pulmonary disease (COPD), pulmonary hypertension and acute respiratory distress syndrome (ARDS). We present an account of the high altitude research expedition, Apex Bolivia 2001, that was created by six University of Edinburgh medical students with a common interest in the field of altitude medicine (Figure 1).

FIGURE 1
The six organisers of Apex Bolivia 2001 outside the Chacaltaya laboratory. From left to right: Kenneth Baillie, Roland Partridge, Roger Thompson, Martin Schnopp, Alistair Simpson and Matthew Bates.

Historically, huge practical difficulties have limited the conduct of meaningful research in the mountains. Warm, waterproof and served by a road, the 5,200 m (17,060 ft) high Chacaltaya laboratory in Bolivia removes many of these difficulties. The remaining obstacles were overcome in this expedition, as in any other, by a combination of careful planning and team spirit.

A team of 26 researchers and subjects spent ten days at the Chacaltaya laboratory. The expedition received extensive publicity on BBC's *Tomorrow's World*, and was generously supported by a number of grant-awarding bodies and corporate sponsors. Its research has generated novel findings relating to endogenous antioxidant function, high altitude cough, and endothelial function.

HIGH ALTITUDE PHYSIOLOGY

The study of human function under stress is a cornerstone of physiology. Monitoring the response to alterations in the external environment enables us to examine the design and function of body systems. Physiological research at high altitude has a long heritage of important contributions to our understanding of human function, including the demonstration of pulmonary gas exchange by diffusion, rather than secretion, in Barcroft's landmark 1921 expedition to Peru.[1]

Currently, much research on humans at altitude aims to elucidate the pathogenesis of acute mountain sickness (AMS) and two potentially fatal conditions, high altitude cerebral oedema (HACE)[2] and high altitude pulmonary oedema (HAPE).[3] Around 30% of humans at altitudes above 3,500 m (11,500 ft) and 50–60% at 4,250 m (14,800 ft) suffer from AMS.[4, 5] Rapid ascent to higher altitudes is associated with a much greater incidence of AMS; on this expedition 80% of subjects suffered from AMS on the second day at 5,200 m (17,060 ft). Recent years have seen an increase in travel to high altitude destinations for such recreational activities as skiing, trekking and climbing.[6] Therefore it is likely that the worldwide incidence of high altitude illness is increasing.

Other unexplained biological phenomena are associated with ascent to high altitude. For instance, marked cardiovascular changes including an increased incidence of cardiac arrythmias and a severely debilitating cough, the cause of which remains a mystery.[7]

ORGANISING THE EXPEDITION

The Apex Bolivia 2001 expedition was instigated in 1999, when one of the authors (JKB) met the high altitude physiologist, Professor Claus Behn, in Santiago, Chile and together they made a provisional agreement to arrange a collaborative expedition. The real planning began almost a year later, when a team of five medical students were recruited to help organise the expedition.

The biggest obstacle in organising this expedition was uncertainty: there was something to worry about at every stage. Would the expedition be safe? Would we be

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able to raise sufficient funds? Would enough volunteers be recruited? Would they enjoy themselves or would they resent the research? There was even a time when it seemed likely that Bolivia would fall into civil war and the whole enterprise would have to be cancelled.

The project was graciously supported by a variety of grant-awarding trusts. In addition, sponsorship was offered by numerous companies in the form of clothing, transport, and research and climbing equipment. Undoubtedly this commercial success was made possible by an enthusiastic publicity campaign, in particular the BBC television coverage.

All remaining costs of the expedition were paid equally by the volunteers themselves. In fact, in the initial stages, most of the workload for the organisers of the expedition was aimed at reducing the cost of participating thereby making the expedition more attractive to volunteers. With hindsight, however, the enthusiasm and sense of adventure of Edinburgh's students was underestimated – around 80 people applied to come on the expedition, of whom only 20 were selected.

THE CHACALTAYA LABORATORY

Many international groups have conducted experiments in Chacaltaya, although physiological studies have previously been relatively scarce.[8] Indeed in light of the numerous requests for information about the laboratory that have now been received by our team, the paucity of physiological studies to date was perhaps due to a lack of awareness of the excellent facilities that Chacaltaya provides.

The Chacaltaya laboratory is only a two-hour drive along an exposed dirt track from Bolivia's administrative capital, La Paz (3,650 m/12,000 ft; see Figure 2). It sits in the high Andean wilderness, in the shadow of the threatening and beautiful Huyana Potosi (6,088 m/19,974 ft). The lab itself, built in 1952 to house cosmic physics research, has plenty of room for equipment, as well as living areas and basic sleeping space for about 30 people. Each of the laboratory's three levels has one large room with several smaller rooms leading off, most of which are heated independently. Most importantly, it has a reliable mains power supply that could support the considerable load of our centrifuges, gas analysers and computers without faltering.

FIGURE 2
The Chacaltaya Laboratory (5,200 m).

MOVING OUR EQUIPMENT TO THE LABORATORY FROM LA PAZ

One of the more formidable logistical challenges was getting a reliable calibration cylinder for our CO_2 analysers. Despite assurances from the airline before the expedition that our baggage was safe and would be legitimately transported with us, our attempt to carry an innocuous low-pressure container onto our flight was thwarted by airport security in Miami, whilst an international courier company failed to deliver our backup cylinder. We eventually resolved this problem by purchasing another CO_2 cylinder in La Paz.

Fortunately a more reliable courier had been chosen for our blood samples: one of our sponsors successfully transported our blood samples on dry ice from the doorstep of the Chacaltaya laboratory to the Western General Hospital in Edinburgh.

