ORIGINAL RESEARCH

Medical Knowledge and Preparedness of Climbers on Colorado's 14,000-Foot Peaks

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Objective.—To assess the medical knowledge and preparedness of mountain climbers on Colorado's 14,000-foot peaks and to compare differences in knowledge and preparedness based on demographics, training, and difficulty of the climb.

Methods.—Mountain climbers from 11 14,000-foot peaks in Colorado were surveyed at the time of summiting. These peaks represented every major mountain range and class of difficulty in Colorado. Marijuana use and demographic information including age, gender, state of residence, and income level was collected in the survey. In addition, participants were scored on medical knowledge and preparedness using a novel assessment tool. Scores were then compared and statistically analyzed.

Results.—Mountain climbers scored 2.84 ± 1.25 and 3.92 ± 1.20 out of 6.00 on medical knowledge and preparedness, respectively. Medical training was shown to be the only significant predictor of medical knowledge, whereas age, race, income, and group status were all shown to be significant predictors of preparedness. It was shown that 9.4% of participants were using marijuana. Only 25% of individuals climbing class 3 mountains elected to wear helmets.

Conclusions.—Most mountain climbers had no formal wilderness medicine training and did worse on the medical knowledge assessment than those who did have training. Consistent with previous studies, participants performed poorly on the medical knowledge assessment. As such, ways to improve wilderness medical knowledge among outdoor recreationalists should be sought. The low rate of helmet use on Colorado's technical peaks represents an important area for education and injury prevention.

Key words: mountaineering, hiking, injury prevention, Colorado, preparedness, helmets, education, marijuana

Introduction

Every year, around 500,000 people climb 1 of Colorado's 14,000-foot peaks.¹ From 2010 to 2013, 28 fatalities were reported on these mountains. These deaths occurred across the spectrum of nontechnical and technical mountain classes.^{2,3} Although fatalities on Colorado's 14,000-foot peaks are rare, injuries are common.^{4–6} As more people take to the hills, it is likely that rates of accidents will also increase.⁷ Similarly, as mountain climbing popularity grows, more novices are traveling to the Colorado high country for recreation.¹ These novice climbers represent a vulnerable population because of a lack of experience in a potentially dangerous environment.

Climbing mountains presents certain objective hazards such as storms, lightning, rock fall, icefall, avalanche, and potentially dangerous exposure. Equipment failure is also responsible for some adverse outcomes. However, the largest cause of injury and death on the mountains of North America is human error.⁸ Improper conditioning, mental lapses, group disharmony, poor planning, and lack of knowledge can all contribute to human error.⁸ Importantly, most of these variables are preventable with appropriate preparation and training. These errors also put potential rescuers at risk.

Data concerning number and cost of search and rescue (SAR) operations on Colorado 14,000-foot peaks are not currently available. However, data from the Heggie et al study on SAR operations in U.S. National Parks indicated that 15,535 rescues took place between 2003 and 2006.⁹ Of these, 5607 (36%) took place on similar terrain to that found on Colorado's high peaks with an estimated cost of US \$5.9 million.⁹ A personal interview

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with Glen Kraapz, a mission coordinator for Summit County Rescue Group (September 2015) revealed the following: In Summit County, Colorado, alone, 92 SAR operations were conducted in 2014. Five of these were performed on Quandary Peak (14,265 feet), a popular hike just south of Breckenridge. In 2012 this mountain saw 10 SARs.

Evacuation times from a Colorado wilderness area can vary from hours to days.^{5,6} Because of rapidly changing weather patterns and mountainous terrain, transporting patients to definitive medical care takes considerably longer and is logistically more complex than in urban areas.^{6,8} As a result, simple medical problems may become medical emergencies. Accordingly, a reasonable medical knowledge base and proper preparedness are paramount for both the prevention and treatment of injuries and illness in a wilderness environment. Therefore, promoting wilderness medicine education and the need to continually revisit such a curriculum was an important aspect of this study.

