Canadian Academy of Sport and Exercise Medicine Position Statement: Athletes at High Altitude

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Abstract: Many sports incorporate training at altitude as a key component of their athlete training plan. Furthermore, many sports are required to compete at high altitude venues. Exercise at high altitude provides unique challenges to the athlete and to the sport medicine clinician working with these athletes. These challenges include altitude illness, alterations in training intensity and performance, nutritional and hydration difficulties, and challenges related to the austerity of the environment. Furthermore, many of the strategies that are typically utilized by visitors to altitude may have implications from an anti-doping point of view. This position statement was commissioned and approved by the Canadian Academy of Sport and Exercise Medicine. The purpose of this statement was to provide an evidence-based, best practices summary to assist clinicians with the preparation and management of athletes and individuals travelling to altitude for both competition and training.

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INTRODUCTION

Sojourns to altitude for training, competition, or recreational activity have become increasingly common over the past 25 years. Along with all the positive experiences one can have at altitude, there remain inherent challenges to altitude itself. Lower ambient oxygen and increased radiation can have negative impacts on both health and performance. Individuals at altitude are more susceptible to a compromised immune system, increased levels of fatigue, malnutrition, and overtraining. Therefore, the purpose of this position statement is to examine the various conditions affecting health and performance at altitude and to present strategies for appropriate prevention and management.

As a reference point for this paper, classifications of altitude will follow those described by Bärtsch et al,[1] (Table 1). The extent of impact and degree of acclimatization will depend not only on the altitude visited but, more importantly, the overall hypoxic dose.[2,3] Both in the literature and anecdotally, individual responses to altitude are highly variable and dependent on several factors including fitness level, chemosensitivity to hypoxia and ventilatory responses, the oxygen carrying capacity of the blood, nutritional habits, fatigue and recovery status, genetics, and previous exposure to altitude.

For each of the topics discussed in this paper, relevant searches were performed using PubMed, Medline and Google Scholar. Priority was given to more recent studies and those that used more rigorous study design.

HEALTH CONSIDERATIONS

High Altitude Illness

The term altitude illness refers to a series of conditions that can affect visitors to altitude. The main cause of these conditions is the low ambient oxygen (hypoxia) that is brought about by the low atmospheric pressure at altitude. There is some controversy over whether the hypoxia alone is the stimulus, or the hypobaria (low pressure) associated with altitude is also a contributor.[4] Some studies have shown that the incidence and severity of illness may be worse in hypobaric hypoxic conditions than in normobaric conditions;[5–7] however, these results are preliminary and controversy persists.[4]

The 3 main conditions that are discussed in this paper are acute mountain sickness (AMS), high altitude cerebral edema (HACE), and high altitude pulmonary edema (HAPE). Acute mountain sickness and HACE are likely the same syndrome but represent different ends of the severity spectrum.[8] Both conditions are characterized by headache, nausea, dizziness, gastrointestinal symptoms, and insomnia. Additionally, HACE is characterized by ataxia and altered level of consciousness or even coma. These conditions typically occur within the first 24 hours at a new altitude, and often present in the morning on waking. Acute mountain sickness is generally a self-limited condition, whereby it will gradually resolve over 24 to 48 hours with no further gain in altitude. Once the symptoms have resolved, further ascent can be attempted. Although AMS is not typically life-threatening, it has the potential to adversely affect athletic performance, especially when there are gastrointestinal symptoms, which can affect both hydration and nutrition. As compared to AMS, which is usually self-limited, HACE is always a medical emergency and should be managed aggressively and immediately.

