63 Sports in Altitude

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63.1 Background and Basic Principles

The primary goal of altitude training (or hypoxic training) is to increase blood oxygen-carrying capacity and muscular adaptations in order to improve performance at sea level. Since the 1968 Mexico City Olympics, training in altitude has been commonly used by elite athletes. This method is also employed for competition at altitude and for the acclimatization of mountaineers or trailers. This training strategy is nowadays also applied to sub-elite and recreational athletes. At the beginning, only endurance sports were concerned, then collective team and/or racquet sports start using hypoxic innovative interventions in their planning. Hypoxic training was firstly performed in natural high-altitude areas (hypobaric hypoxia) including Iten in Kenya, Prémanon in France, Crans-Montana in Switzerland, or Colorado Springs in United States. A variety of artificial altitude environment equipment (normobaric hypoxia), such as hypoxic tents or altitude centers, have been developed, since 1990. Although substantial differences exist between these modalities of hypoxic training, both have interesting characteristics, which can be used to enhance performance. To date, several forms of hypoxic training and/or altitude strategies exist: traditional "live high-train high," contemporary "live high-train low," or "live low-train high" approaches. Living High Training High (LHTH) method means living and training in a terrestrial (hypobaric hypoxic) environment at moderate altitude (1500–3000 m), between 2 and 4 weeks. The acclimatization phase lasts 7–10 days. During this period, high intensity exercise is not recommended. Then primary training phase is used to increase the intensity of training. The final phase lasts 2–5 days. The training volume and intensity are gradually reduced. The aim of this phase is to recover from the altitude-induced fatigue. On return to sea level, three phases are usually observed by coaches, not fully supported by the scientific evidence. A first positive phase

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for some athletes, during 2–4 days, followed by a phase of reduced performance fitness. Most of athletes reach their peak performance 15–21 days after return to sea level. The Living High Training Low (LHTL) strategy offers athletes the beneficial effects of altitude acclimatization, without the reduction of training intensities (e.g. running speed), which is the limitation of the LHTH design. Athletes use living and sleeping at moderate altitude (1800–2500 m) and performing training below 1000–1300 m. Training at low altitude allows athletes to train at exercise intensities that are similar to sea level, thereby inducing beneficial neuromuscular adaptations via sufficient physiological stimuli. For sleeping, the athlete can choose between natural altitudes or use artificial altitude in order to reduce the amount of stress and fatigue because of traveling to and from training sites. Several devices allow athletes to sleep in normobaric hypoxia, via nitrogen dilution (hypoxic room or apartments) or oxygen extraction (tents). At least 10–12 h per 24 h have to be spent in a low oxygen environment to have a positive result. The beneficial effect is observed after at least 4 weeks of training twice a week and appears to be maintained over a period of 3 weeks. Last, in "Living Low Training High method" (LLTH), athletes live near sea level and are exposed to short intervals of hypoxic training. Since some years, the traditional "intermittent hypoxic training" has been replaced by another model, so-called repeated-sprint training in hypoxia (RSH). This method is based on the repetition of short maximal exercise intensity (<30 s) with short incomplete recoveries. Larger maximal repeated sprinting performance improvement and fatigue resistance in normoxia is observed, without any significant stimulation of the erythropoietic pathway. Rather, its efficacy relies on specific skeletal muscle tissue adaptations mediated by an oxygen-sensing pathway (i.e., hypoxic-inducible factors) likely to be fiber-type specific. This attribute is considered important to various intermittent activities (e.g., rugby, soccer, Australian football, ice/field hockey, tennis). The proper training conditions (frequency and duration of exposure, altitude of training, exercise intensity) of a hypoxic training protocol is nowadays still debated. The positive effects of the method are certainly also dependent on sport event altitude, performance level, support of nutrition, and physical and psychological state of subject.

