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Exertional Heat-Related Illnesses at the Grand Canyon National Park, 2004–2009

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Abstract

Background—The Grand Canyon National Park has approximately 4 million visitors between April and September each year. During this period, outdoor activity such as hiking is potentially hazardous owing to extreme heat, limited shade, and steep, long ascents. Given the high visitation and the public health interest in the effects of extreme heat, this study calculated morbidity rates and described heat-related illness (HRI) among visitors.

Methods—We conducted a retrospective cross-sectional study from April 1 through September 30, during 2004–2009. From a review of Ranger Emergency Medical Services (EMS) incident report files, we extracted information on those that met the case definition of greater than 1 hour of outdoor heat exposure with an HRI assessment or diagnosis, HRI self-report, or signs or symptoms of HRI without another etiology noted. Visitor and temperature data were obtained from respective official sources.

Results—Grand Canyon EMS responded to 474 nonfatal and 6 fatal HRI cases, with the majority (84%) being US residents, 29% from Western states. Of the nonfatal cases, 51% were women, the median age was 43 years (range, 11–83 years), and 18% reported a cardiovascular condition. Clinical HRI assessments included dehydration (25%), heat exhaustion (23%), and suspected hyponatremia (19%). Almost all (90%) were hiking; 40% required helicopter evacuation. The highest HRI rates were seen in May.

Conclusions—HRI remains a public health concern at the Grand Canyon. High-risk evacuations and life-threatening conditions were found. Majority were hikers, middle-aged adults, and US residents. These findings support the park's hiker HRI prevention efforts and use of park EMS data to measure HRI.

Keywords

heat illness; hiking; National Park; Grand Canyon; wilderness; emergency medical services

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Background

Annually, 4.4 million people visit the Grand Canyon National Park (canyon), making it one of the most visited national parks in the United States.¹ The majority visit during April through September when air temperatures can exceed 100°F (37°C) on the rim and 120°F (44°C) at the bottom of the canyon.¹⁻³ Most visitors view the canyon from the rim overlooks, although an average of 190,000 visitors camp overnight below the rim and another estimated 400,000 visitors attempt a day hike into the canyon during this period.^{2,3} The canyon's topography makes hiking extremely strenuous because of the long (7–14 miles) and steep (4,000- to 7,000-foot elevation change) trails that have sparse vegetation available for shade, limited potable water, and extreme heat during the summer months.¹ Consequently, hiking—especially below the rim—can become a potentially serious, even life-threatening event, owing to the prolonged exposure to extremely high ambient temperatures while engaged in strenuous physical activity.^{1,3,4}

Heat-related illnesses (HRI) range from heat syncope and heat cramps to the most common type, heat exhaustion.⁵⁻⁷ Heat stroke is the most serious life-threatening condition, and exertional heat stroke (EHS) has been documented among athletes, military recruits, and wilderness enthusiasts engaged in long periods of strenuous physical activity in a hot environment.^{3,5-7} Although similar to classic heat stroke in clinical presentation, EHS often results in rapid onset of severe outcomes such as hyponatremia, acute renal failure, rhabdomyolysis, disseminated intravascular coagulation, and death.⁵⁻⁷ The risk of exertional HRI may increase as a result of lack of heat and altitude acclimatization, poor conditioning, insufficient shade, advanced age, presence of a chronic disease and certain medications, and dehydration caused by significant sweat loss, inadequate water intake, or both.^{5,6} Although HRI is recognized as a serious issue at the canyon and prevention programs have been in place since 1997, the true magnitude, description, and temporal trends of the problem are not well documented.^{3,4} This study calculated rates and describes the epidemiology of HRI among visitors treated by the canyon's Emergency Medical Services (EMS) during a 6-year period to provide the park with a baseline to examine ongoing prevention programs.

