CARE OF THE WILDERNESS ATHLETE

Medical Clearance for Desert and Land Sports, Adventure, and Endurance Events

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Endurance events are increasing in popularity in wilderness and remote settings, and participants face a unique set of potential risks for participation. The purpose of this article is to outline these risks and allow the practitioner to better guide the wilderness adventurer who is anticipating traveling to a remote or desert environment.

Key words: wilderness medicine, environmental medicine, hyponatremia, endurance events, spelunking, adventure racing, desert, triathlon, preparticipation

Introduction

Endurance events are increasing in popularity in wilderness and remote settings, and participants face a unique set of potential risks for participation. The purpose of this article is to outline these risks and allow the practitioner to better guide the wilderness adventurer who is anticipating traveling to a remote or desert environment.

Methods

The following databases were searched: MEDLINE and Cochrane Database of Systematic Reviews. Articles were limited to those printed in English between 1980 and 2014. Key terms included preparticipation physical examination. The initial process yielded 96 articles. The manuscripts and references, as well as text books, were reviewed for use in this article.

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Definitions

To better understand the factors involved with clearance for participation, it will be important to define some commonly used terms.

What is an “Endurance Event”? There is no clear definition, but guidelines include:

1. Events in which the majority of participants will take over 2 to 4 hours to complete.
2. Any event in which the athlete must eat during the event to finish or compete effectively.

Endurance events can be divided into competitive events and recreational activities.

COMMON COMPETITIVE ENDURANCE EVENTS

1. Running: trail running (eg, an ultramarathon, defined as any distance greater than 26.2 miles) These typically involve distances of 50 K, 50 miles, 100 K, or 100 miles. May involve multiday staged events of much longer distances such as the Marathon of the Sands or “RacingThe Planet” type events. Some involve individual speed attempts on long distance trails such as the Appalachian Trail, Pacific Crest Trail, or Long Trial in Vermont. Long-distance

orienteering and “bushwhacking” (crosscountry without a specific trail) events, such as regaining, are also increasing in participation.

2. Biking: road events such as the RAM (transcontinental road bike race) or mountain bike events of various long distances (100 miles) or duration (24-hour races). There include multiday mountain bike races such as the Tour Divide in which participants race unsupported from Banff, Canada, to the Mexican border along the Continental Divide.
3. Multisport: involving several disciplines such as triathlon (swim/bike/run). These can be any distance, but distances of “Iron” distance (swim 2.4 miles/bike 112 miles/run 26.2 miles) or those beyond, so-called “Ultradistance triathlons” are common examples. Variations on traditional triathlons can be on road or the more challenging off road events involving trail running and mountain biking. Adventure racing is a multisport event typically involving running, mountain biking, orienteering, water sports, and/or climbing. Events can be of “short” duration (4 hours) up to multiday expedition length events covering hundreds of miles of difficult and remote terrain.
4. Obstacle courses: these involve 10 to 12 mile courses with team and individual participants. The Tough Mudder series (multiple event locations) is one such example. Courses are often designed to be physically and emotionally challenging. In 2013, there were 3.5 million participants worldwide.¹ Many of these events are less than 4 hours of duration and there is close medical supervision at most obstacles. Despite this, there have been serious injuries and even deaths at these events.
5. Snow-based races: these include nordic skiing and snow-shoeing races at extended distances, as well as assisted events such as dog-sledding events such as the Iditarod in Alaska.

RECREATIONAL ENDURANCE EVENT ACTIVITIES

Examples include but are not limited to:

1. Hiking and backpacking, ranging in distance and duration from a day hike to 6 months on the Appalachian trail.
2. Caving/spelunking can involve long hours or even days in difficult remote terrain with unique environmental exposures, including fungi, bacterial pathogens, and rabies.
3. Canyoneering involves traversing (climbing and rappelling) narrow canyons with steep terrain and

obstacles. There may also be significant water exposures. Like caving, evacuation for illness or injury can be very difficult.

Environmental Considerations

While some significant endurance events occur in areas of relatively comfortable environments with close access to medical care, many land-based and desert adventure activities involve remote and often hostile conditions, which are not readily accessible to medical services. An understanding of the conditions will help assess and determine the risk to the participant.