63.2 Physiological Adaptations and Risk

Regarding human physiology, the most important environmental factors at natural high-altitude are low atmospheric oxygen concentration and low barometric pressure. The body's first response to high-altitude low oxygen concentration is a ventilatory response triggered by carotid body receptors. Other compensatory changes include increased heart rate, cardiac output, and blood pressure. At an early stage of acclimatization, the renal system responds by excreting bicarbonate and conserving hydrogen ions (altitude-induced diuresis). Increase of hemoglobin mass reflects an important physiological adaptation to exposure at altitude. Among peripheral adaptations, there is an improvement of exercise economy. This might come from a decreased cost of ventilation, greater carbohydrate use, or more likely from improved mitochondrial efficiency. Better lactate exchange and removal and, consequently, a slower pH decrease within "glycolytic" exercise is also observed. Improving of muscle buffer capacity is another adaptive response to altitude. Post-altitude improvement in performance is apparently the result of hematological and peripheral adaptations, and not necessarily associated with an increase in VO_{2max} in elite athletes. In the case of a competition in high-altitude locations, athletes may experience rapid ascent in altitude, which places them at high risk for developing altitude illness. Risk factors for developing high-altitude illness include previous episodes of high-altitude illness, a faster rate of ascent, higher elevation, poor hydration, increased intensity of physical activity, and individual variability. Slow ascent to altitude is the hallmark of prevention for all acute high-altitude illnesses. Guidelines recommend that under 3000 m, altitude should be increased at a rate of 800 m per 24-h period; above 3000 m the rate of 400 m per 24 h period should be respected. Duration of an effective acclimatization also depends on the athlete's residing altitude and the altitude to which the athlete plans to ascend. Physicians of athletic teams traveling to relatively high-altitude locations (e.g., Denver at 1610 m and South Africa 800–1600 m) should be familiar with prevention and management of altitude sickness as well as special considerations for specific conditions and populations. If possible, early arrival to the event is highly recommended, and the medical team should discuss the importance of adequate hydration and caloric intake for better performance.

63.3 Preparation

The first step in the preparation is to evaluate the athlete's sporting practice and especially to check his training schedule. Indeed hypoxia training can never save an inadequate overall planning. The next step will be to evaluate the athlete's hypoxia experience: if in doubt, a hypoxia test should be performed according to Richalet's method, and some contraindications will be systematically sought. In case of intolerance to hypoxia, protocol needs to be adapted, and sometimes, the athlete will not follow hypoxia training. The last step will be a nutritional assessment: iron balance and micronutrients will be systematically checked.

63.4 How to Perform

Whatever the intermittent hypoxic training protocol applied, a period of 4–6 weeks of training is recommended. To be beneficial for performance improvement, sufficient previous volume in fundamental endurance is a prerequisite. Hypoxic training fits into the overall schedule without replacing it. Two protocols are frequently used. The first is the single use of the RSH (twice a week) with two different schools. The first focused on endurance sports and offers hypoxia 30 min sessions remaining in the second respiratory threshold (Hoppeler protocol) for 6 weeks. In this case the authors announce a 35% increase in VMA support time. The second school focused more on team sports or more generally on sports where there are sprint phases, proposes repetitions alternating phase at very high intensity (6–10 s), and recovery phase (20–30 s), for 4 weeks. The results are also positive with effects rather focus on increasing the number of repetitions and increased technical skills and the total power. During the RSH sessions, a medical presence seems to be essential. The second type of protocol combines RSH and LHTL (LHTLHi) as proposed by G. Millet and L. Schmitt. Note that in the LHTL, it is advisable to plan two nights at low altitude every 5–6 nights. It seems that the latter still improves performance for intermittent sprint sports and even endurance sports, with a focus on high-altitude competitions or competitive pre-acclimatization for a very high-altitude project. Since 2018, at the Emmanuel Cauchy SportAltitude Center, a variant of the Hoppeler protocol is applied (alternation of 10-min phases at the second hypoxia respiratory threshold and 3–5 min recovery phases in normoxia), with similar results on the limit time at VMA.

63.5 Recovery

Hypoxia training imposes a recovery period. These sessions will be scheduled in the precompetitive period, 5–6 weeks before a major goal. Apart from the LHTLHi protocol when the recovery is done in normoxia, some propose to add hypoxia recovery sessions as in the Metab Clean protocol. The recovery will also be linked to dietary and fluid balance during the protocol phase. It will therefore be necessary to be attentive with the need for the use of bio impedance.

63.6 Risks and Pitfalls for Athletes

Beneficial results after training in altitude are not always guaranteed. The positive effects are related to an individual response and to multiple factors. First requirement is to associate altitude training with a high volume of training at low intensity at sea level (normoxia). The protocol has to be specific for the type of sport and the athlete. A proper acclimatization is important for those remaining in high altitude (e.g., training camp of several weeks).

63.7 Fact Box

In all cases, the RSH is effective even in terms of pre-acclimatization. There should be two sessions per week for 4–6 weeks and 5–6 weeks before the goal. Coupled with LHTL, the results look better, but this protocol is not available to all. The risks are there, and RSH sessions require the presence of a doctor. The subject must pass an initial visit, and the slightest doubt carries out a test according to the method of Richalet.

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