Methods

STUDY DESIGN AND DATA SOURCES

This was a retrospective, cross-sectional study of HRI cases among park visitors from April 1 through September 30 of 2004–2009. A total of 5547 EMS case incident reports were identified, and after we excluded those with a clear non-HRI etiology (eg, motor vehicle crashes, upper respiratory infections), 3360 reports remained. Ranger mortality reports were reviewed for deaths associated with heat exposure. These sources captured only those incidents responded to by the National Park Service (NPS) within the park boundaries.

CASE-PATIENT IDENTIFICATION

Persons whom EMS treated (or found if deceased) were eligible for inclusion into the study if they were a visitor during the study period and had a documented outdoor heat exposure of more than 1 hour within the previous 24 hours. To be a case there need to be one of the

following documented indicator(s) of heat illness: 1) paramedic assessment of HRI; 2) self-report or phrases that indicated “heat” (eg, “overheated, dehydration”) as a contributing factor; or 3) at least 2 signs and symptoms consistent with HRI not associated with another etiology (eg, nausea and vomiting while hiking). This tiered approach was used to systematically review the EMS case incident reports, which varied in format (eg, SOAP [subjective, objective, assessment, and plan] documentation vs narratives), terminology, and completeness. Excluded from the study were canyon residents such as NPS employees, concession employees, volunteers, and family members. These groups were likely acclimatized to and more cognizant of the heat and the strenuous hiking environment.

DATA COLLECTION AND REPORTING

The 3360 files were reviewed to determine those that met the case definition (described above). Any questions on inclusion or exclusion of cases were discussed among the study team. Information on demographics, activity type, clinical assessment, and medical history was collected on a standardized form. Six age categories (<5 years, 5–17 years, 18–25 years, 26–49 years, 50–65 years, and 65 years and older) were created. Based on the state and country of residence, visitors were dichotomized into non-US residents and US residents. US residents were further categorized into the four US Census regions: West, South, Midwest, and Northeast. A categorical variable described the trail location within the canyon (eg, North and South Rim trails) where a case-patient was located by EMS.

The medical terminology of the clinical assessment(s) varied, although 8 categories emerged: dehydration, heat cramps, heat syncope, heat exhaustion, heat-related illness not specified, suspected hyponatremia, suspected rhabdomyolysis, and other (eg, suspected renal failure, heat stroke). The heat-related illness not specified category was established to collate the nonspecific HRI clinical assessment(s) such as “heat-related illness,” “heat stress,” and “heat sickness.” Because the majority of case-patients had multiple clinical assessments without a primary assessment clearly indicated, frequencies were calculated by tallying the number of times each assessment category was recorded in the study population.

Preexisting chronic medical conditions and medications that have been associated with HRI were identified. Chronic conditions were organized by the body system(s). In some of the records, current medication(s) were recorded as drug descriptor (eg, “high BP [blood pressure] pill”) rather than by a specific drug name or class. To develop a classification scheme, we used Goodman & Gilman’s pharmacology textbook *The Pharmacological Basis of Therapeutics*. Using this book’s therapeutic groupings provided a framework to assign similar medication descriptions (eg, high BP pill) and medications (eg, atenolol) into the applicable category based on specific therapeutic use (eg, “regulate cardiovascular function”). Six categories were used: 1) cardiovascular drugs and therapies, including treatment of hypertension, hypercholesterolemia, and hyperlipidemia; 2) pain medications (eg, opioids, analgesia); 3) anti-inflammatory drugs and other pulmonary pharmacology; 4) hormones (eg, thyroid drugs, diabetic drugs); 5) medication that targeted gastrointestinal function; and 6) drug therapy of depression and anxiety disorders.

VISITATION AND TEMPERATURE DATA

The total number of visitors by month and year were downloaded from the NPS visitor statistics website at <http://www.nature.nps.gov/stats/viewReport.cfm>. Using the monthly overall visitor counts as denominators, rates by month per year were calculated. Historical daily maximum temperatures were available from the National Weather Service weather stations located on the South Rim and at the canyon's base. Monthly maximum rim temperatures for each year were calculated by averaging the daily maximum temperatures for each month. The rim temperatures were used because not all cases hiked to the bottom, and therefore they were not exposed to the highest temperatures. Temperature data for June 2009 were not available.