Colorado 14,000-foot peaks are ideal study locations because they attract a large and diverse group of people. Currently, there are no formal data on how many climbers of Colorado 14,000-foot peaks are medically prepared and possess basic yet essential emergency medical knowledge. Likewise, data concerning medical knowledge and preparedness of outdoor recreationalists in the medical literature are limited.^{10–14}

The authors hypothesized that mountain climbers on Colorado's 14,000-foot peaks would be unprepared for their ascent and lack knowledge about both wilderness medicine and the proper response to injuries. The authors further hypothesized that helmet use on mountains with rockfall potential would be low, particularly on peaks with easy access.

Methods

This was a cross-sectional convenience sample in which mountain climbers were surveyed from 11 different peaks at the time of their summit. There are approximately 55 mountains over 14,000 feet (4267 m) in Colorado, spread geographically over 8880 square miles (23,000 km²).^{1,3} These peaks can be found in 6 different mountain ranges, including the Front, Ten Mile, Sawatch, Sangre de Cristo, Elk, and San Juan ranges. Mountains can be categorized into different classes based on the technical difficulty of the easiest route of ascent; Class 1 and 2 are a hike, 3 is a scramble, and 4 and 5 are technical climbs.^{1,3} Peaks of any given class often have more difficult routes, including some with fifth class climbing.³ Route taken was not specified in the survey. Summits from each range and technical class

were randomly selected as survey sites. Torreys Peak, San Luis Mountain, Mt. Lincoln, Sunshine Peak, Mt. Elbert, Longs Peak, Kit Carson Peak, Wetterhorn Mountain, Capital Peak, North Maroon Peak, and Little Bear Peak were selected as survey sites.³

Surveys were offered to every climber ≥ 18 years old reaching the summit on a given day between 0800 and 1300 hours. Days with favorable weather were chosen to maximize climber volume, summit success, and researcher safety. Each peak was surveyed for 1 day. Surveys were administered between July and September of both 2013 and 2014. These dates represent the mountaineering season in Colorado, a time when the greatest number of climbers can be found on a given peak.¹

The survey was a single page and divided into 3 sections. The first section collected demographic and personal characteristics including age; sex; race; medical training; income; state of residence; occupation; and status as a group leader, group member, or solitary climber. Those who identified as “healthcare professionals” included physicians, nurses, respiratory therapists, and other professions involved directly in patient care. The second section contained 6 questions intended to score an individual's general knowledge of wilderness medicine with specific emphasis on mountaineering injuries and illnesses. The questions dealt with dehydration, high altitude cerebral edema, splinting injuries, scene safety, normal pulse and respiratory rates, and shock due to hypovolemia (Table 1). Topics were chosen in accordance with The American Red Cross Wilderness and Remote First Aid manual and would serve as essential course topics for any accredited 16-hour wilderness first aid course.¹⁵ The Lindsey et al study, which outlined minimum course topics for a Wilderness First Responder, was also used to further validate question selection.¹⁶ The third section assessed preparedness and included questions on helmet and sunscreen use, clothing, first aid supplies carried, knowledge of the local rescue group, a self-assessment of physical fitness, and proper itinerary sharing. The latter question asked whether the group or individual left his or her itinerary

Table 1. Medical knowledge questions

Name 3 symptoms of dehydration?
What are 3 symptoms of high altitude cerebral edema?
What must be checked before and after splinting an injury?
Most important thing to check first at any accident scene?
Normal resting pulse and respiratory rate ranges?
Three things you can do for someone in shock from blood loss on the mountain?

and estimated return date with someone back home. A final question asked about marijuana use while climbing or hiking. This was included because the authors had observed marijuana use in Colorado wilderness areas, and literature quantifying its use in outdoor recreation was not available. The survey was self-administered, required both written and circled answers, and was provided in English. The first author was present on the summit to distribute surveys and assist mountain climbers who agreed to take the survey.

All participants were scored based on the number of questions answered correctly out of 6 for both medical knowledge and preparedness. Mean scores were calculated for the group as a whole. Scores were further compared between subgroups with respect to mountain class, age, sex, race, income, medical knowledge, status, state residency, and marijuana use. Categories with 2 variables were compared using *t* tests, and categories with 3 or more variables were compared using 1-way analysis of variance. All statistical calculations were performed using JMP Pro 11.2.1 (Cary, NC). The Bonferroni correction was used to adjust for multiple comparisons. Because 9 comparisons were performed, *P* values of .05/9 or <.0056 were considered significant. This study was approved by the Colorado Institutional Review Board on May 31, 2013 (Protocol number 13-1704).

