REVIEW ARTICLE

Wilderness and Adventure Travel With Underlying Asthma

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Given the high prevalence of asthma, it is likely that providers working in a pretravel setting will be asked to provide guidance for asthma patients about how to manage their disease before and during wilderness or adventure travel, while providers working in the field setting may need to address asthma-related issues that arise during such excursions. This review aims to provide information to assist providers facing these issues. Relevant literature was identified through the MEDLINE database using a key word search of the English-language literature from 1980 to 2013 using the term “asthma” cross-referenced with “adventure travel,” “trekking,” “exercise,” “exercise-induced bronchoconstriction,” “high-altitude,” “scuba,” and “diving.” We review data on the frequency of worsening asthma control during wilderness or adventure travel and discuss the unique aspects of wilderness travel that may affect asthma patients in the field. We then provide a general approach to evaluation and management of asthma before and during a planned sojourn and address 2 particular situations, activities at high altitude and scuba diving, which pose unique risks to asthma patients and warrant additional attention. Although wilderness and adventure travel should be avoided in individuals with poorly controlled disease or worsening control at the time of a planned trip, individuals with well-controlled asthma who undergo appropriate pretravel assessment and planning can safely engage in a wide range of wilderness and adventure-related activities.

Key words: asthma, β -agonists, corticosteroids, high altitude, scuba diving

Introduction

Asthma affects an estimated 300 million people worldwide,¹ and is considered one of the world’s most common chronic health problems. In the United States alone, 26 million people or roughly 8.2%² of the population have been diagnosed with asthma, with further increases expected in the future. With the large number of individuals traveling into wilderness settings for work and pleasure, and the high prevalence of the disease among young people (60% of all asthmatics are younger than 45 years old),² it is likely that providers who advise patients planning wilderness travel or practice medicine in the wilderness will be asked to provide pretravel advice regarding asthma management in the field or address asthma-related problems that develop during a sojourn.

The purpose of this review is to provide practitioners a framework for approaching the asthma patient in these situations. We begin by considering the frequency with which asthma patients experience worsening control during wilderness or adventure travel. We then described unique aspects of wilderness travel with the potential to affect disease control and provide a general approach to both pretravel evaluation and the assessment and management of asthma during planned wilderness activities. We conclude by addressing 2 particular wilderness situations, high altitude travel and scuba diving, which pose unique risks to asthma patients and warrant more specific attention. A general overview of the pathophysiology and management of asthma is beyond the scope of this review. Readers interested in this topic may refer to several excellent reviews on these topics.^{3,4}

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Asthma Exacerbations During Wilderness Activity

Perhaps the greatest concern regarding wilderness or adventure travelers with asthma is the possibility they

will develop disease exacerbations while away from access to medical resources. Several studies provide information on the extent to which such problems are seen in the wilderness setting. Separate reviews of National Outdoor Leadership School (NOLS) records indicate that 1.9% to 2.1% of reported medical incidents were attributable to asthma,^{5,6} whereas a review of medical incidents from 2003 and 2007 in Shenandoah National Park indicated that 3.5% of reported medical incidents were related to asthma exacerbations.⁷ Data from various types of adventure races suggest between 1% and 6% of participants in such races develop symptomatic asthma requiring medical attention.^{8–10} Comparing data among these studies is challenging as the nature of the activities and the environments in which they are conducted vary among studies and may affect the degree of asthma control.

Only a single prospective study has specifically addressed the extent to which asthmatics experience worsening asthma control during adventure travel. Golan et al¹¹ screened 5835 patients and subsequently identified 203 individuals with asthma who presented to a travel clinic before a planned sojourn. Forty-three percent reported an exacerbation during their trip, and of these individuals, 37% experienced the “worst asthma attack of their life” and 13% reported a life-threatening attack. Risk factors for worsening control included frequent (>3/wk) use of inhaled bronchodilators before the journey and participation in intense physical exertion during trekking. Together with the studies described above, these results suggest that worsening asthma control does occur during a range of activities in the wilderness, and medical providers dealing with patients engaged in such activities should be prepared for this possibility.

Features of Wilderness or Adventure Travel With Potential to Affect Asthma Control

Several features of wilderness and adventure travel have the potential to affect asthma control in either a positive or a negative manner and warrant consideration during the pretravel assessment.