DESERTS

Many adventures take place in the desert or in environments of extreme heat. Protection from heat and hydration are the primary concerns for desert events, and the preparticipation screening needs to address medication, hydration plan, and medical issues addressed in further detail below. Adequate water may not be available to the athlete in all circumstances, or water may be of dubious quality. In addition, local flora and fauna may present unusual problems such as cactus spines and scorpion stings.

CAVES

Many adventure races or wilderness excursions take place in environments where caves or subterranean conditions may exist. These factors may present problems for those with claustrophobia or panic disorders. Exposure to unusual pathogens (histoplasmosis) may present problems to immune-suppressed individuals. Some patients with asthma may have significant respiratory difficulty with high mold exposure. Furthermore, caves may be home to large colonies of bats. The Centers for Disease Control and Prevention (CDC) has included spelunkers among their list of high-risk activities for rabies, recommending pre-exposure rabies prophylaxis. Fortunately, rabies is very rare among cavers.

NORMAL CLIMATOLOGIC VARIABLES

As demonstrated by the 2007 Twin Cities and Chicago Marathons, even urban, well-controlled endurance events can have significant morbidity and mortality associated with unexpected conditions.² While there are established guidelines for staging mass events in hot temperatures, many other environmental variables do not have such guidelines. Some endurance events are deliberately performed under harsh conditions, where consideration may be not given to canceling the event due to “inclement” weather. Therefore, it is imperative that participants be familiar with the typical climate

(including temperature ranges, precipitation, and other important site specific issues) for a given event, with consideration of any forecasted deviations from these conditions.

INTERNATIONAL TRAVEL

Many remote or exotic events occur in international destinations. These may include developing countries with existing or emerging infectious disease considerations as well as wildlife, plant, and insect hazards unique to that area. Therefore, familiarity with local hazards by the participant and screening physician can reduce morbidity of participants.

Physiology of Endurance Exercise

Injuries that occur as a result of endurance exercise can be characterized by organ system. To better understand the possible injuries that may occur during participation in endurance or ultraendurance sport, a brief review of the physiology involved is provided.

MUSCLE

The physiology of endurance exercise starts at the muscle level. Endurance exercise is characterized by low intensities and long durations. Type I skeletal muscle fibers, also known as “slow-twitch” fibers, are predominantly active during endurance exercise. These are oxidative fatigue-resistant fibers.³ Metabolism during endurance exercise is predominantly aerobic, and compared with anaerobic metabolism (which does not involve oxygen), aerobic metabolism provides significantly more adenosine triphosphate per molecule of glucose. As physical activity becomes more sustained, fat rather than glucose becomes the preferred source of fuel.^{3,4}

To provide enough oxygen for an exercising muscle to produce energy, several muscle adaptations to endurance exercise must take place. The blood supply to muscle fibers increases by way of increased capillaries. This allows for increased blood flow to the muscle and a greater surface area for exchange of gases. Within each muscle cell, the number and size of the mitochondria also increase, which improves the oxidative capacity and the ability to extract and use oxygen from arterial blood.³

CARDIOVASCULAR

Several cardiovascular adaptations also take place during endurance exercise. Cardiac output, a product of stroke volume and heart rate, increases with increasing exercise intensity. The cardiac output of trained endurance athletes may increase from 5 to 6 L/min at rest to up

to 40 L/min during maximal exercise.⁵ Stroke volume may increase up to 40% to 60% of VO_2 max then level off, leaving heart rate responsible for the remainder of the increased cardiac output.³ After a few weeks of endurance training, resting heart rate decreases due to an increase in parasympathetic activity and decrease in sympathetic activity. This allows for increased filling time and larger stroke volumes to maintain cardiac output.³

Increases in cardiac output during exercise expose the heart to a greater volume load. The heart adapts to this load with an increase in internal diameter and no change in wall thickness.^{5,6} This change is called eccentric hypertrophy, a response to resistance exercise characterized by an increase in wall thickness with little to no change in chamber size.^{5,6} While these physiological changes are common in endurance athletes, the cardiac adaptations may overlap with the qualities of hypertrophic and dilated cardiomyopathies.^{6,7}