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TABLE 1. Definitions of Levels of Altitude

Altitude (Above Sea Level)	Definition
0–500 m	Near sea level
Above 500 m–2000 m	Low Altitude–minor impairment of aerobic performance becomes detectable
Above 2000 m–3000 m	Moderate Altitude—altitude illness starts to occur and acclimatization becomes increasingly important for performance
Above 3000 m–5500 m	High Altitude—altitude illness and acclimatization become clinically relevant, performance considerably impaired
Above 5500 m	Extreme Altitude—prolonged exposure leads to progressive deterioration

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High altitude pulmonary edema is a separate condition, usually talking longer to occur (2-5 days) and primarily affecting the lungs. Patients present with dyspnoea, cough, hemoptysis and poor exercise tolerance. Like HACE, HAPE should also be treated as an emergency. Acute management of these conditions is not the focus of this position paper, but for more information on acute treatment of these conditions, refer to the Wilderness Medical Society's consensus paper on the treatment of altitude illness.[8]

General Precautions

Acclimatization

Ascent rate to altitude is a key determinant of risk for AMS. Areas where a very rapid ascent rate is possible (such as Mauna Kea in Hawai'i) have a much higher incidence of AMS than areas where a long gradual trek is essentially the only way to get to high altitude.[9] Thus, if possible, planning enough time to slowly acclimatize to the training or competition altitude will be the most effective way to reduce risk of altitude illness. The general recommendation for ascent rate is that at altitudes above 3000 m, individuals can ascend by 300 to 600 m/d with a rest day for every 1000 m gained.[8,10]

Past History

Individuals who have had an altitude illness in the past may be at higher risk of getting the illness again upon return to altitude.[11] As such, clinicians working with these athletes should consider taking extra precautions for these individuals (close monitoring, slower acclimatization, prophylactic medication, etc).

Hydration and Nutrition

At altitude, hydration can be a challenge, insensible losses are increased, and safe water can be hard to come by. Not only can dehydration impair athletic performance, the symptoms of dehydration can mimic or exacerbate those of AMS.[8] Coaches and athletes traveling to altitude should thus anticipate and plan for the challenges of finding safe fluids and maintaining euvolemia while at altitude.

In terms of diet, a high carbohydrate diet has long been recommended due to the theoretical potential for a relative increase in ventilation on a high carbohydrate diet over a low carbohydrate diet. Although it has not been shown to reduce the risk of AMS,[12] there is some evidence that a high carbohydrate diet can improve oxygenation and exercise performance at altitude;[13] therefore, for the performance benefits alone, a high carbohydrate diet should be encouraged in athletes visiting altitude.

Medications

Acetazolamide

Acetazolamide (Diamox) is the most well-known and commonly used medication for the prevention of acute mountain sickness. It is a carbonic anhydrase inhibitor, and in the context of altitude illness, works by lowering the pH of the blood, leading to an increase in minute ventilation and oxygenation. As a diuretic, it is a banned substance according to the World Anti-Doping Agency (WADA), and should not be taken by athletes who are part of an anti-doping program. The recommended dosage of acetazolamide is 125 mg po bid[8] and should be commenced on the day before ascent to altitude. Acetazolamide has a variety of common adverse effects, which can be distracting for athletes who are taking these medications. These include nausea, tingling, altered taste, and even dizziness and headache.

Dexamethasone

Dexamethasone is a second-line pharmaceutical used in the prevention of AMS/HACE. The prophylactic dose is 2 mg po qid. As with acetazolamide, dexamethasone is a banned substance in sport.

Unlike acetazolamide, there is some evidence that dexamethasone can reduce the risk of HAPE,[14] and can be used as a preventative agent for both syndromes. For HAPE prevention, the recommended dosage is 4 to 8 mg po bid, and it has been shown to increase exercise capacity in HAPE-susceptible individuals.[15] Since it is not a permitted substance during competition, its utility is likely limited in athletes, and due to adverse effects should be taken for short periods of less than 5 days where possible.[16]

Ginkgo Biloba

The evidence on the utility of Ginkgo Biloba for AMS/HACE prophylaxis is conflicting.[8] Furthermore, with competitive athletes, supplements such as Ginkgo are less regulated than pharmaceuticals and more likely to contain banned substances. Thus, with the questionable benefit and chance for inadvertent doping violation, Ginkgo Biloba is not recommended as a preventative agent in athletes.

Ibuprofen

Ibuprofen has long been advised for the symptomatic treatment of mild AMS; however, a recent study has proposed that it may be effective in the prevention of AMS. In a small trial there was a possible decrease in AMS incidence and severity in the group who had taken 600 mg po 6 hours before ascent.[17] Ibuprofen is a permitted substance that does not affect exercise performance, and is commonly taken by competing and training athletes.

