BRIEF REPORT

Lightning Safety Awareness of Visitors in Three California National Parks

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Objective.—To assess the level of lightning safety awareness among visitors at 3 national parks in the Sierra Nevada Mountains of California.

Methods.—A 12-question, short answer convenience sample survey was administered to participants 18 years of age and over concerning popular trails and points of interest with known lightning activity. There were 6 identifying questions and 5 knowledge-based questions pertaining to lightning that were scored on a binary value of 0 or 1 for a total of 10 points for the survey instrument. Volunteers in Fresno, California, were used as a control group. Participants were categorized as Sequoia and Kings Canyon National Park (SEKI), frontcountry (FC), or backcountry (BC); Yosemite National Park (YNP) FC or BC; and Fresno. Analysis of variance (ANOVA) was used to test for differences between groups.

Results.—467 surveys were included for analysis: 77 in Fresno, 192 in SEKI, and 198 in YNP. National park participants demonstrated greater familiarity with lightning safety than individuals from the metropolitan community (YNP 5.84 and SEKI 5.65 vs Fresno 5.14, $P = .0032$). There were also differences noted between the BC and FC subgroups (YNP FC 6.07 vs YNP BC 5.62, $P = .02$; YNP FC 6.07 vs SEKI FC 5.58, $P = .02$). Overall results showed that participants had certain basic lightning knowledge but lacked familiarity with other key lightning safety recommendations.

Conclusions.—While there are statistically significant differences in lightning safety awareness between national parks and metropolitan participants, the clinical impact of these findings are debatable. This study provides a starting point for providing educational outreach to visitors in these national parks.

Key words: backcountry, lightning, national parks, California, education

Introduction

The National Oceanic and Atmospheric Administration (NOAA) ranks California 48th on their cloud-to-ground flash density list, with only 0.5 flashes per square mile annually; it boasts the same weighted rank among states with only 0.02 deaths per million inhabitants.¹ Nevertheless, since 1959, California has seen 30 lightning-induced fatalities, including 2 in 2009. In comparison, Florida, which has the highest cloud-to-ground density in the United States, recorded 5 in 2009.¹ Lightning in California occurs predominantly along the Sierra Nevada mountain range.² That range holds popular destinations for outdoor enthusiasts, including Sequoia and Kings

Canyon National Parks (SEKI) and Yosemite National Park (YNP).

NOAA maintains a national database detailing activities of individuals suffering a fatal lightning injury. These activities include occupying a ball field; boating; camping; golfing; being in water or outside in open areas; using a telephone; and being under a tree. For the past 7 years, the top 2 activities associated with lightning fatalities were being caught outside in an open space, and seeking refuge under an isolated tree.¹

Many agencies, including NOAA, the American Red Cross, the National Weather Service (NWS), and the American Meteorological Society (AMS) have created recommendations for lightning safety and have conducted awareness campaigns for the public. Some of the recommendations that relate to outdoor activities include: know and utilize a lightning safety rule for seek-

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ing shelter or evacuating threatening areas; avoid standing under an isolated tree or being the tallest object in an open field; get out of lakes, rivers, and swimming pools; remain in a safe shelter or a closed automobile if available; stay away from metal objects; and, if caught in the open with a group of people, spread out.^{3–5}

Although many of these recommendations make common sense, with an average of 60 deaths in the United States due to lightning each year, it is evident that people too often fail to recognize and respond appropriately to thunderstorms.¹ High profile cases in the California national parks, such as the Boy Scout troop struck by lightning in SEKI in 2005, and the 5 men injured or killed by lightning on the top of Half Dome in YNP in 1985, remind the public of lightning's presence in the Sierra Nevada. Still, throngs of people continue to flock to these parks; during 2008, SEKI and YNP drew over 4.9 million visitors.⁶ Easier access, more park accommodations, and advances in outdoor equipment have brought more people to these parks, but it may have also reduced the proportion of these individuals who are prepared for the environment they have chosen to enter. Limited research exists on the best way to educate these visitors on how to be safe in areas prone to lightning storms.⁶

The purpose of this study is to assess lightning safety knowledge of YNP and SEKI visitors in comparison to an average metropolitan population. This information will help gauge where knowledge deficits exist and help target where an educational intervention would be most useful.

Methods

This study is a convenience sample survey conducted during July and August in 2009.

SURVEY DESIGN

The survey was designed to be given in less than 2 minutes to English-speaking visitors. It was created using recommendations on lightning safety from NOAA, NWS, and AMS. Lightning-related incidents in YNP and SEKI were also reviewed, looking for common patterns that could be addressed in the survey. This is a non-validated survey designed to assess the particular environments of the 3 national parks studied.

FIELD SITE SELECTION

Five predetermined vicinities of interest, consisting of YNP's and SEKI's frontcountry (FC) and backcountry (BC), and Fresno, California, were identified in which to

conduct this study. A surveyor, who was a fourth-year medical student with wilderness experience, received education on lightning and was familiarized with the survey and the correct answers to all questions. He was then stationed at multiple points of interest throughout each locality and collected a convenience sample of visitors. The same surveyor interviewed all participants.

