Sports Med 2010; 40 (6): 519-523
0112-1642/10/0006-0519/$49.95/0

'Combining Hypoxic Methods for Peak Performance': a Biomedical Engineering Perspective

The review 'Combining Hypoxic Methods for Peak Performance'[1] recently published in *Sports Medicine*, attempts to formulate practical proposals for leading athletes to peak fitness. Its format suggests that it is intended as a practical guide for sports practitioners. The objective of simplifying the task for the coach is laudable; however, we are concerned that the conclusions and recommendations of this review are too narrow. This may adversely influence the training practices of the sporting community and misguide further research into athletic health and performance.

The review promotes the idea that the most expensive and cumbersome methods of hypoxia training (e.g. constructing real altitude camps and constant changing altitudes for training and living) are the only valid approaches for athletic performance enhancement. This encourages the misuse of economic resources, leads to using mega-budgets for training a few privileged athletes and justifies the construction of extremely expensive structures (i.e. altitude houses and altitude domes).

Noticeably, the review is not systematic or comprehensive, as research that contravenes the main idea of the review is often omitted from citations. For example, early research on intermittent hypoxic training (IHT) is quoted and criticized as being non-controlled;[2] however, a later, properly designed placebo-controlled study by the same group[3] who demonstrated the same extent of performance enhancement, is not mentioned. Similarly, a recent meta-analysis of various hypoxic training modalities[4] presenting substantially different conclusions to the review was also not quoted. In concluding that "it is known that IHE is inefficient for performance enhancement,"[1] the review completely ignores the substantial amount of data that strongly suggests the opposite.[5-7]

The terminology that is used in the review does not have a sound physiological basis and may confuse the reader. In addition to already confusing terms such as LHTL (live high-train low), LHTH (live high-train high), IHE (intermittent hypoxic exposure during rest) and IHT, an additional, baffling abbreviation LHTLHi (living high-training low and high, interspersed) is introduced. This bias in sources and confusion in terminology needs to be addressed.

Dr Millet and colleagues state that "The underlying mechanisms behind the effects of hypoxic training are widely debated." The origin of this debate, while not explicitly cited, is possibly the erythropoietin (EPO) paradigm of altitude training first suggested in the mid 1990s (LHTL),[8] which has been more recently criticized as incomplete and inconclusive.[9] This EPO paradigm of LHTL is itself based on another paradigm, which suggests that the maximal oxygen uptake ($\dot{V}O_{2max}$) is an accurate predictor of enhanced aerobic performance in highly trained athletes. This hypothesis is questioned by some research[10-13] and it is now being scrutinized.[14] It is problematic to select best training practices based on a misleading end-marker. However, commitment to disproving all alternative altitude training methodology, which is based on the fact that such a method "does not improve $\dot{V}O_{2max}$,"[15,16] might provide an interesting hypothesis; because of the improved economy resulting from the hypoxic training, the $\dot{V}O_{2max}$ could be decreased in highly trained athletes. This data could serve as an indicator of improved performance.

1. What is Being Stressed?

It is now well established that reduced oxygen partial pressure (pO_2), which is monitored by hypoxia inducible factor (HIF)-1α[17] and by mitochondria,[18-20] induces the chain reaction at the cellular level. Only a significant or long-lasting drop in pO_2 provokes detectable response to the altitude training. The reason that passive residing at altitudes of 1800 m fails to increase the