Nifedipine

Nifedipine has long been used in the prevention of HAPE in susceptible individuals. It is not a banned substance in elite sport, but it does affect exercise performance, either by increasing heart rate or lactate levels, as well as decreasing peak performance, all deleterious effects for athletes.[18,19]

Salmeterol

Salmeterol has been shown in one study to reduce incidence of HAPE in susceptible individuals.[20] It has not been compared to the other prophylactic agents, so relative efficacy is unknown. Beta agonists, despite extensive research do not have any demonstrable effect on exercise performance in healthy athletes.[21,22] It is currently a permitted substance, but the status of beta-agonists seems to change frequently, so clinicians need to confirm its doping status before prescribing.

Tadalafil

It appears that tadalafil (10 mg po bid) can be effective to prevent HAPE in susceptible individuals.[14] There is some evidence that sildenafil, a similar medication to tadalafil, can improve exercise performance at altitude,[16,23] but not convincing evidence that the same is true for tadalafil.[14,24] Currently, tadalafil is a monitored substance by WADA, but this status may be subject to change; therefore, it is recommended that prescribing clinicians confirm its status before prescribing.

In summary, there is no ideal prophylactic medication for athletes traveling to altitude. Our recommendation would be that other measures be employed such as gradual acclimatization, hydration, and diet. Where possible a prophylactic dose of ibuprofen can be taken and symptoms of mild AMS can be managed with ibuprofen. If a moderately or severely ill athlete requires more aggressive treatment, acetazolamide and dexamethasone can be used, with the understanding that these medications will disqualify the athlete from competition. Based on their lack of deleterious effects on exercise performance, and their current permitted status, salmeterol or tadalafil would be the recommended medication of choice in HAPE-susceptible athletes training or competing at altitude. For individuals for whom doping considerations are not relevant, again the conservative measures should be maximized, but if the individual has an increased risk of altitude illness due to intrinsic factors (such as previous history) and extrinsic factors (aggressive ascent profile), prophylactic medications may be appropriate.

Ultraviolet Radiation

Ultraviolet (UV) radiation is a well-known occupational hazard that is associated with skin cancer, cataracts,[25] and immunosuppression. Outdoor sporting events, such as professional cycling,[26] long-distance triathlon,[27] and climbing at very high altitude (>4500 m)[28] expose participants to large doses of ultraviolet radiation. It is greatest in equatorial, high altitude, shadeless, and decreased ozone regions. Ultraviolet A (UVA) and ultraviolet B (UVB) radiation increase between 11% and 19% per 1000 m of elevation.[29] Dosage is especially high during summer months and from 10 AM to 2 PM. Additionally, high altitude areas are covered with snow, which is highly reflective of UV light. The albedo (ratio of reflected radiation off a surface) and changes in the incident angle of radiation increase exposure. Consequently, there is an increased incidence of cutaneous melanoma[30] and seborrheic dermatitis[31] in high altitude residents and mountaineers, respectively.[28,31]

Barrier protection includes shelter, sunglasses, clothing, and sunscreen for UVA and UVB rays with at least a Sun Protection Factor (SPF) of 30. However, not all clothing provides equal sun protection, and some may be inadequate.[32] For example, polyester is more protective than cotton, and many fabrics only provide protection equivalent to an SPF 15 sunscreen.[33] Sunglasses are designed to protect the eyes from axially-oriented UV radiation; however, they do not offer protection from peripherally incident or reflected rays. Ski goggles provide the best total protection of the eye.[34] There are concerns that sunglasses (especially those without UV protection) may increase cataract rate because of resulting pupil dilation from less squinting.[35] Strategies to minimize UV radiation are outlined in Table 2.