RENAL

With the increase in blood flow to the exercising muscles during prolonged exertion, the blood supply to the renal and splanchnic circulation is decreased. Exercise leads to diminished renal plasma flow and glomerular filtration rate.^{8,9} Studies have shown diminished renal function after long distance races, but the clinical significance of these changes is unknown.¹⁰

Proteinuria is commonly seen after exercise, is often benign in nature, and more of a function of exercise intensity than duration. After moderate-intensity exercise, glomerular proteinuria is observed, where the proteins in the urine are more similar to plasma proteins. During strenuous exercise, tubular proteinuria is seen, comprised of proteins that are normally reabsorbed by the tubules.⁸ Exercise-induced proteinuria usually resolves within 24 to 48 hours.⁸

Hematuria may also be seen during or after exercise, related to both intensity and duration. There are several proposed mechanisms for exercise-induced hematuria: hypoxic damage due to the decreased blood flow may increase glomerular permeability and excretion of erythrocytes into the urine; renal vasoconstriction in the efferent glomerular arteriole increases filtration pressure and filtration fraction leading to the passage of red blood cells in the urine; hyperthermia may lead to erythrocyte destruction; and foot strike hemolysis may also lead to hematuria.^{8,9} Similar to exercise-induced proteinuria, hematuria usually resolves within 24 to 72 hours without long-term consequence.⁹

The kidneys also play a major role in regulation of total body fluid volume. Balancing fluid intake during

exercise is a balance between avoiding dehydration and fluid overload. Too much free water can be fatal, yet restricting fluid can interfere with heat transfer and increase the risk of heat stroke. Normal body water volume varies within a narrow range and is regulated by several hormones, including arginine vasopressin (AVP), atrial natriuretic peptide (ANP), aldosterone, b-type natriuretic peptide, and oxytocin. Most adults require 2 to 4 L of fluid daily, where 20% to 50% of daily water intake comes from ingested foods. Exercise increases water requirements and some people can require >10 L/d, especially with fluid losses in dry heat or activity wearing heavy or occlusive clothing or equipment.¹⁰ Sweat losses during physical activity range <0.5 to >2.5 L/h and in rare situations sweat rates approach 3 L/h.¹¹ Losing >2 to 3% of body weight loss is considered dehydration and peak performance is adversely affected.¹¹ However, the body can tolerate greater fluid losses, but in hot conditions further fluid losses begin to affect intravascular volume and heat transport. Sweat sodium concentration during exercise is variable based on conditioning and genetic factors, and can range from <20 to >80 mmol/L.¹¹

When there is excess water or decreased sodium content in the extracellular space, water flows into cells from the extracellular space. This causes cellular swelling (edema) and associated electrolyte imbalances. While reasonably tolerated in some tissues such as skeletal muscle, there is high potential for serious medical problems or death if this fluid accumulation occurs in the lungs or in the brain.

GASTROINTESTINAL

The gastrointestinal (GI) system can withstand a 75% decrease in blood flow at rest for up to 12 hours without major histological changes.^{12,13} But as exercise intensity increases, splanchnic blood flow decreases, which may lead to ischemia. Worsening ischemia may lead to intestinal mucosal dysfunction or cellular injury, necrosis, and mucosal erosions. Dehydration and hyperthermia may exacerbate gut ischemia. All of these factors may lead to pain, cramping, and GI bleeding.¹²

High-intensity exercise slows the rate of gastric emptying, which may lead to nausea, vomiting, acid reflux, and chest pain. Dehydration and hyperthermia further slow gastric emptying.¹³ Diarrhea is a common complaint among runners.¹² Increased sympathetic activity associated with exercise decreases parasympathetic effect on colonic motility, which leads to a decrease in smooth muscle tone and resistance, accelerating (production of?) colonic contents into the rectum. Activities with repetitive impact, such as running, may also contribute to increased

colonic motility. The osmotic effect of sports drinks and gels, as well as intake of large amounts of fiber, may also contribute to lower intestinal discomfort and diarrhea.