EXERCISE

A common feature of many forms of wilderness and adventure travel is that they involve exercise ranging from mild to severe in intensity. This is important in the context of asthma management as large numbers of asthma patients report exercise as a trigger for worsening disease control. Fifty-four percent of patients reporting to an emergency department¹² and 41% of the travelers in a travel clinic,¹¹ for example, identified exercise as a trigger for asthma symptoms. Even among the general population without asthma, a significant proportion have

an entity known as exercise-induced bronchoconstriction (EIB), defined as reversible airways obstruction triggered by physical exertion or forcible inhalation of dry cool air.^{13,14} Sonna et al,¹⁵ for example, reported that 7% of military recruits undergoing basic training manifested evidence of EIB, whereas prevalence rates as high as 35% have been reported in figure skaters.¹⁶

ALLERGEN EXPOSURE

For many patients, exposure to environmental allergens has a significant impact on symptom control. Fifty-four percent of emergency department patients and 25% of travel clinic patients in the studies noted above identified allergens as a trigger for their exacerbation.^{11,12} Such individuals may be at risk for worsening control with wilderness or adventure activities if their itinerary involves travel into regions with a greater allergen burden, such as springtime travel into areas with high pollen counts. In some cases, however, wilderness travel may actually decrease allergen exposure. At high altitude, for example, the burden of dust mites, a common trigger for many patients, is decreased owing to the lower humidity and other environmental factors and has been associated with outcomes such as decreased airway reactivity to methacholine and histamine challenge.¹⁷

AIR POLLUTION

Because wilderness and adventure activities are typically conducted outside an urban environment, it would seem reasonable to expect that participation in such activities would involve travel into areas with better air quality and less risk of worsening symptoms. This may not always be the case, however. Adventure travel, for example, frequently requires passing through major international cities such as New Delhi, Bangkok, or Kathmandu, which are notorious for poor air quality. Even in mountainous regions, asthmatic patients may be exposed to poor air quality, as mountain valley systems can trap moisture and air pollution from remote urban settings.¹⁸ In addition, along many major trekking circuits, yak dung and other biomass fuel sources are commonly used in stoves and heaters in local lodges, leading to poor local air quality in the early morning and early evening hours when use of such stoves is at its highest. Indoor air pollution may also be a problem in some regions if stoves in lodges or teahouses are not well ventilated to the external environment.¹⁹

CHANGES IN AIR TEMPERATURE

As with exercise, a significant proportion of asthma patients report cold air as a symptom trigger.^{11,12} Other

studies have also documented a high prevalence of asthma symptoms and EIB in cross-country skiers and ski mountaineers, 2 groups of individuals whose activities involve sustaining high levels of minute ventilation in a cold environment.^{20,21} Given that a significant amount of wilderness and adventure travel occurs in the winter months or may involve exposure to colder temperatures at higher elevations, this should be seen as another potential risk to asthma patients in the wilderness.

Pretravel Evaluation and Planning

Practitioners should perform 2 primary tasks when asthma patients present for pretravel evaluation: 1) assess the adequacy of asthma control, identify potential risk factors for exacerbation, and adjust the medication regimen accordingly; and 2) establish a plan for monitoring symptoms and responding to worsening control during the sojourn.

ADEQUACY OF CONTROL, RISK FACTOR ASSESSMENT, AND MEDICATION ADJUSTMENTS

A key principle of wilderness and adventure travel with asthma is that the disease should be under good control before starting travel. The degree of control can be assessed in an objective manner using a classification scheme outlined in the National Heart, Lung, and Blood Institute's Asthma Education and Prevention Program Expert Panel Report (Table 1).³ This takes into account a variety of markers of asthma control including the frequency of short-acting bronchodilator use, which, as noted earlier, was identified as a risk factor for worsening asthma control during adventure travel.¹¹ In patients

deemed "not well-controlled," medication adjustments can be considered before the planned sojourn according to the stepwise approach outlined in published guidelines.³ Patients might, for example, start or increase the dose of inhaled corticosteroid or consider use of alternative agents such as a leukotriene receptor antagonist. Importantly, long-acting bronchodilators such as salmeterol or formoterol should not be added as a sole controller medication because of concerns about increased mortality when used as monotherapy in asthma patients.²² The appropriate choice for such patients would be an inhaled corticosteroid. Patients with "very poorly controlled" disease should be counseled against their planned sojourn. If such travel cannot be avoided, medication adjustments should be instituted and evaluated before the planned trip, and a plan for responding to problems during the trip should be delineated (discussed further subsequently).