Results

SURVEYING AND DEMOGRAPHICS

Three hundred fifty-seven adult mountain climbers successfully reached a survey site (summits). Of these individuals, 95.2% elected to participate. A total of 340 surveys were completed.

Demographic and study population variables are summarized in Table 2. Of those surveyed the majority were white (88.9%) men (65.6%) from Colorado (54.1%) climbing on either class 1 or 2 mountains (64.2%). Thirty-two states and 6 countries were represented within the study population.

MEDICAL KNOWLEDGE

The mean medical knowledge score was 2.84 ± 1.25 out of 6.00. Mountain climbers were knowledgeable about the symptoms of dehydration and high altitude cerebral edema, with 85% and 63% of questions answered correctly, respectively. Proper splinting and vital sign values were much less familiar to mountain climbers, with only 16% and 27% of answers being correct. Scene safety and hypovolemic shock questions were answered correctly at rates of 41% and 52%, respectively.

Table 2. Demographics and study population variables

<i>Variable</i>	<i>n (%)</i>
Mountain	
Class 1	42 (12.4)
Mt. Elbert	34 (10.0)
San Luis Mountain	8 (2.4)
Class 2	176 (51.8)
Torreys Peak	120 (35.3)
Sunshine Peak	33 (9.7)
Mt. Lincoln	23 (6.8)
Class 3	80 (23.5)
Longs Peak	49 (14.4)
Wetterhorn Peak	22 (6.5)
Kit Carson Peak	9 (2.6)
Class 4	42 (12.3)
Capital Peak	21 (6.2)
North Maroon Peak	14 (4.1)
Little Bear Peak	7 (2.1)
Age (y)	
18–24	75 (22.5)
25–34	120 (35.9)
35–50	85 (25.4)
51–74	54 (16.2)
75 +	0
Sex	
Male	214 (65.6)
Female	112 (34.4)
Race/Ethnicity	
White	288 (88.9)
Asian	24 (7.4)
Latino	6 (1.9)
Black	1 (0.3)
Other	5 (1.5)
Medical training	
First aid	20 (6.2)
First responder	77 (23.7)
EMT	14 (4.3)
Healthcare professional	33 (10.2)
Self-taught	94 (28.9)
No experience	87 (26.8)
Income	
<\$25,000 USD	82 (25.8)
\$25–\$50,000 USD	70 (22.0)
\$50–\$100,000 USD	96 (30.2)
\$100,000+ USD	70 (22.0)
From Colorado	
Yes	177 (54.1)
No	150 (45.9)
Group status	
Leader	54 (16.9)
Member	203 (63.4)
Solitary	63 (19.7)
Marijuana use	
Yes	32 (9.4)
No	307 (90.6)

EMT, emergency medical technician; USD, US dollars.

Table 3 summarizes the medical knowledge scores categorized by demographic variables. Previous medical training was shown to be the only significant predictor of medical knowledge score. Emergency medical technicians (EMTs) had the highest medical knowledge scores of any group (average, 4.37).

PREPAREDNESS

The mean preparedness score was 3.92 ± 1.20 out of 6.00. Ninety-three percent ($n = 316$) of mountain climbers felt that their physical preparation was adequate for the trip, and 81.5% ($n = 277$) of those surveyed used sunscreen. Only 12.3% ($n = 42$) of mountain climbers could correctly identify the local rescue service. Sixty-three percent ($n = 214$) of mountain climbers carried some form of a first aid kit, 63.9% ($n = 217$) were not wearing cotton clothing, and 76% ($n = 258$) of those surveyed left their itineraries with someone back home.

Age, race, income, and group status were all shown to be significant predictors of preparedness (Table 3). Group status proved to be the most powerful predictor of preparedness, with those who identified themselves as group leaders having the highest preparedness score of any subgroup. Their average score of 4.55 was 17.5% higher than those who identified themselves as solitary mountain climbers.