Medical Conditions in Endurance and Wilderness Athletics

Long endurance and multiday activities expose the participant to unique medical problems other than the expected overuse injuries and trauma. These are intimately related to the physiology of endurance events discussed above, environmental conditions, and a participant's risk factors. The most severe potentially life-threatening medical complications of exercise or sports in remote desert environments include heat injuries (discussed in a corresponding article Medical Evaluation for Participation in Extreme Environments: Heat) and hyponatremia.

EXERCISE-ASSOCIATED HYPONATREMIA

Exercise can change fluid and electrolyte balance based on the sum of replacement and losses. This can be amplified by hot dry conditions, lack of acclimatization to heat, and misunderstanding of fluid and electrolyte recommendations.

Exercise-associated hyponatremia (EAH) is clinically defined as a serum sodium <135 mmol/L and can be subdivided into 3 main categories:

1. Asymptomatic incidental finding.
2. Symptomatic—presence of some symptoms.
3. Severe encephalopathy—any low sodium level with symptoms resulting from brain swelling.¹⁴

Exercise-associated hyponatremia exists in athletes on a continuum from hypervolemic hyponatremia to hypovolemic hyponatremia,¹⁵ although formal case documentation of hypovolemic EAH is not well defined in the literature. The mechanisms of onset lie on a spectrum of excessive fluid intake with inadequate fluid excretion, due to inappropriate release of AVP, also known as antidiuretic hormone (ADH), to high sweat salt loss with inadequate salt and water replacement.¹⁶

Presenting symptoms can be variable from case to case even at the same serum sodium level and can overlap with other exercise-related medical issues. Symptoms can be categorized as (1) early—lightheaded, dizzy, and nausea; (2) middle—headache (severe, progressive), vomiting, “puffy” extremities, muscle cramping, a feeling of “impending doom,” dyspnea, and confusion; and (3) late—ashen, gray appearance, prolonged seizure activity, and obtundation. The blood

pressure, heart rate, and respiratory rate are usually normal in hypervolemic cases and will reflect dehydration in hypovolemic cases.¹⁴

Balance between fluid intake and sweat or urine losses is required to maintain a normal serum sodium level in both the resting and exercising individual. Regulation is triggered mainly by serum osmolality but can be affected by heat and exertion,¹⁷ decreased plasma volume, pain, fear, anxiety, stress, nausea/vomiting, and potentially muscle release of IL-6 and other mediators.^{18,19}

Hyponatremia is a particular risk for those who have high sweat sodium concentrations and those who habitually drink high water volumes in the wilderness, especially hot dry environments, without a period of acclimatization. Multiple cases and near fatalities have occurred in the Grand Canyon along trails that are easily accessible to both novice and experts alike.^{20–22} Hyponatremia accounted for 19% of heat-related illness from 2004 to 2009.²³ Failure to take precautions for heat and fluid replacement, misunderstanding of personal fluid requirements, and inadequate physical preparation for the outing are common causes. Taking in too much free water or dilute fluids plus the failure to promote excretion of the excess water, coupled with high sweat rates in this environment are the major contributors to these incidents. In addition, the hot dry environment may inappropriately stimulate the release of ADH causing loss of normal fluid excretion and an excess in total body water that manifests as cerebral and/or pulmonary edema. Both can be fatal if the excess water is not removed from the cells and the system. Higher sodium fluid replacement and foods high in salt can reduce but not always eliminate the problem.

While dry heat is the most likely environment for EAH, it can also occur in cold environments and has been documented in the 161-km Alaskan Ididitport ultramarathon race. In this race, the hyponatremic group drank more fluid per hour (0.5 vs 0.4 L/h) and consumed less sodium per hour (235 vs 298 mg/h) compared with the normonatremic group.²⁴ Hyponatremia can be prevented through education, risk factor modification, and environmental acclimatization.

CARDIAC CONDITIONS

Sudden cardiac death has been reported as a significant contributor to morbidity and mortality of endurance events as described above. This is most well documented in cases of death during the swim portion of triathlons,²⁵ (a discussion of this point is beyond the scope of this article) but can occur in any endurance event. There is also increasing evidence that overtraining or long-term participation in endurance events can predispose to atrial

fibrillation and other cardiac arrhythmias later in life.^{26,27} Screening for cardiac conditions as part of the preparticipation evaluation should be similar to that for any athletic participation.²⁸ Cardiac screening in asymptomatic individuals without cardiac risk factors, whether through electrocardiogram, echocardiogram, or exercise stress testing, remains controversial and of unclear benefit.