Medication adjustments can also be considered if the planned activity will expose the traveler to known triggers of his or her disease. Patients with mild or intermittent asthma who are traveling into a region with poor air quality might, for example, consider adding an inhaled corticosteroid, whereas patients with well-documented EIB should consider several alternatives including administration of a short-acting inhaled bronchodilator or a mast-cell stabilizing agent, such as cromolyn sodium, before planned exertion or initiation of daily inhaled corticosteroids or a leukotriene receptor antagonist.^{14,23–25}

Whether to screen patients for EIB is unclear owing to a lack of supporting evidence, but consideration should be given to the above-noted pharmacologic adjustments in patients with documented EIB or those with at least 2 episodes of asthma per week specifically triggered by

Table 1. Simplified categorization scheme for the degree of asthma control

<i>Variable</i>	<i>Well-controlled</i>	<i>Not well-controlled</i>	<i>Very poorly controlled</i>
Symptoms	≤2 days per week	>2 days per week	Throughout the day
Nocturnal awakening	≤2 times per month	1–3 times per week	>4 times per week
Interference with normal activity	None	Some limitation	Extremely limited
Frequency of SABA use ^a	≤2 days per week	>2 days per week	Several times per day
FEV ₁ or PEF	>80% predicted or of personal best	60–80% predicted or of personal best	<60% predicted or of personal best

FEV₁, forced expiratory volume in 1 second; PEF, peak expiratory flow.

Adapted from National Heart, Lung, and Blood Institute, National Asthma Education and Prevention Program. Expert Panel Report 3: Guidelines for the Diagnosis and Management of Asthma: full report 2007. Available at: <http://www.nhlbi.nih.gov/guidelines/asthma/asthgdln.pdf>. Accessed October 16, 2013.

^a Refers to use of short-acting bronchodilators (SABA) for symptom relief and not for pre-exercise use for prevention of exercise-induced bronchoconstriction.

exercise.²⁶ If a decision is made to evaluate for the presence of EIB, testing options include exercise testing with pretest and posttest spirometry and eucapnic voluntary hyperpnea (EVH), with the latter test likely being a more sensitive measure of EIB among elite athletes.²⁷ A more complete discussion of the diagnosis and management of EIB can be found in recently published guidelines on this topic.¹⁴

MONITORING ASTHMA CONTROL AND RESPONDING TO CHANGES DURING THE SOJOURN

In addition to ensuring adequate control before the planned trip, patients should be encouraged to monitor symptoms during their excursion and have a response plan in the event control worsens. Disease activity can be formally monitored using either symptom questionnaires and daily diaries²⁸ or daily peak expiratory flow (PEF) monitoring. The PiKO-1 system, a small, portable device capable of measuring both PEF and forced expiratory volume in 1 second (FEV₁) can be used as an alternative to standard PEF meters.²⁹ While on their sojourn, patients can use a color-coded grading scheme, which compares PEF measurements to a pretravel baseline established during a period of optimal control and guides medication adjustments based on observed changes (Table 2). Failure to improve despite appropriate adjustments or persistent values in the red zone should serve as a warning for the patient to seek definitive care. Individuals using PEF monitoring should be aware that ambient temperature and pressure can cause variation in measured values over time independent of disease activity.³⁰ If there is concern for such variability because of extreme environmental conditions, individuals should focus on PEF trends, rather than absolute values, in conjunction with symptom assessment.

Individuals who experience a severe exacerbation with signs of respiratory distress should receive 60 mg of prednisone or an equivalent corticosteroid dose (repeated daily) and repeated inhalations of a short-acting β -agonist (eg, 2–4 puffs every 15–20 minutes) while plans are made to evacuate the patient. If available, supplemental oxygen and subcutaneous epinephrine (0.3 mL of the 1:1000 mix) should also be considered, with the latter reserved for individuals refractory to prednisone and inhaled bronchodilators. Various expedition companies or organizations with a wilderness medicine focus have protocols for responding to such acute episodes.^{31,32} These protocols have not been studied systematically but provide a reasonable guide for how to approach these situations.

