

ORIGINAL RESEARCH

To Air Is Human: Altitude Illness During an Expedition Length Adventure Race

Timothy S. Talbot, MD; David A. Townes, MD, MPH, FACEP; Ian S. Wedmore, MD, FACEP

From the Department of Emergency Medicine, Blanchfield Army Community Hospital, Fort Campbell, KY (Dr Talbot); the Division of Emergency Medicine, University of Washington School of Medicine, Seattle, WA (Dr Townes); and the Department of Emergency Medicine, Madigan Army Medical Center, Fort Lewis, WA (Dr Wedmore).

Objective.—To calculate the incidence and prevalence of altitude illness (acute mountain sickness [AMS], high altitude pulmonary edema, and high altitude cerebral edema) during an expedition length adventure race and to determine factors contributing to its development as well as identify cases requiring medical treatment, withdrawal from the event, or both.

Methods.—The Primal Quest Expedition Length Adventure Race was held in Colorado in July 2002. Sixty-two coed teams of four participated in the event. It began at an altitude of over 9500 feet, ascended to an altitude over 13 500 feet with a cumulative elevation gain of 69 400 feet, of which 40 000 feet occurred in the first 12 hours of the event. There was 138 800 total feet of altitude change during the event. All racers underwent a prerace medical assessment 24 hours before the start of the race and completed an Environmental Systems Questionnaire version 3-R (ESQ 3-R). Onsite medical staff provided treatment during the event. A standard medical encounter form was used to record all patient encounters including a presumed diagnosis and disposition.

Results.—At the start of the race, the prevalence of altitude illness was 4.5%. The incidence of altitude illness requiring medical treatment during the race was 14.1% (AMS, 33 [13.3%]; high altitude pulmonary edema, 2 [.81%]) resulting in 4 (14.3%) of the 28 medical withdrawals from the race. There was no correlation between home altitude, prerace ESQ scores, and successful completion of the race.

Conclusions.—Altitude illness occurs among participants in expedition length adventure races and contributes significantly to withdrawal from the event.

Key words: acute mountain sickness, high altitude pulmonary edema, high altitude cerebral edema, adventure racing, multi-sport, ESQ-3R

Introduction

Adventure racing or multi-sport racing is one of the fastest growing outdoor sports in the United States and throughout the world.¹ Multi-sport events require participants to perform disciplines such as mountain biking, kayaking, mountaineering, trekking, trail running, and orienteering in some of the most extreme terrain and conditions on earth. The origin of adventure racing stems from the first organized races including the Coast-

to-Coast, started in New Zealand in 1980, and the Alaska Wilderness Classic held in Alaska since 1983. The first official international competition, The Raid Gauloises, began in New Zealand in 1989. From these beginnings came several large international competitions, including the Southern Traverse, started in New Zealand in 1991, the Eco-Challenge, started in the United States in 1995,² and the Primal Quest, started in the United States in 2002. Adventure races vary in duration from sprint races (<6 hours), intermediate races (6–12 hours), long races (12–36 hours), and expedition races (>36 hours).

There is little published literature investigating the injury patterns of race participants. Previous published works included case reports of disease outbreaks,^{3,4} investigations of respiratory illness,^{5,6} a survey of injury

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Corresponding author: Timothy S. Talbot, MD, 3888 Parade Dr, Clarksville, TN 37040 (e-mail: Usurugger@aol.com).

and illness during a 2-day multi-sport race,⁷ and a case report of a death during a multi-sport race in North America.⁸ More recent work by Townes et al (oral communication, 2002) detailed the overall injury and illness pattern in a 10-day expedition length multi-sport event.

There has been no investigation of altitude illness during multi-sport events. The purpose of this study is to calculate the incidence and prevalence of altitude illness (acute mountain sickness [AMS], high altitude pulmonary edema, and high altitude cerebral edema), to determine factors that contribute to its development, and to identify those cases requiring medical treatment, withdrawal from the event, or both.

Methods

The Primal Quest Expedition Adventure Race was based in Telluride, CO, July 7–16, 2002. The 248 participants in the race included elite athletes representing 9 countries. The 238-mile course required trail running, hiking, mountain biking, white water boating, fixed line mountaineering, rappelling, and orienteering. Originating at a base altitude of more than 9500 feet and reaching altitudes higher than 13 500 feet, the race features a total elevation gain of 69 400 feet, with 138 800 feet of altitude change.