Immunosuppression

On its own, UV radiation is an immunosuppressant. The amount of UV radiation required to affect the cellular and humoral immune systems ranges from the minimal erythemal dose [1MED (250 J/m^2)]—minimal dose required to cause erythema in Fitzpatrick II skin) to chronic accumulative doses.[36] The consequences are increased susceptibility to infection (viral, bacterial, parasitic and fungal),[37] carcinogenesis, and decreased allergic and immune response. Since sunscreens may not prevent UV-induced immunosuppression,[38] it is recommended that the athlete use physical barriers or avoidance from the sun. As mentioned above, not all clothing is UV protective, and there

TABLE 2. Strategies to Decrease UV Exposure

Strategy	Comment
Minimize sun exposure	Especially 10 AM to 4 PM
Sun protection	Wrap-around sunglasses with UVA and UVB block
	Tightly-woven clothing with UV protection
	Hat with brim
Sunscreens	At least SPF 15 with UVA and UVB block (SPF 30 or higher in mountainous or polar regions)
	Consider zinc oxide creams for mountaineering
	Skin and lips, inside nose (reflection off snow, water, asphalt, sand)
	Reapply every 2 h, even on cloudy days
Artificial Tanning	Avoid
Education	Sun safety education for coaches, athletes, and physicians
	Be aware of UV index and strategies to minimize sun exposure on high UV index days (train indoors or in the shade)
Policy	Organized athletic training facilities to have sun-protected areas

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UV, ultraviolet; UVA, ultraviolet A; UVB, ultraviolet B; SPF, Sun Protection Factor.

should be thoughtful consideration of its sun protection factor. Sun avoidance is not always feasible in athletic events, trekking, or mountaineering, but it is advised that the participant minimize solar exposure. Exercising under shelter and avoiding exercise at midday are possible strategies.

Athletes who continuously train in hypoxic environments, such as the mountains, are exposed to multiple immunosuppressive factors and, as a result, have higher incidence of infection.[40] Strenuous exercise, especially repeated bouts, is immunosuppressive and is hypothesized to be from the suppression of different components of the immune system.[41–44] Additional factors associated with exertion at altitude, such as pathogen exposure, sleep deprivation, mental stress, malnutrition, weight loss[1,45,46] hypoxia, protein catabolism, and UV exposure[47–50] all compound risk. Ironically, individual factors exacerbate others. For example, hypoxia induces sleep deprivation that exacerbates mental stress. Extended and prolonged exercise at high altitude causes protein catabolism, which exacerbates weight loss,[2,49,50] and these, in turn, are immunosuppressive.

The window for infection is between 3 and 72 hrs following prolonged endurance exercise.[45,51–53] Recommended countermeasures to decrease exercise-induced immunosuppression include adequate nutrition, optimal sleep, avoidance of sick contacts, not overtraining, decreasing mental stress, avoiding rapid weight loss, obtaining the influenza vaccine during the winter, and avoiding self-innoculation by not putting the hands to the nose.[25,45,53]

From a nutrition perspective, carbohydrate beverages may be helpful since they boost the humoral immune system.[44,54] Mice experiments demonstrate that UV-induced damage of the keratinocytes is reversible[27,37] and that the final pathway of UV-induced immunosuppression is from oxidation of cells. Therefore, it is hypothesized that an antioxidant rich diet, including selenium, fish oil, or vitamin E, may be protective.[28,55] However, megadoses of vitamins, fat-rich diets, echinacea, zinc supplements, probiotics, and high dose vitamin C are not recommended.[54]

Immunization

It is recommended that any athlete going to a high-altitude venue in a foreign country follow the recommended travel medicine guidelines for vaccination, and public health hygiene measures. Resources are readily available through the local travel medicine clinic. There are also comprehensive Internet resources, such as the Public Health Agency in Canada (http://www.publichealth.gc.ca) or Centers for Disease Control in the USA (http://www.cdc.gov).[29,56] The sports medicine physician should be aware of the general principles of vaccination since some need to be done 6 months in advance, and can cause myalgias immediately postvaccination. In addition, vaccinations are expensive and often not covered by universal health insurance.

PERFORMANCE CONSIDERATIONS

Preparation (Natural or Simulated Altitude)

Over the last 20 years, there has been considerable attention in the literature given to the effects of both natural and simulated altitude on physiological responses and exercise performance. The primary focus of this research has been on performance at sea level with several review papers available.[3,57] The concept behind altitude training is to expose the athlete to some degree of hypoxia (normobaric or hypobaric) in order to stimulate the acclimation process, resulting in enhanced performance. In this regard, haematological, ventilatory, and muscular (buffering and metabolic efficiency) adaptations are most likely to have an impact on sea-level performance.