The national parks' frontcountry is composed of outdoor areas that may be easily accessed by vehicles and mostly visited by single-day users. The FC often has modern conveniences like easy road access, running water, cell phone coverage, and developed campgrounds. The BC is a geographic area that is isolated, underdeveloped, and generally inaccessible by vehicles. Backcountry hiking is entered with greater effort and by longer hikes in distance and time. The BC is typically accessed by hiking a day or more, and overnight sites lack significant amenities. The NPS uses similar definitions for FC and BC and allocates resources accordingly.

To gather a broad sampling and to maximize exposure to pedestrian traffic in lightning-prone areas in the national parks, sites were chosen with the aid of park rangers (see Table 1). Surveys for the comparison group were collected in popular public areas, including 2 local

Table 1. Survey locations in Sequoia and Kings Canyon National Park and Yosemite National Park

	<i>Yosemite National Park</i>	<i>Sequoia and Kings Canyon National Park</i>
Frontcountry	Happy Isles Trail Mist Trail Upper Yosemite Falls Trail Yosemite Village Camp Four North Pines Campgrounds Curry Village Royal Arches Yosemite Camp Backpackers Camp	Lodgepole Cedar Grove Kings Canyon General Sherman Tree General Grant Tree Moro Rock
Backcountry	Half Dome Trail Little Yosemite Valley Cloud's Rest Trail John Muir Trail	Whitney Portal Mount Whitney Mount Whitney Outpost Camp Whitney Trail Outpost Camp Trail Camp Portions of the Mount Whitney Trail

Table 2. Demographic information for Fresno, Yosemite National Park, and Sequoia-Kings National Park sample population

	<i>Fresno</i>	<i>YNP</i>	<i>SEKI</i>
Mean Age	35 (95 CI, 32.1-37.9)	35.4 (95 CI, 33.5-37.3)	39 (95 CI, 37.2-40.8)
Men	43	132	132
Women	31	64	60

malls in Fresno, a city of approximately 500 000 people in the central valley of California.

PARTICIPANTS

All people traveling through the area where the surveyor was located who were over 18 years old and able to complete a survey that was written in English were eligible for inclusion in the study. Volunteers were asked to answer questions on lightning awareness. Additionally, they were asked to provide demographic information, as well as intended camping itinerary and hiking activities while in the parks.

PROCEDURE

Participants were either provided a copy of the survey or, if preferred, it was read to them. Upon completion of the survey, answers were verified by the surveyor, and explanations of the correct answers were verbally provided. Answers were based on established recommendations from the NOAA, NWS, and AMS. Participant answers were assigned a binary value, 0 or 1, for survey questions 9 through 12. A point was assigned for each correct response. Overall, 10 points were assigned to the survey instrument. The survey with the accepted answers is shown in the supplemental Appendix (available online at www.wemjournal.org).

The study was approved by the Community Regional Medical Center Institutional Review Board in Fresno, California, and by the review boards of YNP and SEKI.

STATISTICAL ANALYSIS

All data collected were entered into an Excel database (Microsoft 2007, Microsoft Corporation, Redmond, WA) and then imported into SAS (version 9.1, Cary, NC) for analysis and into GraphPad for graphical representation (GraphPad Prism 5.03, GraphPad Software, La Jolla, CA). Survey questions were equally weighted in the analysis, totaling 10 possible points. Results were tabulated by location of major groups, city versus wilderness, and sub-groupings, specific national park and location within the national park. One-way ANOVA was calcu-

lated for each location and within each park, and compared to the front and backcountry of each park.

Results

A total of 467 individuals completed the survey. Participants' mean age was similar in all groups, but more men participated in the survey in the national parks when compared to volunteers in Fresno (see Table 2). A breakdown of the numbers of respondents in each location and the results of the survey are displayed in Table 3.

There was a slight difference when comparing overall survey responses in the urban setting versus the national parks (YNP 5.8, SEKI = 5.7, Fresno = 5.1, $P = .0032$). Comparisons within and between the parks also revealed some disparity in knowledge; there was a difference between FC and BC responses for YNP (6.1 and 5.6, $P = .02$) and between FC in YNP and SEKI (6.1 and 5.6, $P = .02$). Although these findings were statistically significant, their practical relevance is questionable and may be due to the large sample size or the statistical methods used.

Discussion

The results of the survey demonstrated that most subjects had basic lightning awareness about avoiding an isolated tree, water, and metal objects. Participants in the national parks were more aware that lightning is most likely to strike in the afternoon in the Sierra Nevadas than their urban counterparts, and they were also more aware of the relative safety of a thick grove of trees. All groups lacked knowledge of a basic lightning safety rule, such as the 30-30 rule: When you see lightning, count the time until you hear thunder; if this time is 30 seconds or less, seek proper shelter; wait 30 minutes or more after hearing the last thunder before leaving shelter. They were also unfamiliar with the recommended position to take when caught in the open during a thunder storm.

