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Tolerance to Hypoxia: A High Altitude Paradox

Because oxygen is essential for cellular metabolism, when only an acutely diminished amount is available (hypoxia), survival is at risk—paradoxically, more so at sea level than at high altitude. Extremely low arterial oxygen tensions (P_{aO_2}) are quite well tolerated at high altitude. For example, at 3600 m in La Paz, Bolivia, patients can present with P_{aO_2} between 30 mm Hg and 40 mm Hg. Recovery is uneventful within a few days after the efficient treatment of the underlying cause. At this altitude, the normal acid-base values are P_{aO_2} 60 ± 2 mm Hg, arterial carbon dioxide partial pressure (P_{aCO_2}) 30 ± 2 mm Hg, pH 7.40 ± 0.02 , and SpO_2 $91\% \pm 1\%$, giving course to completely normal cellular function. Conversely, at sea level, a patient presenting with a similar P_{aO_2} of 60 mm Hg acutely is sent to an intensive care unit as that person's life is in peril.

Immediately upon arrival at high altitude, arterial oxygen and carbon dioxide partial pressures decrease. The persistent low levels of P_{aCO_2} , due to not only hyperventilation but also to high altitude per se, induce changes in the acid-base balance. The pH is inextricably linked critically with hemoglobin (Hb), carbon dioxide, and oxygen status, all crucial at high altitudes. The alkaline pH during acute high altitude exposure shifts the oxygen dissociation curve to the left, allowing more capture and transport of oxygen. Another variable that can allow for the tolerance to extremely low P_{aO_2} values is a normal low (relative to sea level) P_{aCO_2} . The acid-base balance in the human body is calculated using the Van Slyke equation based on sea level measurements.

The maintenance of blood pH within a fairly strict range at approximately pH 7.4, with due consideration of the effect of hyperventilation, is essential for cellular function at any altitude. That is because various chemical processes occurring in the body, for example, those involving proteins and enzymes, are pH dependent. Therefore, for a more precise recalculation of the titratable hydrogen ion difference that should use Hb and HCO_3^- values for a particular altitude, we previously derived our modified Van Slyke equation. An adequate acid-base balance is probably one of the fundamental metabolic adaptations that allow for mountaineers to tolerate extreme hypoxia and even reach the summit of Mount Everest. Furthermore, the increase in Hb and decrease in arterial carbon dioxide tension (P_{aCO_2}) are 2 essential changes that occur with high altitude chronic exposure. We propose the following formula: tolerance to hypoxia = $Hb/P_{aCO_2} \times 3.01$. In conclusion, we present evidence that the direct relationship between Hb and the inverse relationship with P_{aCO_2} concomitantly linked to the high altitude acid-base status explains the tolerance to hypoxia at high altitude.

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Measurable and Quantifiable Uncertainties at High Altitude Condition

Self-protection is the basic requirement in undisturbed nature. Resistance to the impact of a changing environment is a natural phenomenon and is part of the inbuilt system in all forms of life. The lower the availability of oxygen, the higher the carrying capacity of the oxygen and supporting multiorgan system is. Various kinds of predictable and measurable variations in the natural environment are known and realized by all forms of life. These variations, acute or chronic in nature, have both deleterious and beneficial (warning) impacts on life processes realized from scientific studies in the past.

Evidence indicates that the impact of a high altitude condition such as hypoxia is not exempt from this law of nature. Both acute and chronic hypoxia are known to trigger the dormant cells in the central nervous system. It is interesting to note that the basic five senses in animal systems are the nature-provided preliminary tools in all of us to predict, recognize, and evaluate the extent to which environmental changes do have an impact on our life. Man-made scientific tools provide fine tuning, but with the delay in responding, by that time much of the damage is already realized. Apart from that, inbuilt instincts (sixth sense) play a major role in the process of adjustment, acclimatization, and adaptation. Many lowlanders have experienced several scientifically unexplainable events. The life system is provided with an inbuilt mechanism to either activate or deactivate the basic instincts.

We can calculate with experience minute changes in the living environment (highlanders) or when exposed to new environmental conditions (lowlanders exposed to high altitude conditions) with fairly good precision and accuracy, leading to the measurement of uncertainties. Of late, modern humans, with logical conclusions, have depended on scientific tools to gather data for understanding; in contrast, animals without any such tools living in harmony with nature are more precise, with the least uncertainty to quickly realize changes in the environment. That is the basic law of protection. I have made an effort to develop a hypothesis that provides models for understanding our inbuilt nature, providing physical, instinct driven, spiritually realized (unbiased natural behavior), and neurologically experienced basic senses. The proposed hypothesis signifies the