It is well accepted that the best option to optimize performance is to provide sufficient time for acclimatization to the altitude where the activity will take place. The precise amount of time will depend on the competition altitude (low, moderate, high, or extreme), individual adaptability, and individual susceptibility to AMS. As discussed earlier, rate of ascent is critical in ascents to altitudes over 3000 m, with sufficient time allocated to acclimatization at intermediary points along the way. Furthermore, from a competitive sport perspective, this acclimatization needs to be balanced with maintaining optimal fitness and performance. In sport events at low to moderate altitude, it is recommended that athletes reside at the altitude at which they will compete for roughly 2 weeks prior to competition.[2,28,58–61]

The strategy of live high-train low (LHTL), first introduced by Levine and Stray-Gundersen, requires athletes to reside at an altitude between 2000 to 3000 m while travelling to lower elevations (usually $<$1000 m for less than 3-4 hours per day) to train at higher intensities. This has been shown to be effective at enhancing aerobic performance at lower altitudes; however, its effectiveness as a tool to enhance performance at altitude $>$ 2000 m has not been well researched. Theoretically, this strategy could be used as part of an acclimatization process. Anecdotally, teams and athletes are using this strategy over a period of 7 to 21 days (depending on the altitude and event) upon arrival to minimize impacts and regain sea-level performance for events at moderate altitude and lower. Levine et al[59–61] suggest that for altitudes up to 2500 m, athletes can regain half the performance decrement within 14 days of acclimatization. For altitudes $>$ 4000 m, 6 days of staging at 2200 m was effective at inducing ventilatory adaptations and enhancing exercise performance at 4300 m in moderately trained individuals.[2]

More often than not, use of natural altitude is not always feasible for logistical, geographical, or financial reasons. This has led to the development of numerous devices that provide a hypoxic stimulus (eg, tents, breathing systems, hypobaric chambers). Although the effectiveness of such devices for prolonged or intermittent hypoxic exposures (normobaric and hypobaric) on enhancing performance is controversial, their use is widespread. In turn, this has given rise to the use of various hypoxic strategies to provide a preexposure "dose" in hopes of initiating the acclimatization process prior to going to altitude. In 2008, Gore et al[46] included an analysis of the theoretical basis for such strategies as part of a consensus statement on preparation for football competition at moderate to high altitude. Recently Fulco et al[2] reviewed a series of preacclimatization studies performed by their group to compare the effectiveness of various strategies at preacclimatizing moderately trained individuals to 4300 m. There are 2 primary adaptations that are likely to have the greatest impact determining the effectiveness of a preparation strategy.

Ventilatory Adaptations

On ascent to altitude, lower ambient oxygen pressure results in a lowering of oxygen saturation (SaO_2) in the blood. To compensate for this, the body responds by increasing ventilation as a result of a hypoxic stimulus to the chemoreceptors and this is referred to as the hypoxic ventilatory response (HVR). The resultant improvement in SaO_2 would have significant impacts on recovery, sleep, and exercise performance at altitude. Natural altitude is quite effective at increasing resting ventilatory drive at rest and likewise so is intermittent hypoxia of varying durations.[2,58,60,62] Any increases in HVR at rest, however, may be short lived (<3 days) if the athlete does not go directly to altitude.[61] More importantly, the key is whether or not a change in resting HVR has an impact on exercise ventilation. Katayama et al[63] saw no improvements in exercise ventilation at sea level following 7 days of intermittent hypoxic exposure (IH); however, Townsend et al[61] have shown that after 20 nights of LHTL, increases in exercise ventilation during submaximal exercise at 600 m was correlated with increased HVR at rest. Furthermore, Katayama et al[62] have shown brief exposures to 4500 m for 7 days resulted in enhanced HVR and subsequent SaO_2 during exercise in extreme hypoxia. Whether or not this leads to an enhanced performance is questionable, as early insights provide mixed results.[2,64,65] More well-defined and controlled studies in this area are required.

