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REVIEW

Tibetans at Extreme Altitude

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Between 1960 and 2003, 13 Chinese expeditions successfully reached the summit of Chomolungma (Mt Everest or Sagarmatha). Forty-five of the 80 summiteers were Tibetan highlanders. During these and other high-altitude expeditions in Tibet, a series of medical and physiological investigations were carried out on the Tibetan mountaineers. The results suggest that these individuals are better adapted to high altitude and that, at altitude, they have a greater physical capacity than Han (ethnic Chinese) lowland newcomers. They have higher maximal oxygen uptake, greater ventilation, more brisk hypoxic ventilatory responses, larger lung volumes, greater diffusing capacities, and a better quality of sleep. Tibetans also have a lower incidence of acute mountain sickness and less body weight loss. These differences appear to represent genetic adaptations and are obviously significant for humans at extreme altitude. This paper reviews what is known about the physiologic responses of Tibetans at extreme altitudes.

Key words: Everest, altitude, Tibetan

Introduction

On May 29, 2003, people interested in high altitude celebrated Edmund Hillary and Tenzing Norgay's first ascent of Chomolungma 50 years earlier. That achievement was a landmark in high-altitude medicine and physiology.[1] One of the commemorative activities was the 2003 Chinese Chomolungma Expedition. On May 21 between 1:40 and 2:10 PM, 8 climbers reached the summit. Five of them were Tibetans, who were faster reaching the world's highest peak than the Han (ethnic Chinese) climbers.

Between 1960 and 2003 in China, there were 13 expeditions to Mt Qomolungma (Everest) organized by the Chinese Mountaineering Association, including 5 international friendship expeditions, in which 80 climbers reached the summit. Among them, 45 climbers (56%) were Tibetan highlanders, and if 4 Sherpas are added, the percentage of summiteers that were Himalayan highlanders was 61%, compared to summiteers who were Han (11 persons [14%]) and the foreign climbers (20 persons [25%]).

Impressive evidence indicates that Tibetans have developed an unusual degree of adaptation to high altitude.[2] This review deals with some of the clinical and physiological characteristics of Tibetans at high altitude and extreme altitude (above 18 000 feet or 5500 m). Sherpas, who are mainly of Tibetan origin,[3] are renowned for their work capacity at extreme altitude, and Sherpas have reached the summit of Everest on many occasions.[4] Their physiological characteristics can be referenced; less information is available on Tibetan and Han climbers. Various characteristics of Tibetan climbers at extreme altitude are discussed.

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PHYSICAL PERFORMANCE

During the Chinese Everest expeditions (1960, 1975, 1988, 1990, 1992, 1993, 1997 twice, 1998 twice, 1999, 2002, and 2003), Tibetan climbers frequently carried heavy loads without supplemental oxygen and ascended as fast as those with oxygen. The Chinese Mountaineering Party does not completely support ''oxygenless climbing''; however, during the 1975 Chinese Mt Chomolungma Expedition, climbers used supplementary oxygen, but only during halts and not while actually climbing.[2,5] The expedition was brilliantly successful—9 climbers reached the summit on May 27, 1975. All of the summiteers but one (a Han) were Tibetans. In addition, 6 Tibetan women climbers reached 8000 m: 3

reached 8200 m, and another 3 reached 8600 m, almost as high as some elite male climbers.[5]

The expedition placed a survey tripod on the summit that allowed the altitude to be determined from the north side (the altitude was 8848.13 m[2,5]) (Figure 1). However, from a physiological point of view, the more remarkable feature of the expedition was the Tibetan climbers' ability to perform very heavy work drilling holes in rocks to install a metal tripod with legs as long as 3 m for the trigonometric survey. This work was carried out at an altitude of 8848 m for 70 minutes without supplemental oxygen.[5] The barometric pressure on the summit was about 251 mm Hg,[6] and the alveolar P_{O_2} was about 35 mm Hg.[7] The Tibetan climbers were on a physiological knife-edge and demonstrated an astonishing hypoxic tolerance.