HELMET USE

Helmet use varied greatly with mountain class ($P < .0001$). Of those climbing class 1 or 2 mountains, 4.6% wore helmets, whereas 88.1% of those on class 4 mountains wore helmets. On class 3 mountains, only 25% of those surveyed elected to wear helmets.

Discussion

Schoffl et al estimated 2.5 accidents per 1000 mountain climbers per year.⁷ Extrapolating from these injury rates, approximately 1250 accidents occur every year on Colorado's 14,000-foot peaks.¹ Stated another way, approximately 250 of 100,000 mountain climbers experience an accident, and 2 of 100,000 mountain climbers are killed.^{1,2,7} Over one half (55.7%) of the study cohort had no formal medical training. Twenty-five of these individuals also identified themselves as group leaders, defined as being responsible for others on the mountain. The number of accidents on these mountains merits a need for more formal medical training.

The average medical knowledge score (47.3%) was worse than hypothesized. After a 2-day Wilderness First Aid course, one reasonably could be expected to score 6/6 on this section.^{15,16} Only 5.6% of those surveyed

scored $\geq 5/6$. Just 16% of participants were knowledgeable about the need to check for neurovascular status before and after applying a splint. This finding is concerning because of the high rates of lower extremity injuries sustained while climbing mountains.⁷ The Kupper study, which analyzed 2730 alpine rescue operations, found that 72.8% ($n = 1987$) of rescues were because of traumatic injury, with 39.6% ($n = 1081$) of these involving the extremities.¹⁷ Only 41% of those surveyed understood the importance of assessing scene safety first at any accident scene. Failure to do this represents immediate failure on the EMT-Basic practical test and is particularly relevant in a hostile mountain environment.

Other studies also report deficits in wilderness medical knowledge.¹⁰⁻¹² Kuepper et al administered a 17-question survey regarding wilderness medical knowledge to 283 mountaineers in the Swiss Alps and found 58.1% of answers to be correct.¹² Researchers concluded that this cohort performed poorly. Two additional studies looked at lightning safety awareness in California national parks (average score, 5.54/10.00) and understanding of altitude illness of foreign travelers in Peru.^{10,11} Meritt et al found that 58% of participants could identify 2 or fewer symptoms of acute mountain sickness.¹¹ Recognition of these symptoms is particularly important given that rates of altitude illness range from 28% to 34% of on peaks >4000 meters (13,123 feet).⁷

Like the Campbell et al study, we are able to report that medical training is associated with higher medical knowledge scores.¹³ Table 3 demonstrates the increase in knowledge scores ranging from those with no previous experience to those with EMT training. The rising scores from First Aid, to First Responder, and finally to EMT is not surprising because all 3 cover similar material. However, approximate course lengths for these credentials are 16, 76, and 128 hours, respectively. It is likely the repetition and subsequent retention that lead EMTs to score the highest on this section.¹⁸

Overall, the study population performed better than hypothesized on the preparedness section. However, only 12.3% of participants could correctly identify the local rescue service. Although this probably does not affect rescue outcomes because of 911 emergency dispatch centers' ability to route calls, it may represent a lack of understanding concerning the rescue process.

Encouragingly, those who identified themselves as group leaders scored highest in preparedness (average, 4.56). However, the fact that solitary mountain climbers only scored 3.51 is alarming. Solitary mountain climbers are potentially more vulnerable if injured, at least on less-crowded peaks.