Hematological Adaptations

Altitude training literature provides us significant insight into the timelines for hematological adaptations. For detailed examinations and comparisons of different training methods, the reader is directed to extensive reviews in this area.[2,3,57,64,65] Gore et al[46] categorize the changes as being either short term (minutes to days) or medium term (days to months). The most recognized beneficial hematological change is an increase in red cell mass; however, this requires significant time (21 + days) at an altitude of greater than 2000 m. Although one early study suggested a positive red blood cell response to IH over 3 weeks,[66] the vast majority of recent studies at rest have failed to show any impact of IH on red cell mass and erythropoiesis.[67,68] Altitude tents and "hotels" at sea level have the potential to induce erythropoiesis; however, the literature suggests that a minimum of 14 to 16 hours per day be spent in the hypoxic environment of 2500 to 3000 m over at least 4 weeks.[3,41] Additional blood-based adaptations include a decreased plasma volume on ascent to altitude and subsequent hemoconcentration, and an increased pH resultant of ventilatory changes previously mentioned. There is little research reporting the efficacy of IH in altering plasma volume.

In summary, the best strategy for preparation to optimize performance at altitude is to allow for acclimatization to occur. This can be enhanced by travelling to lower altitudes or use of supplemental O_2 for high intensity training (LHTL). Although the use of preparatory IH strategies to enhance performance at altitude may provide some benefit, further research is required in this area. Furthermore, potential negative effects of regular IH use that simulate those observed in sleep apnea patients (eg, elevated blood pressure, changes in sympathetic nerve activity) need to be considered.[69] Such strategies may be warranted in elite athletes where changes in performance of less than 0.5% can have a significant impact and there is access to ongoing monitoring from sport science and medicine staff. However, in most other populations, the cost-benefit of IH as a preparation strategy needs to be evaluated on an individual basis and long-term use is discouraged.

Nutrition

There are 2 primary nutritional concerns athletes should be aware of that may impact performance at altitude: maintaining hydration and the need for iron. Athletes are encouraged to ensure they are drinking sufficient fluids while at altitude due to the tendency for hypohydration. On exposure to altitude, there is a drop in plasma volume leading to a lower cardiac output and, in part, maximal aerobic power. Not being adequately hydrated can further exacerbate the negative impacts of hypoxia. Castellani et al[70] demonstrated that being hypohydrated reduced cycling time-trial performance by more than 2-fold versus euhydration in hypoxia. The impacts can be even more detrimental in warm climates where thermal stress may be a factor. Due to the strong demand on erythropoiesis at moderate altitude and higher, the importance of iron cannot be understated. It is recommended that athletes are screened for appropriate serum ferritin levels 8 to 10 weeks prior to going to altitude, allowing sufficient time for supplementation under the direction of a physician if needed.[71] It is also common practice to recommend athletes increase dietary intake of iron through various foods.

Sleep Hygiene

Proper rest is important for athletes training and competing, especially while traveling. While at altitude, sleep quality is reduced; the athlete will notice more frequent arousals and an increased prevalence of periodic breathing.[72] Poor sleep quality can be further aggravated in the presence of jet lag. Primary management of poor sleep on trips to altitude should involve an effective regimen of sleep hygiene.[73]

Effective sleep hygiene in the traveling athlete would include an environment that is quiet and dark, and at a comfortable temperature. Athletes should avoid caffeine, nicotine, and alcohol, as they all decrease sleep quality. Sleep is enhanced with exercise in the late afternoon or early evening,[73] so training schedules should be adjusted accordingly. A light bedtime snack can improve sleep by staving off hunger.

Jet lag should be aggressively managed.[56] Typically it takes 1 day per time zone to fully acclimatize. A few days prior to departure, athletes can start shifting their sleeping time. Travel should be arranged to improve acclimatization to the new time zone. Once the aircraft is boarded, the travellers should adjust their time-keeping devices to the destination time zone and to try to behave as if they are already at the destination time zone.[74] Sleep should be encouraged during long overnight flights. If layovers occur during the day, athletes should, if possible, have a period of activity, preferably in the presence of natural daylight. For a more detailed program of managing jet lag, refer to the Position Statement for the European College of Sport Science on Coping with Jet Lag.[74]