PULMONARY CONDITIONS

Asthma is a common pulmonary medical concern among wilderness endurance athletes. Awareness of triggers, avoidance of dehydration, and an asthma action plan are essential for counseling asthmatics before their events. Pulmonary edema has been reported in numerous endurance swim events (swimming-induced pulmonary edema), where hypertension and fish oil consumption have been potentially linked as risk factors.²⁹ Pulmonary edema can be associated with hyponatremia (EAH?) or cardiac conditions, as well as a physiologic complication of altitude.

DEHYDRATION/RENAL ILLNESS/METABOLIC ISSUES

In addition to EAH, other fluid and nutritional conditions exist during wilderness endurance events. Dehydration can occur with prolonged endurance activities, particularly in desert conditions. Food intake must be adequate in terms of nutrition type and caloric content for the demands of the event. As discussed above, hematuria and myoglobinuria are not uncommon events in athletes. Dehydration and heat exposure, particularly with concomitant sickle cell disease, can result in rhabdomyolysis and acute renal failure, a commonly reported hazard in endurance events.³⁰

PSYCHIATRIC CONSIDERATIONS

Sleep deprivation is common during multiday events, and resulting psychiatric problems (acute psychosis), hallucinations, cognitive impairment, and seizures have been reported. Spelunking carries a high risk of psychiatric events due to claustrophobia or panic disorders, as do “challenge” events, which deliberately place participants in psychologically stressful situations.

OCULAR HAZARDS

Corneal edema leading to transient vision loss and been seen ultradistance runners if running through the night due to drying of the cornea. Endurance events held on sand or snow have also reported corneal injuries associated with them.

INFECTIOUS DISEASE

Immunizations may be needed for travel to certain areas hosting competition or recreational endurance events. The CDC Travel Medicine Web site (<http://wwwnc.cdc.gov/travel>) is an excellent resource for immunization requirements and recommendations for adventurers before departure. Travel to tropical locations with high levels of mosquitoes may warrant malaria prophylaxis. Finally, as discussed above, spelunkers may face additional potential concern for exposure to histoplasmosis, rabies, and fungal pathogens and should be counseled on pre-event risk planning.

Epidemiology of Wilderness Endurance Athletics: Morbidity And Mortality

There is a paucity of high-quality literature specifically focusing on endurance activities in wilderness environments. However, good data do exist for endurance activities that occur in more accessible or populated environments. These data can be somewhat extrapolated to the wilderness setting, which can help adventurers prepare and physicians advise athletes before departure.

Cardiovascular emergencies remain quite low in endurance events. In some of the largest studies to date, cardiac arrest among marathon runners has been described at approximately 1 in 100 000 participants, with older age and male gender as risk factors.³¹ In 2 years from 2006 to 2008, there were 13 triathlon swim deaths of approximately 1 million participants, 11 of whom cardiac anomalies were the clear cause of death.²⁵

Hyponatremia has been documented in hikers in the Grand Canyon and other remote locations, but the actual prevalence is unknown.^{20,22,23} Studies have demonstrated that EAH can occur in up to 30% of asymptomatic Ironman triathletes and other ultraendurance athletes. The incidence of clinically significant EAH, however, is much lower.³² Furthermore, published data from marathons show that asymptomatic biochemical EAH occurs in up to 13% of finishers, but encephalopathic EAH incidence is <1% of finishers.^{33,34} Asymptomatic biochemical EAH has been reported in ultraendurance swimmers at up to 36% in a 26.4-km swim,³⁵ but larger studies show that ultraendurance athletes in general have similar rates of hyponatremia ($\approx$ 6%) as marathoners and ironman-distance triathletes.³⁶ No encephalopathic EAH occurred in these studies.