Table 3. Medical knowledge and preparedness scores by demographic variables

<i>Variable</i>	<i>Medical knowledge score $\pm$ SD</i>	<i>P value</i>	<i>Preparedness score $\pm$ SD</i>	<i>P value</i>
Class		.038		.072
1 and 2	2.74 $\pm$ 1.21		3.83 $\pm$ 1.16	
3	3.15 $\pm$ 1.32		3.98 $\pm$ 1.32	
4	2.81 $\pm$ 1.21		4.29 $\pm$ 1.11	
Age (y)		.372		.0004
18–24	2.71 $\pm$ 1.18		3.45 $\pm$ 1.15	
25–34	2.99 $\pm$ 1.26		3.95 $\pm$ 1.19	
35–50	2.75 $\pm$ 1.20		4.12 $\pm$ 1.23	
51–74	2.92 $\pm$ 1.33		4.26 $\pm$ 1.05	
Sex		.640		.013
Male	2.87 $\pm$ 1.26		4.04 $\pm$ 1.23	
Female	2.80 $\pm$ 1.25		3.69 $\pm$ 1.13	
Race/Ethnicity		.089		.0043
White	2.90 $\pm$ 1.23		4.01 $\pm$ 1.16	
Asian	2.31 $\pm$ 1.26		3.17 $\pm$ 1.20	
Latino	2.81 $\pm$ 1.02		3.50 $\pm$ 1.05	
Black	1.00 $\pm$ 0.00		2.00 $\pm$ 0.00	
Other	3.27 $\pm$ 0.56		3.80 $\pm$ 0.84	
Medical training		<.0001		.026
First aid	3.43 $\pm$ 0.91		4.35 $\pm$ 1.04	
First responder	3.57 $\pm$ 0.99		4.25 $\pm$ 1.25	
EMT	4.37 $\pm$ 1.00		4.07 $\pm$ 1.49	
Healthcare professional	3.88 $\pm$ 1.09		3.67 $\pm$ 1.11	
Self-taught	2.35 $\pm$ 1.03		3.83 $\pm$ 1.11	
No experience	2.08 $\pm$ 0.91		3.73 $\pm$ 1.23	
Income		.965		<.0001
<\$25,000 USD	2.83 $\pm$ 1.28		3.59 $\pm$ 1.20	
\$25–\$50,000 USD	2.83 $\pm$ 1.27		3.70 $\pm$ 1.17	
\$50–\$100,000 USD	2.89 $\pm$ 1.29		4.15 $\pm$ 1.19	
\$100,000+ USD	2.92 $\pm$ 1.13		4.36 $\pm$ 0.98	
From Colorado		.006		.724
Yes	3.03 $\pm$ 1.31		3.96 $\pm$ 1.25	
No	2.65 $\pm$ 1.12		3.91 $\pm$ 1.13	
Group status		.089		<.0001
Leader	3.21 $\pm$ 1.14		4.56 $\pm$ 1.06	
Member	2.86 $\pm$ 1.21		3.92 $\pm$ 1.16	
Solitary	2.72 $\pm$ 1.38		3.51 $\pm$ 1.26	
Marijuana		.720		.327
Yes	2.92 $\pm$ 1.34		4.13 $\pm$ 1.04	
No	2.84 $\pm$ 1.23		3.91 $\pm$ 1.22	

EMT, emergency medical technician; USD, US dollars.

Preparedness scores increased linearly with age as well as income. Age often portends more experience and potentially greater aversion to risk. Because medical kits, sunscreen, technical outerwear, and synthetic clothing can represent a significant cost burden, it was not surprising that individuals with greater wealth scored higher using this survey instrument. Caucasians scored higher on preparedness than other races or ethnicities. Thirty-four individuals (11.1%) identified themselves as

nonwhite; only 1 of these 34 identified as a group leader, potentially confounding this result. Further research is needed to fully understand differences in preparedness scores based on race or ethnicity.

Helmets are useful for the prevention of head injury and concussion.¹⁹ Class 3 and 4 mountains pose significant risk of rockfall and mountain climber fall, both of which can lead to traumatic head injury. Although rare, such injuries are often devastating.⁷ An

analysis of 215 injuries on class 5 routes in the Sierra Nevada Mountains found that all 17 fatalities mostly involved head injuries.²⁰ Although 88.1% of mountain climbers on class 4 peaks elected to wear helmets, only 25% wore helmets on class 3 mountains. On Longs Peak (class 3) only 16.3% elected to wear helmets. This may be the result of Longs Peak's easy access and the high volume of tourists in Rocky Mountain National Park.¹ Because class 3 and class 4 have overlapping dangers in the form of steep terrain, rockfall potential, and unstable footing, the authors believe the differences in helmet use represent an area for future education and injury prevention.