All racers completed a mandatory medical history form during the prerace medical check-in that captured demographics (eg, age, sex, and home altitude); medical and surgical history; and prescribed, over-the-counter, and herbal medication use. At that time, volunteers were recruited and consent obtained for participation in the study. Study volunteers completed a prerace survey, including the Environmental Symptoms Questionnaire version 3 Revised (ESQ-3R). The ESQ is a standard altitude illness assessment tool that identifies cerebral (AMS-C) and respiratory (AMS-R) effects of altitude illness.⁹ The ESQ-3R is specific in identifying altitude illness while excluding symptoms resulting from other environmental factors and illness that may mimic the AMS-C and AMS-R symptoms of altitude illness.^{10,11} ESQ-3R scores were used to identify altitude illness among racers at the start of the competition.

All 248 racers and their support crews, 40 medical team members, 25 media personnel, and 110 race support staff were provided didactic instruction on the recognition of altitude illness. Medical staff members received additional training in the recognition and treatment of altitude illness. During the event, care was provided by medical staff stationed at 7 medical tents along the course and by mobile medical teams stationed along high altitude sections of the course. Medical personnel

Table 1. Racer demographics

Sex	<i>n</i>	(%)
Male	178	(72.4)
Female	68	(27.6)
Total	246	
Age	Median	(range)
Male	34.7	(19–49)
Female	34.5	(23–48)
Overall	34.7	(19–49)
Home altitude (ft)	Median	(range)
Male	2214	
Female	2493	
Overall	2282	(0–11800)
Previous altitude illness	<i>n</i>	(%)
Male	8	(4.4)
Female	4	(5.7)
Total	12	(4.8)

included physicians, physician assistants, nurses, paramedics, and emergency medical technicians.

All medical encounters were recorded on a standard medical encounter form at the time of treatment, which included the presumed diagnosis and disposition. The diagnosis of altitude illness was made by established clinical criteria.¹² Medical encounter forms were used to determine the incidence of altitude illness and determine the number of racers requiring medical treatment, withdrawal from the race because of altitude illness, or both. The use of prophylactic medications for altitude illness was prohibited.

The study received approval by the Institutional Review Board and Human Subjects Committee at our institution.

DATA ANALYSIS

All injury and illness data were abstracted from the standard medical encounter forms. Training history, medical history, and demographic information were abstracted from the prerace survey forms and entered into a master ACCESS database (Microsoft, Seattle, WA). The significance of difference between groups was analyzed using the χ^2 -square test for proportion and the analysis performed using Stata version 8.0 (Stata Corporation, College Station, TX).

Results

The study period was the 10-day duration of the race from July 7 to July 16, 2002. Of 248 eligible racers, 246

Table 2. Demographics of racers experiencing altitude illness

<i>Subject</i>	<i>Sex</i>	<i>Age</i>	<i>Type</i>	<i>Previous altitude illness</i>	<i>Home altitude</i>	<i>Medical withdrawal</i>	<i>Finish race</i>
1	F	48	AMS	No	300	No	Yes
9	M	47	AMS	No	1200	No	Yes
17	M	32	AMS	No	350	No	No
18	F	38	AMS	No	350	No	Yes
23	M	37	AMS	No	8150	No	No
26	M	35	AMS	No	0	No	Yes
27	F	36	AMS	No	20	No	Yes
28	M	30	AMS	No	0	No	Yes
29	F	25	AMS	No	8500	Yes	No
36	F	36	AMS	No	500	No	Yes
47	M	34	AMS	No	0	No	No
49	M	43	AMS	No	720	No	No
70	M	31	AMS	No	0	No	Yes
74	F	36	AMS	No	850	No	Yes
88	M	37	AMS	No	1000	No	No
89	M	40	AMS	No	1200	No	No
104	M	37	AMS	No	0	No	No
106	M	31	HAPE	No	550	Yes	No
110	F	32	AMS	No	300	No	Yes
119	M	41	AMS	No	0	Yes	No
125	F	33	AMS	No	500	No	Yes
126	M	36	AMS	No	300	No	Yes
143	F	29	AMS	No	2900	No	Yes
145	M	38	AMS	No	330	No	Yes
150	M	37	AMS	No	38	No	Yes
167	F	46	AMS	No	0	No	Yes
168	M	31	AMS	No	7400	No	Yes
172	M	35	AMS	No	500	No	Yes
186	F	26	AMS	No	0	No	No
192	M	38	AMS	No	0	No	Yes
206	F	28	AMS	No	3300	No	Yes
224	M	43	HAPE	No	50	Yes	No
225	M	36	AMS	No	250	No	No
233	M	30	AMS	No	6700	No	No
234	M	28	AMS	Yes	500	No	No
Mean		35.4			1324		

*AMS indicates acute mountain sickness; HAPE, high altitude pulmonary edema.

volunteered to participate in the study. Of these, 244 questionnaires were completed (98% return rate). Twelve (4.8%) racers reported a history of altitude illness on their medical history form.