Numerous sport-specific musculoskeletal conditions exist and should be recognized by participants and preparticipation medical personnel. These include “ultra-marathoners ankle” (tendinitis of the foot dorsiflexors), “aeroneck” (fatigue and pain of the paracervical

musculature in longdistance cyclists), and diverse injuries from obstacle courses/races, including insect bites, falls, and exposure to electrical shock.¹

Extrapolating from what is known from the above studies, it would seem that morbidity and mortality risk is relatively low for wilderness adventurers.

Preparticipation History and Physical Examination

When evaluating an athlete for risk of EAH, patient history should be similar to that of a traditional preparticipation clearance. In addition, however, for endurance events, we recommend also screening for previous problems with fluid balance, or a history of headaches, malaise, body swelling, nausea, or excessive urination after exercise. Attention should be focused on patient preparedness for the expected environmental conditions and the fluid replacement plans. Further risk factors can be seen in Table 1 and an example of history questions found in Table 2. Knowing a participant’s anticipated exertion level, duration of exposure, education level on

Table 1. Hyponatremia risk factors for endurance athletics^{10,11,14,15,36}

<i>Intrinsic participant risk factors</i>
Age (>60 yrs or children)
Underlying chronic medical condition
Family history of sudden cardiac death
History of hyperthermia/syncope/heat illness
History of frostbite or cold injury
Musculoskeletal factors, including injury history, osteoarthritis, and surgical history
Modifiable participant risk factors
Overtraining
Poor judgment/inexperienced athlete
Inappropriate footwear/clothing/equipment
Risk-taking behavior
Poor acclimatization (heat, altitude)
Medications/substance use (diuretics, nonsteroidal anti-inflammatory drugs, antihistamines, alcohol, recreational drug use, beta blockers, and performance-enhancing agents)
Dietary and fluid intake “training”
Environmental
Extreme heat and cold/windchill
Mixed terrain (rock and snow/ice)
Toxic gas exposure (spelunking/canyoneering specific)
Histoplasmosis (bat droppings in caves)
Schistosomiasis/leptospirosis (triathletes swimming in freshwater lakes/ponds)

Individual risk factors for endurance athletics can vary highly depending on the event and conditions. In general, consideration for the preparticipation evaluation should focus on the following categories. Specific medical and environmental conditions are covered in more detail.

Table 2. Hyponatremia risk factors: example history questions²⁸

Have you been diagnosed with exertional hyponatremia in the past?

Do you sweat heavily and do you lose a lot of salt in your sweat (clothes turn white, salt precipitates on skin and hair)?

What medications are you using (paying special attention to diuretics, aldosterone antagonists, nonsteroidal anti-inflammatory drugs, and antipsychotics)?

Do you have hypertension, diabetes, or renal disease?

Do you have any chronic skin conditions, such as psoriasis or eczema that may affect sweating?

Do you sunburn easily and do you have a plan for skin protection?

How do you plan to acclimatize to heat and do you have a plan for keeping cool (eg, Grand Canyon trails in heat—long sleeve white cotton shirt to be soaked and worn until dry to promote body cooling)?

conditions, wilderness experience, and previous fluid problems allows for targeted education to decrease risk.

The preparticipation physical examination done for land-based or desert environments should not differ from the normal preparticipation physical examination.²⁸

The information gained from the history, physical assessment, risk factor assessment, and knowledge of the event and the environment can then be used to guide decision making and clearance for participation with a goal to minimize or mitigate potential risks while maximizing safety and enjoyment of the participant.

Conclusions

Wilderness endurance events are becoming more popular and athletes are more commonly participating in remote, austere, and extreme environments. With a proper identification of personal and environmental risk factors and an understanding of the demands of the event, safe and enjoyable adventure is possible.

Recommendations

1. Obtain a thorough cardiac personal history and family history.
2. Strongly consider additional cardiac screening for higher risk athletes or sports.
3. Assess psychiatric compatibility with sport/activity being attempted.
4. Assess knowledge of participant and provide education on local hazards, climate conditions, and assess equipment and fitness preparedness.
5. Educate and provide appropriate immunizations and prophylaxis to select populations.
6. Provide education to encourage participants to know their sweat rate, monitor urine color, and have a fluid replacement plan.
7. Assess patient medications with attention to potential side effects with endurance events and educate participant of early symptoms and signs.

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