ORIGINAL RESEARCH

Viewing Lava Safely: An Epidemiology of Hiker Injury and Illness in Hawaii Volcanoes National Park

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Objective.—To report the injuries and illnesses encountered by wilderness hikers in Hawaii Volcanoes National Park attempting to hike to active lava flows and to investigate the roles that demographics, prior hiking experience, hiking behavior, and preparedness play in hiker vulnerability to injury and illness.

Methods.—During an 8-week period, daily on-site exit interviews of lava hikers were conducted by a uniformed park ranger and park volunteer. Information about the hiker's home residence, wilderness hiking experience, preparedness, health status, and health problems encountered during the hike was collected from a total of 804 hikers.

Results.—A high rate of injury and illness was found among the study population. Scrapes and abrasions (59%), blisters (51%), and muscle strains and sprains (47%) were the most common injuries. Dehydration (77%) and respiratory irritation (46%) were the most common illnesses. Lower extremities were the most common site of injuries, and beginning hikers were the most vulnerable to injury and illness. Many hikers were inexperienced tourists willing to disregard warning signs and enter high-risk areas.

Conclusions.—Hawaii Volcanoes National Park is one of 22 US national park units with volcanic resources. The injuries and illnesses reported by the study group identify the impact that this type of environment can have on the safety of wilderness users in areas with similar resources. Recreating in remote and severe areas has inherent risks, but the high rate of injuries and illnesses sustained by the hikers of this study can potentially be reduced through the development of more direct risk management methods.

Key words: wilderness, recreation, hiking, lava, risk, injury, illness, tourist

Introduction

Recreating in wilderness environments entails a degree of risk that is difficult to remove. Indeed, outdoor and wilderness activity exposes individuals to injury and illness.¹ As more people participate in outdoor and wilderness activities in more severe and remote areas, it is inevitable that there will be an increase in accidents, injury, and illness in these environments.² During the past 10 years, hiking to active lava flows has become an increasingly popular activity among visitors to Hawaii Volcanoes National Park. This activity requires participants to hike long distances over sharp and rugged basaltic terrain underlined by unseen lava tubes. Additionally, hikers expose themselves to dense volcanic fumes,

extreme weather conditions, scorching heat from active lava flows, hydrochloric steam explosions that can shower coastal areas with hot spatter and tephra, and frequent coastal land collapses.

Many of the lava hikers do not have the requisite wilderness skills. As a result, injuries and illnesses requiring first aid and medical attention are common. Additionally, in recent years, there have been 5 known mortalities to lava hikers. The increasing interest in hiking to active lava flows and the resultant number of injuries and illnesses represent an emerging issue for park managers and health care professionals. Thus, the situation warrants research and management attention. To address this issue, this study reports the injuries and illnesses encountered by lava hikers at Hawaii Volcanoes National Park and investigates the role that demographics, prior hiking experience, hiking behavior, and hiker preparedness play in hiker vulnerability to injury and illness.

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Materials and Methods

The setting for this study was the eruption site in Hawaii Volcanoes National Park. Located 28 miles from the park visitor center, the eruption site is a lava field where active lava flows from the ongoing 1983 eruption of the Pu'u 'O'o Vent have covered 16 km of the Chain of Craters Road and destroyed 181 homes and buildings in the Royal Gardens subdivision. The active lava flows in the area are dynamic, and the hiking distance to lava flows and ocean entries where lava pours into the Pacific Ocean varies. Prior to entering the lava field, hikers pass 3 large signs warning them of extreme danger when hiking in coastal areas and recommending that each hiker carry at least 3 L of water, wear sturdy shoes and a hat, and carry a flashlight if hiking after dark. Additional signs warning hikers of immediate danger are also posted 0.5 km from the ocean entry where the land becomes unstable and lava flowing into the sea creates a hydrochloric acid plume laced with glasslike silica particles. At the time of this study, no marked trails existed on the lava field beyond a 300-m overlook area.

The study was carried out during an 8-week period between mid-June and mid-August 2001. On a daily basis, a uniformed park ranger and park volunteer conducted on-site interviews of every third lava hiker departing the eruption site or receiving first aid attention between 1300 and 2100 hours. The total study sample consisted of 804 hikers, all of whom had just completed a 4- to 10-km round-trip hike over a rugged volcanic landscape. The information collected was based on questions about the hiker's residence, wilderness hiking experience, preparedness, health status, and health problems encountered during the hike. The injuries and illnesses reported by the hikers were confirmed by a park ranger or park medic. All of the information collected from the hikers was coded and entered on SPSS/PC 11.0 software. Chi-square analysis was used to determine whether there were significant differences between beginning, novice, and experienced hikers and the frequency with which they sustained injuries and illnesses.

Results

DEMOGRAPHICS

Of the 804 hikers in the study population, 63% were male and 37% were female. The mean age of the hikers was 39 years ($SD = 6.2$; range, 7–89 years). The study population consisted primarily of hikers from North America, Europe, Asia, and Hawaii (Figure 1; Table 1).

Figure 1. Primary residence of lava hikers.