Two hundred forty-eight racers (62 coed teams of 4) started the race, with 183 (73.8%) completing the event. Of those who completed the race, 12 completed a modified short course, and 27 finished unranked after losing one team member. Demographics of the racers are shown in Table 1.

A total of 243 medical encounters and 302 injuries and illnesses were recorded. Racers accounted for 232

of 243 medical encounters. Of the 302 injuries and illnesses recorded, there were 35 cases of altitude illness among racers, yielding an incidence rate of 11.6%. Of the 65 racers who did not finish, 28 withdrew for medical reasons, with 4 (14.3%) of those because of altitude illness.

Of the 35 cases of altitude illness reported, 33 (94.3%) were AMS and 2 (5.7%) were high altitude pulmonary edema. There were no cases of high altitude cerebral edema reported. Twelve (34.3%) women and 23 (65.7%) men were treated for altitude illness. Only one reported a history of altitude illness. Eighty-eight percent of the

Table 3. Prerace altitude illness and demographics

Subject	Sex	Age	Home altitude	AMS-C	AMS-R	Finish
10	M	30	6	0.176	0.696	Yes
34	M	33	6	0.349	0.651	Yes
42	M	37	35	0.141	0.696	No
68	F	27	0	0.247	1.635	Yes
84	F	34	0	0.363	1.006	Yes
147	M	33	180	0.090	0.612	Yes
151	M	30	1000	0.568	0.858	No
154	F	29	600	1.529	2.323	No
221	M	35	1000	0.754	0.777	Yes
229	M	35	800	0.00	0.615	Yes
232	F	31	0	0.772	0.517	No
Mean		32.2	330	0.454	0.949	

*AMS-C indicates acute mountain sickness-cerebral; AMS-R, acute mountain sickness-respiratory.

racers treated for altitude illness re-entered the competition, whereas 11.4% withdrew voluntarily or were disqualified from further participation at the time of initial treatment. Fifty-seven percent of those treated for altitude illness completed the entire course. Table 2 shows the demographics of racers experiencing altitude illness.

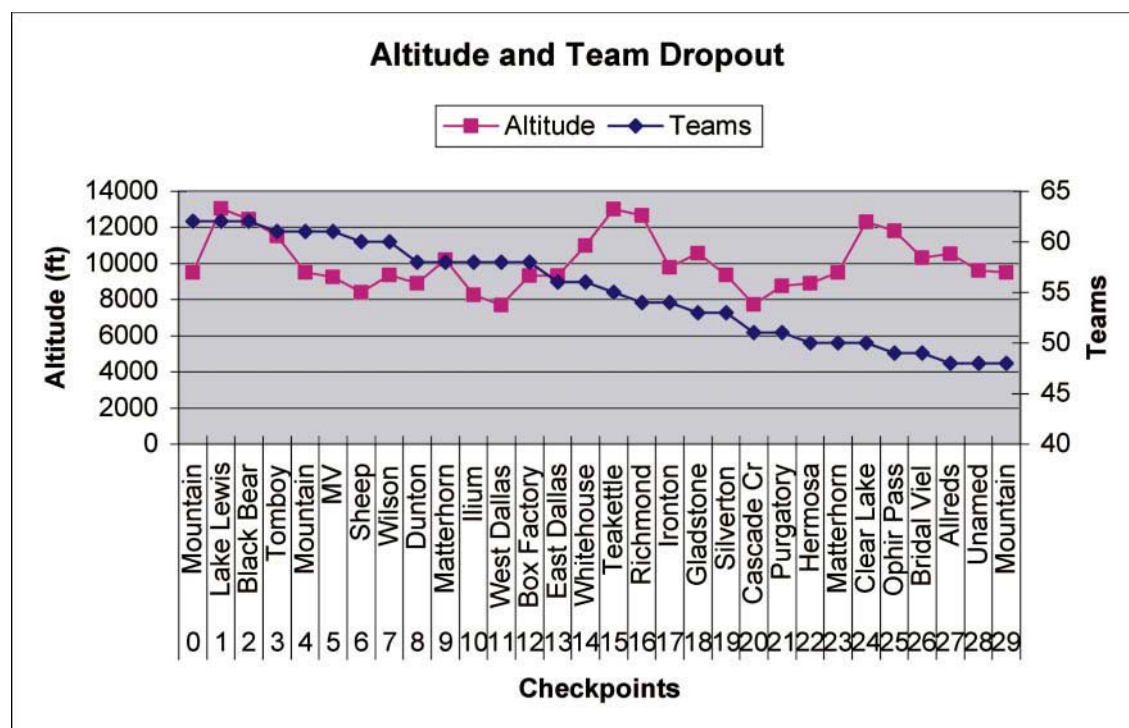
Of the 246 racers who completed the ESQ-3R 24