Because the initial response to worsening symptom control typically involves self-administered pharmacologic interventions, asthma patients should travel with a supply of rescue inhalers and oral corticosteroid, in addition to their regular medications. It is advisable to bring a backup supply of medications and store them in a separate location from the primary medical kit in case of loss. The precise amount of oral corticosteroid to carry is not clear and will vary based on the duration of the trip and ease of travel to definitive medical therapy. A 7-day supply of 60-mg prednisone or an equivalent dose of an alternative oral corticosteroid would likely be sufficient in most cases but could be increased in situations of travel into very remote areas with long anticipated evacuation time. Individuals should be instructed to keep their inhalers warm as cold exposure can decrease the delivery of medication.³³ Extreme warm temperatures in the range patients may experience do not appear to affect the function of short-acting β -agonist inhalers.³⁴

Beyond being prepared to respond with pharmacologic interventions, asthma patients should also develop plans to access more definitive medical resources in the event of a severe exacerbation or worsening control not

Table 2. Color-coded scheme for responding to changes observed during peak expiratory flow monitoring

<i>Color</i>	<i>Peak expiratory flow</i>	<i>Plan</i>
Green	>80% of personal best	Continue long-term control medications
Yellow	50–80% of personal best	Continue long-term control medications Add 2 puffs of short-acting β -agonist every 20 minutes and reevaluate in 1 hour If improved back to green zone after 1 hour, continue close monitoring for 1–2 days If not improved, continue above medications and add oral steroids and consider seeking more advanced care
Red	<50% of personal best	Take 4 puffs of short-acting β -agonist and take oral steroids Consider seeking more advanced care

Adapted from the Asthma Action Plan developed by the National Heart, Lung, and Blood Institute. Available at: http://www.nhlbi.nih.gov/health/public/lung/asthma/asthma_actplan.pdf. Accessed October 16, 2013.

responding to appropriate interventions. Local clinics or hospitals and methods for traveling to these resources should be identified ahead of time. When traveling into remote regions, care should be taken to ensure adequate communication options and strong consideration given to obtaining traveler's insurance.

Asthma in Specific Wilderness Settings

Although the issues discussed above apply to asthma patients in a variety of settings, 2 specific activities warrant further consideration: high altitude travel and diving.

HIGH ALTITUDE TRAVEL

Although precise information about the extent to which asthma patients travel to altitudes greater than 2440 m (8000 feet) is lacking, the report by Golan et al,¹¹ in which 72% of the surveyed patients trekked at high altitude, and other recent reports from Tibet and Africa^{35,36} suggest asthmatic patients are engaged in a full spectrum of activities at elevations as high as 6400 m and perhaps higher.

Unique environmental features at high altitude that may affect asthma patients

Hypoxia. The decrease in barometric pressure at high altitude leads to lower alveolar and arterial oxygen tensions. When viewed in isolation from other aspects of high altitude exposure, the effect of hypoxia on airway function is not clear. Some studies show conflicting evidence regarding hypoxia's effect on bronchial responsiveness to methacholine administration,^{37–39} whereas other data suggest hypoxia reduces the airway response to bronchodilators⁴⁰ and potentially reduces sensations of dyspnea and chest tightness after methacholine administration.⁴¹ This last result is concerning in that it suggests asthmatic patients may experience decreased symptoms with worsening asthma control, although this has never been systematically studied at high altitude.

Hypocapnia. Hypoxemia stimulates peripheral chemoreceptors in the carotid bodies, causing an increase in minute ventilation, referred to as the hypoxic ventilatory response. This leads to a decrease in arterial carbon dioxide tension, which may, in turn, affect airway function. Van den Elshout et al,⁴² for example, demonstrated that a 7.5-mm Hg decrease in end-tidal carbon dioxide increased airway resistance and decreased airway reactance, whereas Newhouse et al⁴³ showed that decreasing alveolar partial pressures of carbon dioxide to 20 to 25 mm Hg led to increases in

inspiratory flow resistance and the work of breathing. Although the changes in end-tidal and arterial carbon dioxide experienced by asthmatic patients after ascent will vary from the changes induced in these studies based on the altitude attained and the duration of exposure, these studies do suggest that hypocapnia can impact airway function.

