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BIOLOGICAL BASIS OF CHRONIC MOUNTAIN SICKNESS[1]

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SUMMARY. The Andes completed its present elevation about 18 million years ago when mammals had already expanded at sea level about 65 million years ago. Therefore, mammals are recent invaders of the Andean high altitude. Andeans are newcomers to high altitude with only thousands of years of hypoxic exposition. High altitude is a great biological challenge for animal life and chronic mountain sickness is the result of this disease at sea level, where mammals evolved their respiratory function in the hyperoxic atmosphere. Chronic mountain sickness constitutes an excessive response of physiological mechanisms which appear in the course of acclimatization of newcomers to high altitude or in high altitude natives, which eventually lead to symptoms of intolerance to the hypoxic environment. There is total loss of hyperventilation with PaO_2 of 40 Torr in high altitude natives with excessive polycythemia and symptoms of chronic mountain sickness compared with 32 Torr in the younger asymptomatic ones (excessive hypoventilation). About 33 % of the population living in Cerro de Pasco (4340 m) older than 50 years have concentrations of hemoglobin above 21.3 g/dl. In chronic mountain sickness is observed an exaggerated increase in arterial pulmonary hypertension, enlargement of the carotid bodies in high altitude natives and a high incidence of chemodectomas.

Key Words. Acclimatization, Andes, Evolution, Chronic Mountain Disease.

RESUMEN. Los Andes completaron su elevación actual hace 18 millones de años cuando los mamíferos ya se habían expandido por el nivel del mar 65 millones de años atrás. Por lo tanto, los mamíferos son invasores recientes de los Andes. Los andinos son recién llegados a la altura con sólo miles de años de exposición a la hipoxia. La altura es un gran reto biológico para la vida animal y el mal de montaña crónico es el resultado de esta enfermedad a nivel del mar, donde los mamíferos evolucionaron su función respiratoria en la atmósfera hiperóxica. El mal de montaña crónico constituye una respuesta exagerada de los mecanismos fisiológicos que aparecen en el curso de la aclimatización de los recién llegados a la altura o en los nativos de la altura, que eventualmente conduce a síntomas de intolerancia al medio hipóxico. Hay una total pérdida de la hiperventilación con PaO_2 de 40 Torr en nativos de la altura con excesiva policitemia y síntomas de mal de montaña crónico comparado con 32 Torr en los sujetos jóvenes asintomáticos (hipoventilación excesiva). Cerca del 33 % de la población de Cerro de Pasco (4340 m) mayores de 50 años tienen concentraciones de hemoglobina por encima de 21.3 g/dl. En el mal de montaña crónico se observa un aumento exagerado de la hipertensión arterial pulmonar, agrandamiento de los cuerpos carotídeos en nativos de la altura y una alta incidencia de quemodectomas.

Palabras Claves. Aclimatización, Andes, Evolución, Mal de Montaña Crónico.

The evolution of mammals is a late evolutionary event during which the concentration of oxygen in the atmosphere reached maximum values.

The lung function of mammals evolved in this highly oxygenated atmosphere. Blood of mammals saturates at the sea level PaO_2 pressure of about 100 Torr and any elevation above sea level will unsaturate the blood. From this point of view, altitude starts as soon as we leave sea level.

The Andes completed its present elevation about 18 million years ago when mammals had already expanded at sea level about 65 million years ago. Therefore, mammals are recent invaders of the Andean high altitude niche and carry with them a basic sea level design but with enough evolutionary time to develop genetic adaptations to the hypoxic environment.

Andeans are newcomers to high altitude with only thousands of years of hypoxic exposition and without enough geographic isolation to reach the genotypic capacities of the better

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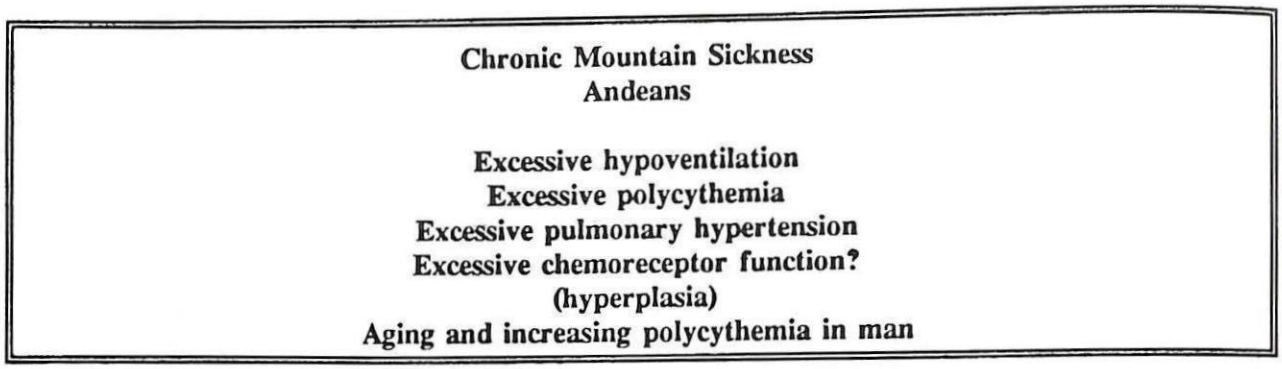

Figure 1.- Excessive physiological adaptive responses of Andeans to the hypoxic environment.

adapted animal species. High altitude is a great biological challenge for animal life and chronic mountain sickness is the result of this disease at sea level, where mammals evolved their respiratory function in the hyperoxic atmosphere.

The basic design of the respiratory function of mammals and birds is a sea level design but the basic genetic capacity, which allows the fetus to live on top of "mount Everest" inside the uterus, can be expressed high altitudes.

Chronic mountain sickness is not a discrete clinical entity. It constitutes an excessive response of physiological mechanisms which appear in the course of acclimatization of newcomers to high altitude or in high altitude natives. Figure 1 summarizes some of these exaggerated responses which eventually lead to symptoms of intolerance to the hypoxic environment. Monge et al (1964) have reported the total loss of hyperventilation with PaO_2 of 40 Torr in high altitude natives with excessive polycythemia and symptoms of chronic mountain sickness compared with 32 Torr in the younger asymptomatic ones (excessive hypoventilation).

The epidemiological studies conducted in Cerro de Pasco at 4300 meters have set the maximum figure for hemoglobin concentration at 21.3 g/dl. About 33% of the population older than 50 years have concentrations above this figure (excessive polycythemia), (León-Velarde and Arregui, 1994); León-Velarde et al 1993; Monge CC et al, 1989).

Peñaloza et al (1971) have reported an exaggerated increase in arterial pulmonary hypertension in cases of chronic mountain sickness (excessive pulmonary hypertension). Arias-Stella (1963) described the enlargement of the carotid bodies in high altitude natives and Saldaña et al (1973) found an incidence of chemodectomas 10 times larger in high altitude natives than in sea level controls (excessive chemoreflex activity of the carotid bodies?).

The excessive responses described above seem to indicate that the continuous "struggle for oxygen" (Barbashova, 1964) in Andeans living at high altitude can lead to the loss of adaptation to their native high altitude environment. These results should not be extrapolated to other high altitude populations like Tibetans, who seem to have a better genetic selection for the hypoxic environment (Zamudio et al, .1993; Beall, 1993). However in future times when the genetic pool of Tibetans becomes diluted by admixture with sea level genes, when transportation facilities will impede geographic isolation and when industry will westernize life in the Hymalayas, it is very probable that the Andean model of weak high altitude adaptation will also be established in Tibetans.

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