If sleeping medications are necessary while traveling to altitude, there is a theoretical risk of respiratory depression from the medication worsening night-time oxygenation and increasing the risk of altitude illness. Of all sleeping medications, temazepam, zaleplon, and zolpidem are the best studied in the context of altitude.[74] Nickol et al,[75] showed that temazepam (10 mg po qhs) reduced the frequency of periodic breathing during sleep. The temazepam also decreased mean arterial oxygen saturation to 76% in the experimental group as compared with 78% in the placebo condition. Despite the decrease in oxygenation, there were no deficits in cognitive performance on the subsequent day. At the time of writing, temazepam is neither banned nor monitored by WADA. In some countries (such as Canada, and the United States) the 10 mg dose is not available, so 7.5 or 15 mg is recommended as an alternative.[72]

Alternatively, zaleplon and zolpidem (10 mg of each) have been shown to improve sleep quality at altitude without affecting nocturnal oxygenation and without impairing cognition the following day.[76] One identified concern with these medications is the increased prevalence of disordered sleeping behaviors such as somnambulation, which may be particularly hazardous in the mountain environment.[72] If this is not a concern, these medications may be a suitable alternative to temazepam. At the time of writing, neither agent is banned by the WADA.

Acetazolamide has already been discussed in the prevention and treatment of acute mountain sickness, but it also has a role in improving sleep quality at altitude. As with temazepam, acetazolamide has been shown to decrease the amount of time spent in periodic breathing and to increase arterial oxygenation during sleep.[77,78] The recommended dose of acetazolamide for improving sleep quality is 125 mg po qhs.[72] There are 2 potential downsides to using acetazolamide to improve sleep in athletes: its action as a diuretic and its doping status. Acetazolamide is a mild diuretic, and although it has been shown to improve sleep quality at altitude,[78] if it predisposes the athletes to nocturia, sleep could be interrupted as a result. A typical recommendation is to take this medication at dinnertime, a few hours before bed, in order to allow time for diuresis prior to sleep. As acetazolamide is a diuretic, it is currently banned in and out of competition by WADA. As such, its use is inappropriate in athletes competing and training under the provisions of WADA.

In summary, athletes travelling to altitude for training and competition are at risk for poor sleep quality as a result of both jet lag and the altitude itself. Proper preparation includes anticipation and pretrip management of jet lag, implementation of good sleep hygiene practices, and if necessary, sleep medications such as temazepam, zolpidem, zaleplon, or acetazolamide may be prescribed.

Training while at Altitude

Perhaps the biggest challenge for athletes while at altitude is maintaining a level of fitness and performance while minimizing fatigue and illness. This task becomes increasingly difficult as the altitude increases for 3 primary reasons: increased physical stress due to hypoxia, longer recovery times and poor sleep, and the inability to maintain exercise intensity during training. The guiding principle when training at altitude is to respect the altitude. There is a tendency for athletes to want to do too much too soon. Although modifications to training should be done on an individual basis, best practice recommendations in sport are to reduce training volumes up to 50% and minimize high intensity training time in the first 3 to 7 days at moderate altitude and longer at higher altitudes. Both intensity and volume can be gradually tapered back into training as acclimatization at 2000 to 3000 m allows near sea-level performances at 10 to 14 days.[59] Where possible in the first 2 weeks, intensity work should be done at lower elevations (<1500 m) or include the use of supplemental oxygen to simulate lower altitude and promote O_2 transport and utilization.[49] In either of these situations, additional recovery time should be planned to ensure adequate recovery from an increased relative training load. The use of supplemental oxygen can be used to enhance recovery between training intervals and sessions.

CONCLUSIONS

For individuals travelling to train, compete, or otherwise exercising at altitude, there are a variety of important precautions to take to minimise morbidity and maximise performance. The most important consideration would be to maximise acclimatization through early arrival and gradual ascent to higher altitudes. Altitude visitors can consider prophylactic medications if at increased risk of altitude illness, but competitive athletes must be mindful of doping considerations. At the same time, optimization of nutrition, hydration, and sleep quality are important adjuncts. Altitude exercisers need to prepare for and mitigate UV and immunosuppression. If training at altitude, where possible, the use of lower altitude exercise or supplemental oxygen to mitigate the performance decrement is encouraged.

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