There was also a pervasive lack of awareness that seeking shelter in a small cave or group huddling can actually increase the chance of lightning injury. Small caves can conduct lightning ground current and cause injury to those seeking shelter and, although it is a

Table 3. Correct survey responses by location (first number listed is raw number of individuals who answered correctly and the number in parenthesis is the percentage)

<i>Questions</i>	<i>Fresno</i> <i>No. (%)</i> <i>(n = 77)</i>	<i>YNP</i> <i>No. (%)</i> <i>(n = 198)</i>	<i>YNP FC</i> <i>No. (%)</i> <i>(n = 98)</i>	<i>YNP BC</i> <i>No. (%)</i> <i>(n = 100)</i>	<i>SEKI</i> <i>No. (%)</i> <i>(n = 192)</i>	<i>SEKI FC</i> <i>No. (%)</i> <i>(n = 106)</i>	<i>SEKI BC</i> <i>No. (%)</i> <i>(n = 86)</i>
Time of Day Lightning Strikes	35 (45)	150 (76)	64 (65)	86 (86)	160 (83)	82 (77)	77 (90)
Lightning Safety Rule	2 (3)	8 (4)	5 (5)	3 (3)	10 (5)	5 (5)	4 (5)
Objects/Situations to Avoid:							
a. An isolated tree	61 (79)	184 (93)	90 (92)	94 (94)	175 (91)	98 (92)	77 (90)
b. Water	62 (80)	149 (75)	83 (85)	66 (66)	129 (67)	77 (73)	51 (59)
c. Metal objects	70 (91)	188 (95)	91 (93)	97 (97)	179 (93)	98 (92)	80 (93)
d. A thick grove of trees	45 (58)	158 (80)	79 (81)	80 (80)	146 (76)	78 (74)	68 (79)
e. A hard top car	53 (69)	127 (64)	66 (67)	60 (60)	125 (65)	76 (72)	49 (57)
f. Huddling with other members of your group	32 (42)	81 (41)	51 (52)	31 (31)	71 (37)	35 (33)	36 (42)
g. Small caves	19 (25)	42 (21)	23 (23)	19 (19)	36 (19)	16 (15)	21 (24)
Body Position	18 (23)	69 (35)	43 (44)	26 (26)	58 (30)	27 (25)	30 (35)

natural human instinct to want to gather together in the face of danger, group huddling actually increases the chance of side splash, if a strike occurs, that can lead to multiple individuals being injured.

Also of note is that BC respondents did not necessarily have greater knowledge of at-risk situations than those in the FC. It might be expected that those who travel to the BC would be more experienced and knowledgeable of the environmental risks that they face, but our survey does not support this supposition.

The findings of this study suggest limitations in the public's knowledge of lightning safety, both in an urban setting and in visitors to the front- and backcountry of YNP and SEKI. It is possible that educational outreach in the national parks might help to bridge some of these gaps for park visitors. Based on the results of the survey, an initial focus on providing visitors with information on a lightning safety rule, making them aware of the lightning safety position, and providing them information on what situations to avoid in a thunderstorm might be of highest yield.

There are many limitations to this study. The survey was a nonvalidated tool that was specifically designed to address lightning awareness issues in the 3 national parks located in the Sierra Nevada. Two of the questions (10 and 12) were open-ended, which can create difficulties in interpreting survey results. Clearly, this leaves room for bias in the interpretation of the surveyor; however, given that the same surveyor collected all of the information, the bias should be equal over all groups.

Another issue with the study design was that the survey was a convenience sample of only English-speaking visitors and, thus, not all potential individuals were

surveyed. Also, there was no attempt to match participants by demographic variables in the different settings. These factors certainly could introduce selection bias into the study results, especially as non-English foreign travelers to the parks were not interviewed and their knowledge base regarding lightning may be very different than their English-speaking counterparts.

Some may also question the use of the lightning safety rule, for example the 30-30 rule, as the example of a lightning safety decision tool described in the survey. This rule, along with many of the commonly advocated lightning safety slogans, is designed for an urban population. However, the majority of outdoor adventure programs use it, or a variation, in their lightning safety education.⁷ Also, although it may not have as much relevance in the BC setting, it is a useful rule in the FC of the national parks where the majority of people visit.

Finally, although many of the recommendations regarding lightning safety make sense, given the mechanisms of lightning injuries, they have not been rigorously proven to be effective and are debatable among experts in lightning safety. Even with all of the inherent limitations of this study, we believe that the findings provide a good starting point for providing educational outreach to visitors in SEKI and YNP, and for further study regarding lightning injury prevention.

Conclusions

The results of this survey demonstrate multiple opportunities for lightning awareness and safety education in 3 California national parks. Trailhead awareness placards, park visitor pamphlets, public service announcements,

and national park web site education portals are a few of many concepts that have the potential to impact visitors' knowledge of the risks of lightning. Further studies will be needed to determine the impact of such educational efforts on improving lightning safety knowledge and decreasing lightning injuries.

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Supplementary data

Supplementary data associated with this article is available online at www.wemjournal.org.

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