UNDERSTANDING THE ULTIMATE

ALISTER G. MACDONALD

Reader in Physiology, University of Aberdeen

The one hundredth number of this *Journal* prompts questions of how times have changed since its first edition in 1893, and in particular of how mountaineering has changed.

Although in 1893 it was known that the highest mountains on earth were in the Himalayas, the height of Everest was only settled in 1954 at 8848 metres (29,028 feet). Early attempts to climb Everest were very nearly successful, in particular the astonishing achievement of Somervell and Norton in reaching over 8500 metres on the northern approach in 1924, without using supplementary oxygen to assist their breathing. The main difficulty of high altitude climbing, the lack of oxygen, was fully appreciated, but Norton (1925) and his colleagues, Odell and Hingston in particular, were correct in their view that exceptional climbers could reach the summit without carrying oxygen. Nevertheless most subsequent attempts to climb Everest were large scale 'siege' expeditions, in which oxygen cylinders were used. Edmund Hillary and Sherpa Norgay were the first to reach the summit of Everest, and they did it assisted by cylinders of oxygen and the support of the Hunt expedition in 1953 (Hunt, 1953). Numerous similarly equipped expeditions followed, some successful, others not, but the scientific climbing world was astonished when in 1978, the Austrians Reinhold Messner (Messner, 1979) and Peter Habeler (Habeler, 1979) reached the summit without using supplementary oxygen, and without large scale expeditionary support. In 1980 Messner repeated the climb – solo!

In this article I want to explain the physiological significance of these climbs. The results of the 1981 American Medical Research Expedition to Everest are now published (West, 1982) and together with other developments provide us with a reasonably clear understanding of Messner and Habeler's achievement.

The atmosphere at high altitude

Air is four fifths nitrogen and one fifth oxygen and at sea level their combined pressure is 760 Torr of which oxygen constitutes about 152 Torr. (1 Torr is the pressure which will support one millimetre of mercury and is equal to 1/760 standard atmosphere or 133·32 Pascals). Atmospheric pressure decreases with an increase in height in a predictable way, subject to local climatic conditions. The 1981 American expedition recorded the pressure on the summit of Everest at 253 Torr which is significantly higher than predicted. This provides an oxygen pressure of about 50 Torr, which is desperately low to sustain active climbing. In fact by the time the air is drawn into the lungs, where it is mixed with the water vapour and carbon dioxide coming out of the body, the effective pressure of oxygen in resting conditions is down to 35 Torr. This should be compared to 100 Torr in normal conditions. It is also important to realise that high altitude atmospheres are also very cold, windy and dry. Water vapour is rapidly driven off by bodily heat, especially through the lungs, and the ensuing dehydration is a major debilitating factor.

The need for oxygen

Oxygen is a vital chemical in the process through which muscles release energy in the form of movement and heat. The rate at which we can carry out muscular exercise is called fitness, and this is largely set by the rate at which we can get oxygen to the muscles. Oxygen moves down a series of pressure gradients; lung gas to blood, blood to muscle cell, cell to the chemical reaction, and the rate at which this can occur is fundamentally limited by the initial pressure of oxygen in the lung. Should the muscles use oxygen more rapidly than the rate at which it can be supplied, lactic acid accumulates, acidified blood forces our breathing rate up even faster and painful exhaustion ensues. We cannot go on so we reduce our oxygen 'demand' by resting. Oxygen is also a vital chemical in the reactions supporting consciousness and other functions of the brain. We rapidly lose consciousness when the rate at which oxygen reaches the brain cells falls below a critical level, and irreversible damage can occur if the reduced oxygen supply is severe or prolonged.

Breathing is normally an automatic process, although we can impose temporary, conscious control over it. The normal breathing rhythm at rest or asleep is set by the acidity of the blood, but at high altitude the low oxygen pressure takes over and drives a vigorous breathing rhythm, which maintains as high an oxygen pressure as possible in the lungs. The extra requirements of muscular exercise drive the breathing rhythm even faster. From all this it is apparent why very high altitude climbing is made desperately hard by the lack of oxygen and was considered by some to be potentially dangerous through the sudden loss of consciousness, or worse.

Fitness at high altitude

Successful high altitude acclimatisation is a prerequisite for a serious attempt on Everest, with or without supplementary oxygen. Acclimatisation takes many weeks and involves a shift in the breathing rhythm to an automatically high setting and changes in the blood and its circulation, all of which assist in a good delivery of oxygen to the tissues. Sometimes the body responds poorly, as if it is anaemic rather than short of oxygen and it can also get its blood pressure out of balance. The result is an insufficient oxygen supply to the tissues, fluid in the lungs, and a sick climber who has to retreat, because he may die if he does not.

When the revised figures for the oxygen pressure at the summit of Everest became available, it was calculated that it was just possible for an exceptional individual to supply oxygen to his muscles at a rate which would support a slow rate of climbing. Ascending at a rate of, for example, 2 metres per minute, implies a certain rate of oxygen consumption, which is primarily limited by the oxygen pressure in the lungs and the blood circulation to the muscles. The oxygen pressure in the brain of such a climber is calculated to be 30% of normal, and his maximum oxygen consumption (fitness) has been measured at 25% of normal. Climbers usually adopt a pace at which they consume oxygen at between ½ to ⅔ of their individual maximum. At extreme altitude, without supplementary oxygen, this involves very hard breathing and frequent rests. A typical description would be Somervell's (1925):

"Approaching 28000 feet, I found that for every single step forward and upward, seven to ten complete respirations were required."

Habeler and Messner not only acclimatise to high altitude very effectively, they possess other important physiological properties. They are exceptionally good athletes; about 50% better than some other Everest climbers, and they have a remarkable cerebral tolerance to low oxygen pressure. Indirect evidence shows they also have exceptional tolerance to dehydration and when fasting, readily switch to metabolising fat. These last two attributes are important in other endurance 'sports'. It has been estimated that during their three day final assault on Everest they consumed about 10% of the calories required for the energy expended.

Their climbing technique complements their remarkable physiology. By all accounts their technical climbing skill and judgement is outstanding. Quite simply, they climb very fast without expeditionary support. On Everest their speed and endurance enabled them to carry few supplies, which, in the absence of oxygen cylinders, kept the packs they wore to the summit down to only 10 kg, compared to the 26 kg carried by Hillary and Tenzing. Above all else however is their superhuman commitment to succeed. Their fitness did not protect them from the mental stress of forcing their bodies to the theoretical limits of physical exercise. Messner's account (1979) makes this very clear:

"As we get higher it becomes necessary to lie down to recover our breath."

This seems quite relaxed when compared to his experience at the top:

"I am nothing more than a single, narrow, gasping lung, floating over the mists and the summits".

REFERENCES

Habeler, P. (1979). *Everest: Impossible Victory.* Arlington Books, London.
Hunt, J. (1953). *The Ascent of Everest.* Hodder and Stoughton, London.
Messner, R. (1979). *Everest: Expedition to the Ultimate.* Kay & Ward, London.
Norton, E.F. (1925). *Fight for Everest: 1924.* Arnold, London.
Somervell, T.H. (1925). *Journal of Physiology.* 60, pp. 283-285.
West, J.B. (1982). *Journal of Applied Physiology. Respirat. Environ. Exercise Physiol.* 52 (6) pp. 1393-1399.