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LETTER TO THE EDITOR

Normobaric hypoxia and sports: the debate continues

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We have read with interest the recent letter of Sanchis-Gomar et al. (2010), and we basically agree with the authors who concluded that normobaric hypoxia can significantly modify several hematological parameters tested by anti-doping authorities so that anti-doping organizations should take into account the possibility of including normobaric hypoxia among the doping practices at least as a masking method in sports. Nevertheless, we raise several doubts about the fact that two out of three criteria presented by the World Anti-Doping Agency (WADA) for substances and methods to be considered for placement on the prohibited list (i.e., normobaric hypoxia does not exert significant ergogenic effects, and real or simulated altitude is quite safe and unlikely to injure an athlete) were considered by the authors not applicable to normobaric hypoxia.

As regards the biological mechanisms supporting the potential ergogenic effect of normobaric hypoxia, these have been recently reviewed by Lemaître et al. (2010) and include (a) optimization of the stimuli needed to improve oxygen delivery while avoiding the detraining effects associated with chronic hypoxia, (b) the splenic contraction effect which increases both hematocrit and hemoglobin between 2 and 5% independently of hemoconcentration and reduces arterial oxygen desaturation, (c) the reduction of blood acidosis (which is enormously advantageous for exercise performance), oxidative stress, and basal metabolic rate, and (d) and the increase in lung volume. It was also recently observed that although 8 weeks of respiratory muscle training did not increase maximum oxygen uptake ($\dot{V}_{O_2\,max}$), maximum exercise in hypoxia causes a significant increase in expired and alveolar ventilation (+12 and +13%, respectively). Accordingly, also the alveolar partial pressure of oxygen after respiratory muscle training significantly increased by approximately 10% (Esposito et al. 2010). In another article published in this journal by Sanchis-Gomar et al. (2009), it was previously shown that intermittent hypoxic treatment is at least as effective as the administration of recombinant human erythropoietin to increase the red blood cell mass and, inherently, the aerobic performances, in agreement with the previous findings of Mackenzie et al. (2008). Taken together, these data support the hypothesis that normobaric hypoxia might indeed contribute to improving sports performance.

We have earlier speculated that normobaric hypoxia might produce straightforwardly unfavorable biochemical changes, which include decreased anti-oxidative capacity and increased lipid peroxidation, which would lead to suppression of vascular endothelial function and cause impairment of vascular hemodynamics. It is also notable that the boost of "natural secretion" of erythropoietin with concomitant increase of platelets and red blood cells

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mass have significant effect on the blood rheology and blood pressure, exposing the athletes to the serious risk of hemoconcentration and thereby thrombosis, especially in endurance athletes who might undergo frequent episodes of dehydration (Lippi et al. 2007; Lippi and Franchini 2010). Accordingly, Richardson et al. (2009) also recently showed that hydration states above and below euhydration, which are both commonplace in athletes, have detrimental consequences on physiological strain when the athletes are exposed to normobaric hypoxia.

The debate about normobaric hypoxia continues. Besides the fact that using "artificial" systems for improving sport performance the spirit of sport might be lost for corrupting ethics, fair play, honesty, health, excellence, dedication, respect for rules and laws, whether normobaric hypoxia might be considered as a doping practice is still uncertain so far. Nevertheless, we still believe that the current scientific evidences about its ergogenic and potentially harmful effects should definitely assimilate this practice to several others already included in the WADA-prohibited list of substances or methods.

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