Decreased air density. Air density decreases as one gains elevation and barometric pressure decreases. Theoretically, this may improve airflow obstruction in patients with active asthma, but the issue has never been systematically studied at high altitude. Information on this question can be gleaned by considering the effect of low-density helium-oxygen mixtures (heliox) in nonintubated patients with asthma exacerbations. The density of a heliox mixture including 80% helium and 20% oxygen is 0.428 g/L, much lower than the density of ambient air at sea level (1.29 g/L). Although various studies show this intervention leads to improvements in subjective dyspnea,⁴⁴ spirometry parameters such as FEV₁ and PEF,⁴⁵ and delivery of nebulized solutions to the lower airways,⁴⁶ systematic reviews have yet to show any significant benefit on patient outcomes.⁴⁷ The lack of benefit is important as the density changes seen at altitudes visited by most adventure travelers are actually lower than that experienced with heliox. At an altitude of 5500 m, for example, where the barometric pressure is on average about one half of what it is at sea level, air density is 0.645 g/L, still higher than that of heliox. Given the lack of clear benefit from heliox at sea level, it is likely that the milder density changes at altitude will not exert significant clinical effect.¹⁹

Outcomes in the field

In many of the studies noted above, the effect of a single variable is isolated from other factors. When asthma patients travel to high altitude, however, all of the factors play a role together and as a result, the most useful information regarding asthma patients at high altitude is from field studies. The available studies suggest well-controlled asthmatic patients with mild disease tolerate travel to moderate altitudes without significant difficulty. Allegra et al⁴⁸ and Cogo et al,⁴⁹ for example, demonstrated decreased bronchial response to inhalation of hypo-osmolar aerosol or methacholine at altitudes between 4559 and 5050 m. More recently Huismans et al³⁵ showed that well-controlled mild asthmatic patients trekking as high as 6400 m did not experience increased symptoms or need for medications, and Stokes et al³⁶ demonstrated that ascent to 5895 m was feasible without evidence of asthma exacerbations or

increased risk of acute mountain sickness relative to nonasthmatic climbers. Other studies have reported decreases in FEV₁⁵⁰ or PEF⁵¹ during high altitude trekking, but the effects were small and not associated with significant changes in symptoms. Although these studies suggest that asthma patients generally tolerate travel to elevations above 6000 m, it must be emphasized that they included only mild asthmatic patients with well-controlled disease. No firm conclusions can be drawn regarding patients with moderate or severe asthma or those with worsening control at the time of their excursion. Travel to extreme elevations such as those seen on 8000-m peaks may be feasible in patients with well-controlled mild asthma but data on this issue are lacking.

Planning for high altitude travel with asthma

Individuals with well-controlled, mild asthma at the time of their sojourn can travel to altitudes over 6000 m whereas any individual with an active or recent exacerbation or with moderate or severe persistent disease should avoid high altitude travel, particularly into remote areas away from medical resources. Patients should travel with an adequate supply of controller medications and rescue inhalers and need to be aware that the number of puffs per inhaler may be decreased at elevations above 3000 m.⁵² Patients should remain on their baseline medication regimen while traveling at high altitude, but if an individual's disease is known to worsen with exposure to cold or exercise, consideration can be given to adding or increasing the intensity of controller therapy or, in the case of exercise-induced symptoms, initiating pre-exercise short-acting bronchodilator or leukotriene receptor blockade. Patients can consider breathing through bandanas or balaclavas to warm and humidify inhaled air, but there is no evidence supporting this practice.

When asthma patients experience worsening symptoms at altitude, other entities warrant consideration in the differential diagnosis including pneumonia, pulmonary embolism, high altitude cough, and most importantly, high altitude pulmonary edema. Distinguishing among these entities can be difficult in the field, but the presence of fever, sputum production, hemoptysis, severe hypoxemia, crackles on lung auscultation, or asymmetric lower extremity edema would point away from asthma and toward another diagnosis.

SELF-CONTAINED UNDERWATER BREATHING APPARATUS (SCUBA) DIVING

The prevalence of asthma among divers is not known, but a survey by Weaver et al⁵³ suggested 6% to 15% of

recreational divers have self-reported asthma and up to 12% have evidence of airflow obstruction on pulmonary function testing. Because scuba diving is associated with unique physiologic challenges that predispose to significant complications, any asthma patient considering scuba diving must undergo careful prediving evaluation. The issue of diving with asthma remains controversial, and prediving evaluation practices, including whether to screen all individuals with spirometry beforehand, vary from country to country.