Of the North American hikers, the most commonly reported residences were California, Texas, New York, Illinois, New Jersey, Florida, and Colorado. The most common European residences were Germany and England, followed by Switzerland, Austria, the Netherlands, and Poland. Eighty-one percent of the Asian hikers were Japanese, and 56% of the hikers residing in Hawaii were US military personnel temporarily based on the island of Oahu.

WILDERNESS HIKING EXPERIENCE AND BEHAVIOR

More than half of the study population (52%) were beginning hikers with no previous experience in wilderness areas. Another 31% were novice hikers with 1 to 5 previous hikes in wilderness areas, and 17% were experienced hikers with more than 5 previous hiking trips. Only 12% of the hikers reported having previous experience on volcanic terrain. The volcanic landscapes that hikers with previous experience reported hiking were Mount Etna in Italy, Craters of the Moon National Monument in Idaho, Mount Fuji and Asama Volcano in Japan, Mount Semeru in Indonesia, and Mount Saint Helens in Washington. A total of 301 (37%) hikers reported shortening their hike either for health-related reasons or because they underestimated the difficulty and nature of the hike. Of the 503 hikers (63%) who completed the hike, 93% reported hiking beyond the warning signs posted 0.5 km from the ocean entry.

PREPAREDNESS OF LAVA HIKERS

Most lava hikers were unequipped for the hike. Only 17% of the hikers carried a first aid kit with them; 73% carried less than 1 L of water or electrolyte replacement, and many wore inappropriate footwear. Only 14% of the hikers wore appropriate hiking boots; 7% wore dress shoes or high heels, 22% wore sandals, and 57% wore

Table 1. State or country of residence reported by lava hikers; $n = 804$

	<i>n</i>	<i>Total study population, %</i>
North America		
California	137	17
Texas	52	6
New York	31	4
Illinois	29	4
New Jersey	28	3
Florida	25	3
Colorado	21	3
Other	184	23
Subtotal	507	63
Europe		
Germany	39	5
England	32	4
Switzerland	17	2
Austria	15	2
The Netherlands	10	1
Poland	8	1
Subtotal	121	15
Asia		
Japan	62	8
South Korea	10	1
Taiwan	5	<1
Hong Kong	3	<1
Subtotal	80	10
Hawaii		
Oahu	46	6
Hawaii	19	2
Maui	5	1
Kauai	1	<1
Molokai	1	<1
Subtotal	72	9
Other		
Australia	8	1
New Zealand	8	1
Israel	6	1
Brazil	2	<1
Subtotal	24	3

running shoes. Although many of the lava hikers did carry sunscreen (88%) and flashlights (63%), less than half of the hikers wore long pants (37%), wore a hat (38%), carried raingear (21%) and extra batteries (16%), and had protective gloves (3%). In addition, only 24% of the hikers reported reading warning and information signs posted at the trailhead or speaking with park rangers prior to beginning the hike.

Figure 2. Injuries and illnesses reported by lava hikers.

HEALTH STATUS

When questioned about their perceived state of health prior to beginning their hike, 38% of the lava hikers described themselves as being in excellent health, 54% described themselves as being in fair shape, and 8% described their health as poor. In response to questions about the preexisting medical conditions they were concerned with prior to starting their hike, 37% of the hikers indicated they were suffering from traveler's diarrhea, 29% reported having cardiac concerns and were taking medication for high blood pressure or high cholesterol, 22% indicated that they were asthmatic or had other related respiratory problems, and 4% were pregnant. Other self-reported conditions were insect bites (15%), arthritis (12%), sunburns (11%), sprained ankles (8%), headaches or migraines (7%), depression (7%), intoxication (5%), and broken bones (3%).

HEALTH PROBLEMS ENCOUNTERED

Injuries and illnesses were common among the hiking population (Figure 2), and many hikers sustained multiple injury and illness events. A total of 471 (59%) hikers suffered scrapes and abrasions, and 403 (51%) de-

Figure 3. Anatomic location of injuries to lava hikers.

veloped blisters. Other common injuries were musculoskeletal problems, including muscle strains and sprains (47%), sunburns (39%), and lacerations (27%). Fifty-one (6%) of the hikers sustained broken bones, 37 (5%) received thermal burns from lava or hot water near the ocean entry, and 22 (3%) sustained dislocations. Lower-extremity regions accounted for most of the injuries; the next most common injuries were to the axial and upper-extremity regions (Figure 3).

The most common illnesses encountered by the lava hikers were dehydration (77%), respiratory irritation (46%), and headaches or migraines (38%). A total of 102 (13%) hikers experienced eye irritations from strong winds, volcanic fumes, or particles in the air near the ocean entry. Another 29 hikers (4%) experienced asthma attacks, 23 (3%) experienced heat strokes, and 3 (0.4%) experienced cardiac distress.

Chi-square analysis indicated a significant difference between hiker experience and the rates at which they suffered injuries and illnesses (Tables 2 and 3). Beginning hikers were significantly more vulnerable to injuries and illnesses than were novice and experienced hikers. Of 472 reported injuries, 331 (70%) were reported by beginning hikers, 124 (26%) were reported by novice hikers, and 17 (4%) were reported by experienced hikers. As well, of 622 reported illnesses, 382 (61%) were reported by beginning hikers, 187 (30%) were reported by novice hikers, and 53 (9%) were reported by experienced hikers.