ANALYSIS

For each study year, the rate of HRI per month was calculated per 100,000 visitors using the total number of visitors per month as the denominator. Frequencies were calculated using SAS (version 9.3; SAS Inc, Cary, NC).

Results

NONFATAL CASES

Of 5547 EMS case incident reports, 474 (8.6%) of all nonfatal cases met our case definition. The majority of cases ($n = 313$; 66.0%) were defined based on paramedic assessment of HRI or a narrative indicating heat-relatedness of the signs and symptoms (eg, "succumbed to the heat"). Another 139 (29.0%) met the definition based on signs and symptoms consistent with HRI plus a supporting narrative indicating prolonged heat exposure while engaged in extreme physical exertion (eg, "strenuous 10-hour hike," "hiked rim-to-rim today"). Twenty-three (5.0%) met the criterion of 2 or more signs and symptoms consistent with HRI (eg, "N/V [nausea and vomiting] after hiking") not associated with another etiology.

Demographic data for HRI cases are presented in Table 1. An equal proportion of males and females were found, and the median age was 45 years (range, 11–83 years). Nearly 85.0% were US residents, including 34.9% from the western region states. Residents of Arizona, California, and Colorado made up the highest proportion of HRI cases from this region (58.0%) (Table 1). The most common chronic medical condition was cardiovascular in nature, mainly hypertension and hyperlipidemia (17.5%; Table 2). Accordingly, the most common medications were those to regulate cardiovascular function (20.0%). In addition, 8.0% of the cases reported taking a prescribed medication(s) to manage an endocrine disorder (Table 2).

Activity and location of cases are shown in Table 3. Of all nonfatal HRI cases, most were engaged in hiking (90.1%) on the South Rim trails (94.0%). More than 69.1% of the nonfatal cases required evacuation assistance; of these, 40.0% were helicoptered out (Table 1). The most common EMS clinical HRI assessments of the nonfatal cases included dehydration (24.5%), heat exhaustion (23.1%), suspected hyponatremia (19.1%), and heat-related illnesses not specified (16.0%; Table 4).

The Figure shows rates of nonfatal HRI and average maximum rim temperature on the South Rim by month for each study year. Although the monthly visitation remained constant, no consistent pattern(s) appeared during the years or months in terms of HRI rate except for May of most years, which had a noticeable increase in rate. The highest HRI rate (5.31 per 100,000 visitors) was observed in May 2006 (Figure). The median spring and summertime seasonal HRI rate was 2.64 per 100,000 visitors (range, 2.34–2.86 per 100,000 visitors).

FATALITIES

Six HRI fatalities were identified, and the majority were male (83.3%) and between the ages of 26 and 49 years (33.3%) and 50 and 65 years (33.3%). All of the fatal cases were US residents and were hiking the canyon at the time of death (Table 1). No other details were available.

Discussion

During the 6-year study period, nearly 9% of all EMS encounters were identified as HRI, and the majority of the case-patients were US residents hiking the inner canyon trails on the South Rim. They tended to be middle aged, at least a quarter of the nonfatal cases had known HRI risk factors such as cardiovascular and endocrine conditions, and nearly 40% were on prescription medications to address these disorders.

Previous canyon studies have identified exertional HRI among hikers and inner canyon rangers; however, these studies focused on hyponatremia and heat exhaustion during short time periods, whereas our study identified all types of HRI treated over the course of several years.^{3,4} Other park EMS studies have indicated HRI is a common problem, although this assessment was often aggregated with other conditions and not stratified by demographics or activity. For example, a study of 8 California National Parks found “dehydration or heat stroke” to be the fifth most-common illness among visitors overall.⁸ Similarly, at Yosemite National Park from 1990 to 1999, the most common complaint treated by EMS was for “dehydration, hypovolemia, and hunger”; however, it was unclear whether these were related to heat or overexertion, and no demographics or other information were presented.⁹ Interestingly, among our cases, the frequency of HRI was highest among Arizona, California, and Colorado residents, which could be a reflection of a greater frequency of these regional visitors; however, one would assume they should be better informed and aware of the extreme heat and topography of the canyon compared with other visitors. Most HRI cases were treated on the most popular and easily accessible below-the-rim trails on the South Rim. The majority of evacuations were by helicopter, which may be a sign of the severity of the patient’s condition or the remote and austere environment. These findings support the existing prevention strategies to target hikers on South Rim trails, especially during the summer months when the South Rim usage is the heaviest by tour operators and the average visitor.¹