SAFETY

The road link between our laboratory and La Paz was crucial to the success of this expedition. In addition to facilitating the easy transport of our equipment to Chacaltaya, it served as a quick and reliable route for the evacuation of any subjects who were dangerously unwell. Although some drugs have been shown to be useful in the management of HAPE or HACE, the only reliable and effective treatment is descent.[9, 10] For this reason, at least one jeep was kept on standby at the laboratory at all times.

After flying from sea level directly into La Paz at an altitude of 3,650 m (12,000 ft), we spent four days in Bolivia's capital before ascending the remaining 1,600 m (5,250 ft) to Chacaltaya (Figure 3). High altitude pulmonary oedema and HACE are more likely to develop after a rapid ascent such as this, but after consulting several international experts on altitude medicine, the unique evacuation facilities at our disposal were judged to be sufficient to ensure the safety of the group.

EVACUATIONS

At 5,200 m (17,060 ft), the inspired partial pressure of oxygen is only 50% of that at sea level (see Figure 3).[1] It was no surprise that on our first day at this altitude almost everyone in the group reported some of the symptoms of AMS: headache, lethargy, nausea and dizziness. One 22-year-old male member of the group reported a very severe headache, and was fatigued and nauseated. On examination, a few hours after our

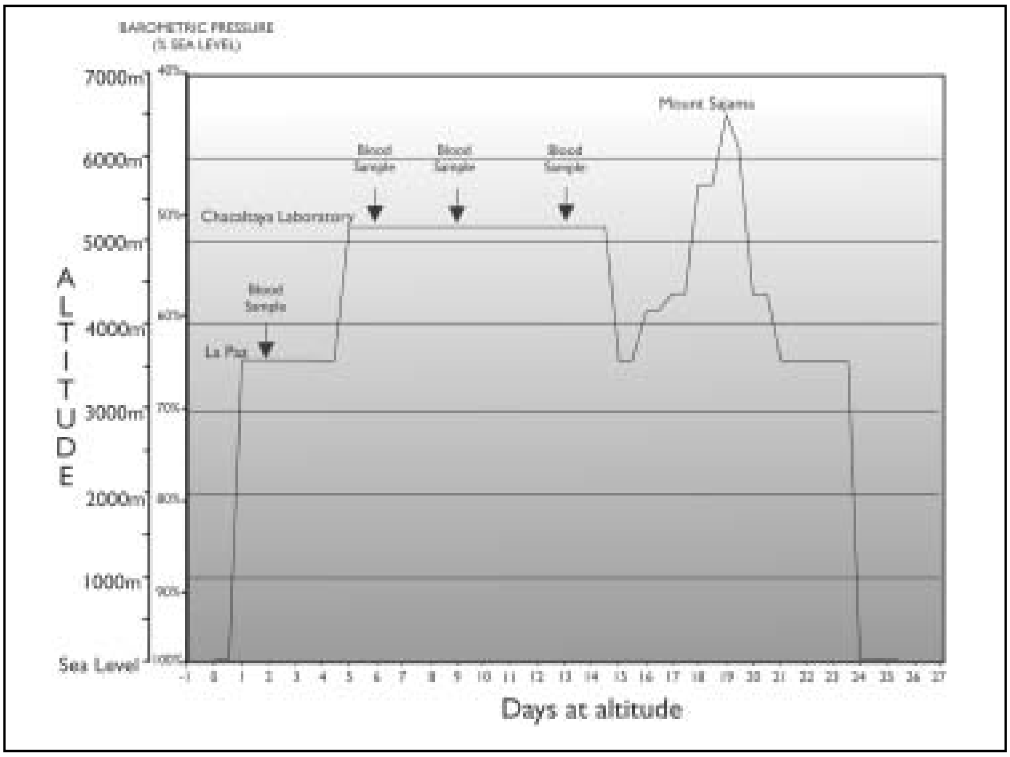

FIGURE 3
Altitude profile showing sample points. Sea level control samples not shown.

arrival at Chacaltaya, he was mildly ataxic and the decision was made to evacuate him. Oxygen and intramuscular dexamethasone were administered immediately whilst the jeep was prepared for the journey with emergency provisions and camping equipment, for use in the unlikely event of an accident or breakdown. At the same time, some of the team set up the centrifuges and freezing equipment in time to receive a blood sample from the casualty for our research. He was then evacuated to La Paz, and later reported that his symptoms had resolved almost completely after descending only a few hundred metres.

The following day, a 23-year-old female volunteer developed severe nausea, headache and photophobia. After several hours of observation, it was decided that it would be safer to evacuate in the early evening than risk driving at night. The same evacuation procedure was followed and her symptoms resolved on descent. One other subject requested to be evacuated, on the fourth day at 5,200 m, with moderate AMS (Lake Louise score = 8) that was not improving. Although it was not believed that she was in danger of HACE or HAPE it was decided that it would be preferable to evacuate her to relieve her symptoms.

CONCLUSION

Hundreds of thousands of people each year are at risk of potentially fatal high altitude illnesses. Medical research at high altitude aims to prevent and treat these pathologies, and to enhance understanding of sea level conditions that are caused or complicated by hypoxia. Apex Bolivia 2001 was a safe and rewarding expedition for the volunteers, and it achieved its aim of advancing understanding in several areas of high altitude physiology. Expeditions such as this one can make use of the unique facilities provided by the Chacaltaya laboratory for physiological studies on human volunteers. Indeed, Chacaltaya is very well placed to become an international centre for physiological research. The Scottish Charity, Apex (Altitude Physiological Expeditions) continues to promote awareness and understanding of altitude illness and has already successfully completed a second, larger expedition: Apex 2 took five teams of 20 volunteers in series to the Chacaltaya laboratory. In this and other expeditions, research at high altitude will hopefully continue to yield important information about human physiology.

Further information about Apex and the 2001 expedition can be found on the website: **www.apex-altitude.com**.

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