hours before the race, 11 (4.5%) had scores consistent with altitude illness. One racer had a score that exceeded the cutoff of 0.700 for AMS-C, 8 had a score that exceeded the cutoff of 0.600 for AMS-R, and 2 exceeded the cutoff for both AMS-C and AMS-R, suggesting that they were experiencing symptoms of altitude illness (Table 3). Seven (63.6%) of the 11 racers identified as having altitude illness by the ESQ-3R completed the race vs the overall completion rate of 73.8% ($P = .49$). Men accounted for 7 (63.6%) of 11 racers experiencing prerace altitude illness. Of those experiencing prerace altitude illness, 5 (71.4%) of the 7 men and 2 (50%) of the 4 women completed the race.

Discussion

Two hundred forty-six of 248 individuals who were eligible to participate in the study were enrolled and completed the ESQ-3R before the start of the event. There was a positive correlation between lower prerace AMS-C scores and successful race completion ($P = .026$), but AMS-R scores did not reach significance ($P = .053$).

Of the 11 racers with scores consistent with altitude illness before the race, only 7 (63.6%) finished compared with an overall completion rate of 73.8%. However, interestingly, none of those individuals who met criteria by ESQ-3R score for AMS on the prerace survey sought



Altitude and team withdrawal.

treatment for altitude illness or officially withdrew because of altitude illness.

There was an inverse relationship between prerace ESQ-3R scores and the racers' home altitude, with those residing at lower altitudes having greater average prerace AMS-C and AMS-R scores. There was no significant correlation between home altitude and race completion ($P = .80$).

Roach et al.¹³ suggest that exercise at altitude may exacerbate AMS. They found that subjects exercising at only 50% of their altitude specific workload (riding stationary bicycles in four 30-minute cycles over the first 6 hours of a 10-hour exposure at approximately 12 000 feet) had an increased incidence of altitude illness compared with those that did not exercise. In the majority of expedition length adventure races, there is a mountaineering section at high altitude. Because workloads would be expected to exceed 50%, one would anticipate a frequent incidence of altitude illness during these events. Whereas the overall incidence of altitude illness during the race is not known, only 12% of racers required medical attention for altitude illness. Because of the competitive nature of the event, teams ascend and descend rapidly, perhaps minimizing exposure to high altitude and thus not allowing severe symptoms of altitude illness to manifest. The staff providing medical support at the first high altitude section (12 000 feet), approximately 2–4 hours into the race, observed that more than 50% of the teams had individuals exhibiting signs or symptoms of AMS. Team withdrawals vs altitude statistics are shown in the Figure. It is interesting that many of the team dropouts occurred immediately after rapid ascents. However, it is unclear which of these dropouts were directly related to altitude, other factors, or a combination of both.

One limitation of the study is the reliance on self-reporting of symptoms. Symptoms of altitude illness may be confused with or confounded by other illnesses, including dehydration, heat exhaustion, and respiratory illness. A second limitation is that the diagnosis of altitude illness is somewhat subjective. All of the medical personnel for the event had experience in recognition and treatment of altitude illness. A third limitation is that the ESQ-3R was administered 24 hours before the start of the race rather than at race start. This may have allowed for some acclimatization to occur, thus affecting results. A fourth limitation is that only those requiring medical attention for altitude illness were identified, and an overall incidence of altitude illness was not determined.

Conclusion

Expedition length adventure racing continues to push the frontiers of human endurance in nature's most extreme environments. Altitude illness was prevalent in 4.5% of the racers at race start. Altitude illness requiring medical treatment during the race had an incidence of 12% and accounted for 14.3% of the medical withdrawals from the event. There was no significant correlation between ESQ-3R scores, home altitude, and successful completion of the race. Further research is required to determine the factors that contribute to the development of altitude illness during these events and to suggest avenues to reduce or modify its impact on the racer.

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