As seen in other heat studies, we noted a rate increase in May; this is often explained as a lack of acclimation to heat at the beginning of summer.^{5,6} Acclimatization improves the body’s ability to adapt to hot environments through increasing the sweat rate and decreasing electrolyte loss, resulting in better heat tolerance.⁷ Improved fitness and acclimatization

training is an effective HRI prevention strategy for visitors, and NPS should consider highlighting these on their hiking webpage.¹ The prevalence of cardiovascular and endocrine conditions, as well as corresponding use of medication for these disorders among the HRI cases, are important findings as these are known risk factors for HRI.⁷ In hot environments, both cardiovascular disease and certain medications (eg, β -adrenergic blocking agents, diuretics) can impact the body's ability to sufficiently increase cardiac output needed to dissipate heat via peripheral vasodilation.⁷ Visitors with chronic medical conditions might consider consulting with their medical provider when planning a canyon hiking trip.

LIMITATIONS

There are some important limitations of this study; the accuracy of the paramedic clinical HRI assessments is uncertain without diagnostic confirmation from a medical provider or laboratory examination. However, previous canyon studies found that 10% of EMS encounters were for HRI.³ Misclassification of heat relatedness might have occurred, although most had narratives documenting prolonged exercise and extreme heat exposure (eg, 10 hours of hiking, 120°F). In addition, our study's annual number of HRI cases and proportion of these to the total EMS encounters were consistent with previous internal heat summary audits compiled by the canyon's EMS. To assist in systematic screening of the files, we used a table of HRI conditions with corresponding signs and symptoms published by the National Athletic Trainers' Association, which included exertional hyponatremia.^{3,6} We recorded rhabdomyolysis as we knew that EMS was documenting if they suspected this outcome. Additional cases were missed if they directly sought medical care at the park's clinic; therefore, we likely underestimated the true HRI burden. Several park studies have used the EMS clinical assessment to determine the incidence of injuries and illnesses despite the difficulty and overlap in clinical impression inherent in prehospital preliminary examinations.¹⁰ A study of HRI cases seen in the canyon's clinic and surrounding area hospitals is warranted. We anticipate that this study will encourage other parks with extreme heat (eg, Death Valley) to examine their EMS data for HRI to better understand the problem, improve medical services including assessment and documentation of HRI, and target prevention strategies.

Conclusions

HRI among hikers remains a public health concern at the Grand Canyon National Park. High-risk evacuations and life-threatening conditions were identified. Across the United States, exposure to extreme heat is a growing national concern. And for this reason, NPS understands that the HRI burden and identification of those requiring EMS assistance is important—both to improve service delivery and to target specific park messaging throughout the park system.