During the same expedition, the female climber Pan-Dou laid down under the tripod on the summit while an electrocardiogram (ECG, lead I) was telemetered to base camp (5154 m) and was noted to be normal[8] (Figure 2). This was the first medical measurement made on the summit of Mt Everest.[2] There is no doubt that humans at the highest point on earth are very close to the limit of hypoxic tolerance.

During the 1988 China-Japan-Nepal Friendship Expedition to Chomolungma, a 29-year-old Tibetan climber, Ciren Daorji, was able to tolerate the summit altitude of 8848 m for 99 minutes without supplemental oxygen.[9]

Tibetan women climbers tolerate hypoxia, cold, and stress as well as men. Four have summited Chomolungma: Pan-Dou (1975), Gui-Shang (1990, 1999), Jia-Zhen (1998), and Pubu-Drolkar (2003). Gui-Shang is the only female climber to have gained the summit on 2 occasions, and Pubu-Drolkar has climbed to more than 8000 m 3 times.

LOW INCIDENCE OF ACUTE MOUNTAIN SICKNESS

During the 1990 China-Japan Joint Medical Research Expedition to Mt Anymaqin (6282 m), a survey of acute mountain sickness (AMS) was carried out in mountaineers of 3 different nationalities: the lowland Han who had resided at moderate altitude (2261 m) for more than 10 years, the Japanese who had lived at sea level, and the Tibetans who had been born and lived at 3719 to 4520 m. The diagnosis of AMS was based on the Environmental Symposium Questionnaire.[10] Symptoms of AMS developed during a period of a few hours or days at 3719 m in the Japanese and at 4660 m in the Han. After ascent to 4904 to 5200 m and 5 days at this altitude, the incidence of AMS was significantly different in the 3 nationalities. In the Japanese, it was 55.6% (5/9), and in some individuals, it was severe. Two climbers were taken down to 4660 m and given oxygen, and 4 developed peripheral edema (periorbital, facial, or ankle). The incidence of AMS in the Han was 15.5% (2/15), but the disorders were mild. No Tibetans (12 subjects) suffered from AMS, even though physical exercise by the Tibetans was much greater than that performed by the Japanese and the Han.[11,12]

The Sherpas, like the Tibetans, appear remarkably free from AMS when moving from low to high altitudes. In 1984, Hackett et al[4] reported 25 Sherpas with a history of 47 expeditions, during which they carried heavy loads to extreme altitudes. None had ever had AMS. In addition, although the Sherpas can now move from low altitudes to their homeland quickly by air transport, few cases of high-altitude pulmonary edema have been reported.

High-altitude retinal hemorrhages are well-recognized phenomena at high altitude. During the Chinese Chomolungma expeditions, high-altitude retinal hemorrhages were found in 78% (7/9) of Han climbers who ascended to between 5000 and 7500 m but were not observed in 12 Tibetan mountaineers.[13] When Rennie and Morrissey[14] looked for retinal hemorrhages in 15 American climbers and 5 Sherpas at an altitude of 5880 m of Mt Dhaulagiri, such hemorrhages were seen in one third of the American climbers but in none of the Sherpas. While more data are needed to confirm that the Tibetans or the Sherpas are relatively immune from AMS and high-altitude retinal hemorrhage, their reported absence in these highlanders is another sign of excellent hypoxic tolerance.

WEIGHT LOSS

Humans can live at elevations considerably greater than 5500 to 5800 m for only short periods. Above that elevation, a progressive worsening in their mental and physical condition occurs and has been termed high-altitude deterioration.[15,16] However, Tibetans seldom develop high-altitude deterioration, even when they stay at higher altitudes for a relatively longer period. Loss of body weight is the most objective aspect of high-altitude deterioration.[17]

During the 1990 Mt Anymaqin Expedition, after a 19-day trek to 4660 m and a 6-day stay at the laboratory camp near 5000 m, Chinese and Japanese mountaineers experienced an increasing loss of appetite despite a palatable diet. Twelve Han mountaineers lost an average of 2.56 ± 1.11 kg during the trek and 3.37 ± 1.09 kg during residence above 5000 m. Eight Japanese members had a mean $2.2- \pm 0.9$-kg weight loss. However, 4