In November 2012, Amendment 64 legalized the recreational use of marijuana in Colorado. Nearly 10% of those surveyed were using marijuana on their hike or climb. Although the authors would recommend the utmost caution to individuals using marijuana while mountain climbing because of its effect on mental and physical performance, its use did not correlate with differences in medical knowledge or preparedness scores.²¹

LIMITATIONS

Because each peak has multiple ascent routes and climbers tend to rest on summits, mountaintops were chosen as the study location to capture as many participants as possible on a given day. Although the authors believe the summit rates of mountain climbers on Colorado 14,000-foot peaks to be high on clear summer days, a validated summit success rate is not available. As a result of this methodology, unsuccessful climbers were not captured, limiting the overall generalizability of these findings.

Avoiding adverse weather is important for both success and safety when climbing mountains.⁷⁻⁹ Climbers who mountaineer in poor weather and those who summit from October through June may represent a different population than those captured in this cohort.

This study represents a cross-sectional convenience sample. The aim of the study was to approximate the knowledge and preparedness of mountain climbers on these high peaks as a whole using a "snapshot" or sampling of them. This design could allow for sample bias to occur if the study was underpowered.

Preparedness is particularly difficult to assess in a survey, and few attempts to do so exist in the literature. The Mason et al study used some overlapping questions but was largely concerned with supplies carried by study participants.¹⁴ Medical knowledge is more objective, but answering questions on a written test does not always correlate to clinical skills.¹⁸ For instance, knowing the

normal pulse rate does not assess one's ability to accurately palpate and measure pulses.

The survey instrument used has never been validated and attempts to assess knowledge and preparedness by measuring a sampling of variables, which would reflect the prior attributes. Limiting the survey to a single page was believed to maximize effort and willingness of mountain climbers to participate. A more comprehensive survey instrument may be better at answering the questions with which this article is concerned. However, it may also affect other important variables like compliance.

As with any survey or test, there is always variability in individual effort. Overall, the authors believe most mountain climbers put forth ample effort under states of relative hypoxia and fatigue at 14,000+ feet.

Conclusion

The majority of mountain climbers surveyed had no formal training in wilderness medicine and did worse on the medical knowledge section than those with formalized training. Older individuals, those with higher incomes, and those identifying themselves as group leaders were most prepared. Mountain climbers on class 3 mountains had low rates of helmet usage despite the objective danger of rockfall and trip hazard. In contrast, those individuals on class 4 peaks had much higher helmet usage rates. Future studies and public awareness programs would be appropriately directed at increasing helmet use among class 3 mountaineers, particularly those on Longs Peak.

More data and interpretation are needed with regard to the epidemiology of illness and injury while climbing mountains to better inform wilderness medicine education content as well as SAR personnel. This information would also allow for more evidence-based medical kits and supplies carried. Research in validating wilderness medicine therapies and treatments will continue to be very important in the field of wilderness medicine education and preparedness. Studies aimed at improving learning and retention for both child and adult students would likely improve wilderness medical knowledge of outdoor recreationalists if appropriately implemented into such courses.

Climbers of Colorado's 14,000-foot peaks performed poorly on the wilderness medicine knowledge assessment. This trend is consistent with previously reported studies.¹⁰⁻¹⁴ Low knowledge scores can be explained by the lack of formal training in this population. Poor information retention is likely responsible as well, illustrating the need to continuously review and revisit wilderness medicine content. Proper preparedness and reasonable medical knowledge are paramount for both

the prevention and treatment of injury and illness in wilderness environments. Therefore, methods to improve these variables should be sought.

There are many potential routes by which wilderness and medical knowledge in general could be improved. Schools represent a logical starting point. Having an accredited 16-hour first aid or wilderness first aid course in both middle and high school seems reasonable, particularly in places like Colorado where outdoor recreation is common. This would provide the public with greater understanding of human health and pathology, add a practical skill set to our education system, potentially save lives, and likely prevent injury.

Acknowledgments

The authors would like to thank the Edgar and Marion Adler Foundation for their help in funding this research study.

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