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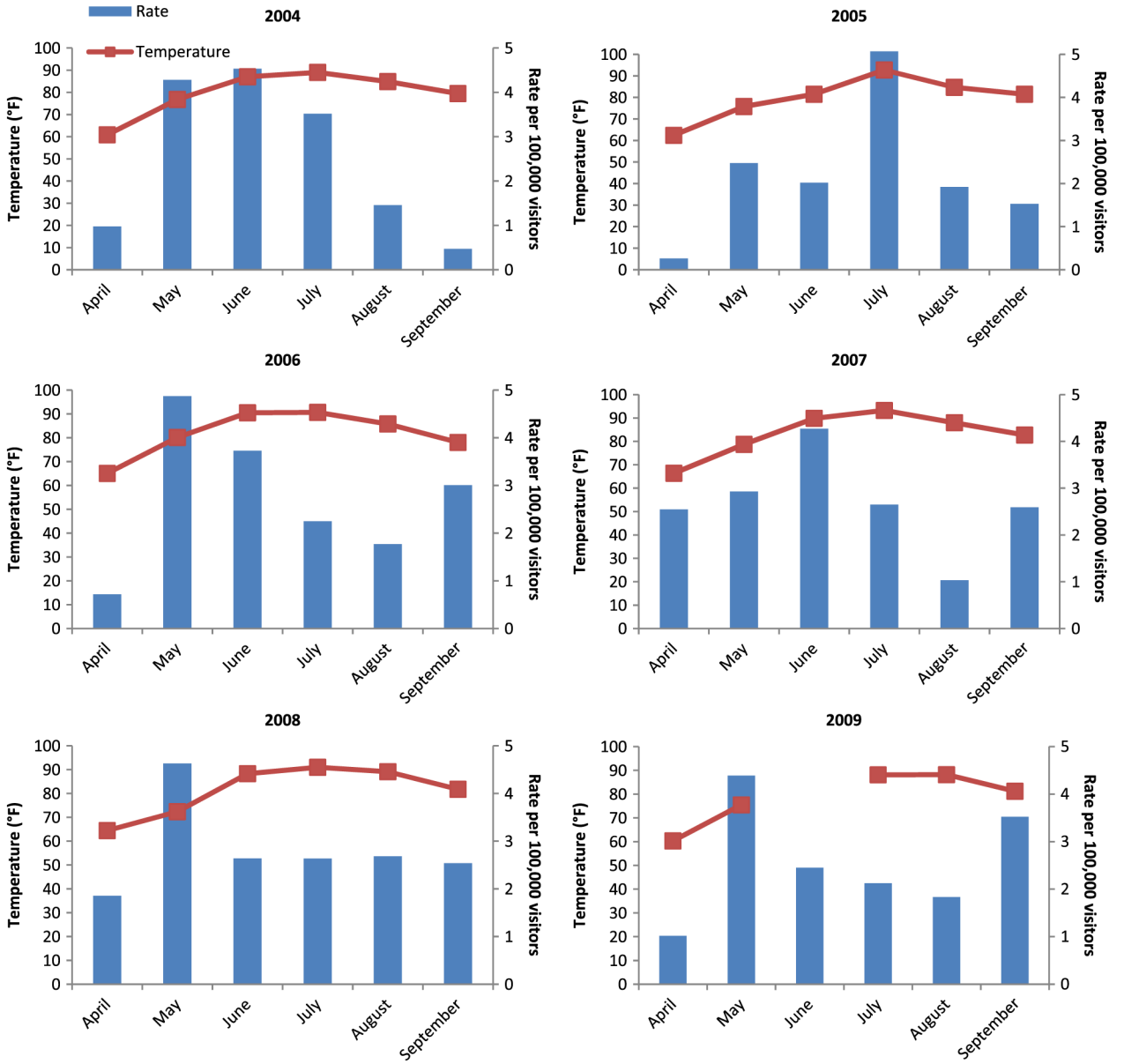


Figure. Rate of nonfatal heat-related illness (bars) and average maximum on-the-rim temperature (dots connected with lines) by month, Grand Canyon National Park, April through September, 2004–2009.

Table 1

Demographics and evacuation status of nonfatal heat-related illness cases at the Grand Canyon National Park, April through September, 2004–2009 (n = 474)

Variable	Number	Percent ^a
Sex		
Female	240	50.63
Male	234	49.37
Age category (years)		
<5	0	0
5–17	26	5.66
18–25	70	15.25
26–49	174	37.91
50–65	142	30.94
65	47	10.24
Citizenship		
US resident	400	84.39
Non-US resident	74	15.61
US Census (region ^b)		
West	193	34.92
South	109	27.39
Midwest	98	24.62
Northeast	52	13.07
Evacuation method		
Helicopter	188	39.66
Walk-assisted	111	23.42
Other (eg, mule, litter carry)	32	6.75
No evacuation reported (eg, not applicable, missing)	79	16.66
Refused additional treatment (AMA)	64	13.50

^aOwing to missing values, percentage will not add up to 100%.