Physiologic challenges associated with scuba diving

Risk of barotrauma. The defining environmental feature of diving is the nearly linear increase in barometric pressure with increasing depth. Scuba equipment is used to counteract the effects of hyperbaria, allowing the individual to preserve lung volume on descent and expand their respiratory system with each inhalation. A fundamental principle of scuba diving is that individuals ascending to the surface must maintain an open glottis and continuous respiration on the way toward the surface. This is necessary because the decrease in barometric pressure that occurs on ascent leads to expansion of air in the alveolar spaces based on the principles of Boyle's law. Failure to maintain an open glottis and allow expanding air to escape may cause significant increases in lung volume and, as a result, alveolar rupture with subsequent development of one of several manifestations of pulmonary barotrauma, including pneumomediastinum, pneumothorax, subcutaneous emphysema, pneumopericardium, or venous or arterial gas embolism. Patients with airflow obstruction caused by asthma are thought to be at increased risk for such complications. If airflow obstruction prevents complete exhalation of the inhaled tidal volume, expansion of the air trapped behind the obstructed airways can lead to increased lung volumes with the potential for barotrauma. For this reason, patients with active or worsening disease should not engage in scuba diving.

Importantly, asthmatic patients should not be at increased risk for another complication of scuba diving, decompression sickness (DCS), which manifests on a spectrum of severity from mild problems such as pruritus and arthralgias to more severe problems including respiratory and neurologic compromise. DCS occurs when individuals ascend to the surface too quickly for the depth and length of their dive, leading to accumulation and expansion of gaseous nitrogen in the blood and tissues, and has the potential to occur in all individuals regardless of their underlying lung function.⁵⁴

Changes in airway hyperresponsiveness. Even if asthma is not active at the time of the planned sojourn,

concern exists about the potential for increased airway hyperresponsiveness and, therefore, greater potential for air trapping with diving. A variety of factors have been hypothesized to increase the risk of airway hyperresponsiveness during diving, including inhalation of dry and cold air, increased air density, allergen contamination of inhaled gas mixtures, salt water aspiration, and exercise.⁵⁵ Evidence for increased airway hyperresponsiveness largely derives from studies in nonasthmatic divers demonstrating findings such as increased airway hyperreactivity in response to methacholine inhalation

after a dive to 50 m⁵⁶ or decreases in spirometry-derived markers of pulmonary function.^{57,58}

Documented outcomes during diving with asthma

Although asthma patients were discouraged for many years from participating in scuba diving based on these concerns, data demonstrating an increased risk of complications are scant. For example, Neuman and Osborn surveyed 696 divers, 5.3% of whom reported a diagnosis of asthma, and noted no serious adverse events in 6000

Table 3. Major society recommendations regarding diving with asthma

<i>Organization</i>	<i>Recommendations</i>
British Thoracic Society ⁶¹	<p>Asthmatics should not dive if they have a history of wheezing precipitated by exercise, cold, or emotion.</p> <p>Asthmatics may dive, with or without regular inhaled anti-inflammatory agents, if they have no current symptoms, normal spirometry (FEV₁ > 80% predicted and FEV₁/FVC ratio > 70% predicted), and a negative exercise test (< 15% fall in FEV₁ after exercise).</p> <p>Asthmatics who have had to use relief medication in the past 48 hours for treatment of symptoms should not dive.</p> <p>Divers should monitor their asthma with twice-daily PEF measurement.</p> <p>Asthmatics active symptoms requiring relief medication within 48 hours of the planned dive, reduced peak expiratory flow (> 10% from personal best) or increased peak flow variability (> 20% diurnal variation).</p>
South Pacific Underwater Medicine Society (SPUMS) ⁶²	<p>Spirometry, rather than peak flow meter assessment, should be performed in all asthmatics who seek to dive. Peak flow meters can be used for day-to-day monitoring of clinical status.</p> <p>Those who indicate a history of asthma in the past 10 years, signs of wheezing or unexplained cough but normal spirometry should undergo bronchial provocation testing.</p> <p>Asymptomatic asthmatics with normal lung function testing on spirometry and negative bronchoprovocation testing can dive with an acceptable level of risk.</p> <p>Symptomatic individuals and those with abnormal spirometry or positive bronchial hyper-reactivity testing should be advised against diving.</p> <p>Divers with controlled asthma, cleared for diving should have annual reviews of their diving fitness.</p>
UK National Sport Diving Medical Committee ⁶³	<p>Asthmatics may dive if they have allergic asthma but not if they have cold, exercise, or emotion induced asthma.</p> <p>Only well-controlled asthmatics should dive. The asthmatic patient should not need more than occasional bronchodilators. Daily bronchodilator usage is disqualifying for diving but inhaled steroids or cromolyns are permissible.</p> <p>Evidence of exercise-induced bronchoconstriction on exercise testing should preclude diving.</p> <p>During the diving season the diver should take PEF measurements twice a day. A decrease of 10% from best values precludes diving until within 10% of best values for greater than 48 hours.</p> <p>Asthmatics should not dive if they have used a therapeutic bronchodilator within 48 hours or have any other chest symptoms.</p> <p>A beta-2 agonist may be taken prior to diving as a prophylactic measure but not to relieve active symptoms at that time. Active symptoms should lead to aborting the planned dive.</p>