Discussion

Hawaii Volcanoes National Park is one of 22 US national park units with volcanic resources. Hiking to active lava flows within Hawaii Volcanoes National Park can be a demanding activity and is best pursued by those who are active, experienced, prepared, and informed. Unfortunately, most of the hikers of this study were inexperienced, unprepared, and uninformed. As a result,

Table 2. Chi-square analysis of the overall rate of injury by hiker experience*

	<i>Beginner</i>		<i>Novice</i>		<i>Experienced</i>	
	<i>No.</i>	<i>%</i>	<i>No.</i>	<i>%</i>	<i>No.</i>	<i>%</i>
Injured	331	79	124	50	17	12
Not injured	87	21	126	50	119	88

* $\chi^2 = 213.45$; $df = 2$; $P = .001$.

the described hiking population experienced high rates of injury and illness.

The level of prior hiking experience was a factor influencing injury and illness rates among the hiking population. Beginning hikers with no previous experience in wilderness areas accounted for more than half of the hiking population and were the most vulnerable to injury and illness. Of further concern was the willingness of many hikers to hike beyond posted warning signs near active lava flows and to expose themselves to immediate and dangerous conditions. In addition, only a small percentage of hikers took the time to read the warning signs at the trailhead informing them of the danger when entering coastal areas, the importance of carrying at least 3 L of water per person to prevent dehydration and heat exhaustion, the need to wear adequate footwear to prevent falling, and the need to carry flashlights if hiking in the dark.

Further influencing the high rates of injury and illness was the small percentage of hikers who had experience on volcanic terrain and the relatively large number of hikers who had preexisting health conditions such as traveler's diarrhea, making them more vulnerable to dehydration and heat exhaustion. In addition, the demographic data indicate that nearly all of the lava hikers were tourists or temporary residents of Hawaii. Previous studies of morbidity and mortality among tourist populations have found that most tourist accidents occur because tourists are unfamiliar with their surroundings, are of a holiday mind-set, and are more willing to take risks.³⁻⁶ Many of the lava hikers commented that they

Table 3. Chi-square analysis of the overall rate of illness by hiker experience*

	<i>Beginner</i>		<i>Novice</i>		<i>Experienced</i>	
	<i>No.</i>	<i>%</i>	<i>No.</i>	<i>%</i>	<i>No.</i>	<i>%</i>
Ill	382	91	187	75	53	39
Not ill	36	9	63	25	83	61

* $\chi^2 = 150.57$; $df = 2$; $P = .001$.

did not plan for hiking when traveling to Hawaii and expressed a sense of safety when deciding to hike within the national park. This suggests that the lava hikers were unprepared for the hike, were unfamiliar with the area they were entering, and had a false perception of safety solely because they were in a national park.

The data collected in this study include all injuries and illnesses sustained by the hikers immediately during their hiking experience rather than only the more severe incidents commonly recorded in national park records. However, the findings of this study are still comparable with epidemiologic research in other national parks and wilderness areas. For example, even though the overall rate of injury and illness was lower than in the present study, a retrospective study of morbidity and mortality in 8 national park units in California also found a prevalence of musculoskeletal or soft-tissue injuries, with the lower extremities being the most common site of injury.^{7,8} As well, many of the injuries in the 8-park study were the result of common activities, such as hiking and walking, and problems such as dehydration, shortness of breath, and pain without trauma were common.⁸ In another study from Sequoia and Kings Canyon national parks, researchers further found extremity trauma to be the most common complaint, abrasions and lacerations the most common provisional diagnosis, and falling and tripping the most common mechanism of injury.⁹

The injuries and illnesses sustained by the lava hikers identify the impact that this type of environment can have on the safety and well-being of wilderness users, not only in Hawaii Volcanoes National Park but also in wilderness areas around the globe with similar resources. Wilderness recreation has inherent risks, and, regardless of the level of experience and preparation, injuries and illnesses can occur. However, the findings of this study indicate that inexperience increases hiker vulnerability. While the public needs to assume a degree of risk when recreating in severe and remote areas, future research investigating different methods that would help the personnel at Hawaii Volcanoes National Park reduce the high rates of injury and illness sustained by lava hikers would be beneficial. Because the hikers have shown a

tendency to ignore and overlook information provided on signs, more direct methods that communicate the risks and hazards lava hikers will face may be more appropriate. Such methods could involve more personal contact between park staff and lava hikers at the eruption site prior to the start of any hike and focus on hikers that appear to be inexperienced, unprepared, and unaware of the health challenges they will face. In addition, communication of the health risks present at the eruption site by park officials at the entrance to the park and inside the park visitor center could potentially help reduce the number of injury and illness events at the eruption site. This may be a challenge for a chronically underfunded and understaffed agency such as the National Park Service, but without the development of better risk management methods, the increasingly popular activity of hiking to active lava flows will continue to yield high injury and illness rates.

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