^bFor those who were US residents, by US Census regions: Northeast region (CT, ME, MA, NH, RI, VT, NJ, NY, PA); Midwest region (IL, IN, MI, OH, WI, IA, KS, MN, MO, NE, ND, SD); South region (DE, DC, FL, GA, MD, NC, SC, VA, WV, AL, KY, MS, TN, AR, LA, OK, TX); and West region (AZ, CO, ID, MT, NV, NM, UT, WY, AK, CA, HI, OR, WA).

Table 2

Medical conditions and prescription medications of nonfatal heat-related illness cases, Grand Canyon National Park, April through September, 2004–2009 (n = 474)

Variable	n	%
Chronic Medical Conditions		
Cardiovascular (eg, HTN, hyperlipidemia)	83	17.47
Endocrine (eg, diabetes, thyroid)	39	8.21
Gastrointestinal/gastrourinary	25	5.26
Respiratory (eg, COPD, asthma)	24	4.84
Muscular skeletal (eg, orthopedic conditions)	22	4.63
At-risk conditions for HRI (eg, past HRI, mental health conditions, anemia, acute infection)	25	5.26
Other (eg, cancer, migraine)	27	5.68
Drug Therapeutics Categories		
Cardiovascular drugs (eg, HTN, hyperlipidemia)	96	20.21
Hormones (eg, estrogen, diabetes medications including insulin, thyroid, oral/inhaled steroids)	77	16.21
Pain medication (eg, analgesia, nonsteroidal, opioids, migraine)	30	6.32
Anti-inflammatory (eg, histamine, nonsteroidal pulmonary drugs)	25	5.26
Drug therapy for depression and anxiety disorders	19	4.00
Gastrointestinal medication (eg, GERD, antiemetic)	16	3.37
Other drugs (eg, antibiotics, acne meds, bone density, multi-vitamins)	33	6.95

COPD, chronic obstructive pulmonary disease; GERD, gastroesophageal reflux disease; HRI, heat-related illness; HTN, hypertension.

Table 3
 Activity engaged by nonfatal heat-related illness cases at onset of illness and location of incident, Grand Canyon National Park, April through September, 2004–2009 (n = 348)

Location	Activity type, n (%)					Total
	Hiking	Walking	Rafting on river	Mule riding	Other (eg, biking)	
All locations	346 (90.10)	15 (3.91)	9 (2.34)	10 (2.60)	4 (1.04)	348 (100.00)
South Rim						
Inner canyon trails	328 (85.42)	0 (0.00)	0 (0.00)	10 (2.60)	0 (0.00)	338 (88.02)
Rim trails	3 (0.78)	15 (3.91)	0 (0.00)	0 (0.00)	4 (1.04)	22 (5.73)
North Rim						
Inner canyon trails	13 (3.39)	0 (0.00)	0 (0.00)	0 (0.00)	0 (0.00)	13 (3.39)
River	2 (0.52)	0 (0.00)	9 (2.34)	0 (0.00)	0 (0.00)	11 (2.86)

Missing data = 126 nonfatal heat-related illness cases with no information on location and activity.

Table 4

Paramedic assessments of visitors with heat-related conditions, Grand Canyon National Park, April through September, 2004–2009 (n = 474)

Paramedic assessments ^a	n	%
Dehydration	116	24.47
Heat exhaustion	109	22.99
Hyponatremia-suspected	90	18.98
Heat-related illness (HRI) not specified ^b	74	15.61
Heat cramps	12	2.53
Heat syncope	9	1.89
Rhabdomyolysis-suspected	7	1.47
Other (suspected renal failure, heat stroke)	37	7.80

^aMore than one diagnosis per person.

^bThe HRI not specified category was established to collate assessments such as “heat sickness,” “HRI,” “heat-illness,” and other nonspecific HRI terms.