FVC, forced vital capacity; FEV₁, forced expiratory volume in 1 second; PEF, peak expiratory flow.

dives.⁵⁹ Similarly, in an analysis of 369 cases of arterial gas embolism and 2720 cases of DCS, the Divers Alert Network found the prevalence of asthma among those experiencing either complication approximated that seen in the general population.⁵⁹ A systematic review⁶⁰ of the limited available literature on this question noted only weak evidence for an increased risk of DCS and increased risk of barotrauma, although the analysis was limited by the fact that included studies were largely uncontrolled surveys, case series, and mechanistic investigations of the effects of diving on pulmonary function.

Recommendations

Specific recommendations regarding the safety of diving with asthma have been made by a variety of diving-related organizations and professional societies (Table 3). The precise recommendations vary among organizations, but the general principles are similar. Patients with asthma warrant careful evaluation before any planned dive. They can partake in the activity provided their disease is under good control and they have normal pulmonary function testing. Diving should not be undertaken in those patients with symptoms provoked by cold, exercise, and emotion. In individuals without known EIB, strong consideration should be given to ruling out exercise-induced changes in pulmonary function using exercise testing with pretest and posttest spirometry or EVH. By mimicking the cooling and drying of airways that occurs with diving, EVH may be a better test for this purpose, but this testing modality has not been specifically studied with regard to diving.

Once cleared for diving, the asthma patient must still pay close attention to disease activity leading up to and during their diving activities and strongly consider twice-daily PEF monitoring for this purpose. Use of a rescue inhaler in the days leading up to the planned dive or significant changes in PEF (>10% decrease from baseline values or >20% diurnal variability) should be considered indications to abort any planned dive.⁶¹ Development of symptoms during diving should lead to abandonment of further diving on that trip and careful reassessment before future dives.

For asthma patients who experience respiratory symptoms during a dive, worsening asthma control or pulmonary barotrauma are the leading considerations, but other entities should also be considered including immersion pulmonary edema and DCS. Immersion pulmonary edema is a form of noncardiogenic edema that can be distinguished from other entities by the fact that symptoms develop during descent or while at depth,⁶⁴ whereas DCS can be distinguished from pulmonary barotrauma by the slower rate of symptom

onset and the presence of nonrespiratory symptoms such as arthralgias and neurologic findings.⁵⁴

Conclusions

Although wilderness and adventure travel may be associated with exposure to factors known to worsen asthma control, asthma patients can participate in a wide range of such activities. Patients should undergo careful pretrip evaluation to identify precipitants of worsening control and assess disease activity. Those with well-controlled disease at the time of the activity can proceed with their planned sojourn, whereas those whose disease is under poor or worsening control should be counseled to avoid the planned activity, particularly if it involves travel into a remote area. Plans should be established to monitor disease activity and respond to adverse changes, including medication adjustments and evacuation to definitive medical care. With such adequate pretravel evaluation and counseling, the majority of well-controlled asthma patients should be able to enjoy a full spectrum of wilderness and adventure activities.

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