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ORIGINAL RESEARCH

Rock Climbing Rescues: Causes, Injuries, and Trends in Boulder County, Colorado

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Objective.—To describe rates and patterns of rock climbing rescue incidents, morbidity and mortality in Boulder County, CO.

Methods.—Rocky Mountain Rescue Group incident reports from 1998 to 2011 were reviewed to provide a 14-year statistical account of rock climbing incidents.

Results.—Rock climbing rescues in Boulder accounted for 428 of a total of 2198 (19.5%) mountain and wilderness rescue victims. Most rock climbing victims were male (78%), and 46% of victims were between the ages of 20 and 29 years; most rock climbing incidents occurred on weekend days (median time of 3:30 PM) during the spring, summer, and autumn. Technical roped climbers accounted for 58% of climbing victims, whereas unroped climbers accounted for 34%. Belay incidents accounted for 12% of climbing victims, whereas rock fall incidents accounted for 4.5% of victims. Most victims were uninjured (43% stranded or lost), whereas lower extremity injuries were the most common injury (29.5% of injured victims). A total of 5.5% of climbing victims were fatally injured (23 victims: 5 from lead falls and 9 from unroped falls).

Conclusions.—The occurrence of rock climbing–related rescue victims comprised one fifth of all rescue victims in Boulder County. A large fraction of incidents and fatalities resulted from unroped climbing. Incidents of lost or uninjured stranded climbers and belay incidents account for more than half of victims, which can likely be prevented by gaining appropriate experience, seeking local information, and applying some simple safety measures for control of rope belays.

Key words: Rocky Mountain Rescue Group, RMRG, mountain rescue, search and rescue, rock climbing incidents, Boulder, CO, Eldorado Canyon State Park

Introduction

There are many popular rock climbing areas in the United States, but few locations have sufficient concentrations of both easily accessible climbing areas and large numbers of local rock climbers to make regular collection and analysis of incident data for a specific location viable.

For North America, the American Alpine Club collects reports on climbing and mountaineering incidents. These reports, submitted by individuals and search and rescue (SAR) teams, include information on cause and injury type for more than 6200 incidents and 11 300 victims (1947 to 2007). Because of the nature of the narrative reporting, these incidents are not documented in a consistent manner, and a statistical summary report is not available.[1] Data covering 50 years of climbing in Australia (302 incidents) provide useful details on incident trends[2]; however, the data collection methodology is inconsistent.

Data on rock climbing incident causes and injuries using consistent data collection methods are limited, with data collected by the US National Park Service providing the most robust datasets.[3–6] A number of studies report climber injury trends when treated in hospitals, and include victims with minor and overuse injuries that may not require SAR assistance.[7–11] In a recent report on rock climbing injuries treated in US emergency departments, Nelson and McKenzie[8] found that there is a disproportionate amount of data available for injuries to elite climbers, and they identify a gap in data for recreational climbing.

In Boulder County, CO, there is a combination of easily accessible and popular climbing areas and high numbers of climbers and climbing rescue incidents. Be-

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cause of this convergence, consistent data collection has taken place here.

Using data gathered from Rocky Mountain Rescue Group (RMRG) incident reports, we present timing of recreational rock climbing incidents and the most common causes of climbing morbidity and mortality. Evaluating these incidents provides valuable information and an epidemiology of climbing-related incidents that augments the limited data presented for other popular rock climbing areas.

Methods and Definitions

The RMRG is a volunteer mountain SAR team that has been active since 1947. In cooperation with the local sheriff's office, the RMRG covers mountain rescue in Boulder County, the state of Colorado, and occasionally beyond. The RMRG's primary purpose is to provide search, rescue, and wilderness medical services to those lost or in distress in the mountains. This study covers all rescues within Boulder County involving incidents while rock climbing or at climbing areas, which we define as including the following: technical roped climbing, unroped climbing (free-soloing or scrambling), mountaineering, bouldering, or incidents involving bystanders at climbing areas. Details of nonclimbing-related rescues were excluded from this study.

Data were collected from RMRG rescue reports, which are completed at the time of rescue missions—or shortly after—by field personnel. We limited our assessment to the years 1998 to 2011 for which both handwritten and digital data collection were available to augment one another. The majority of reports contain the following data: date and time of SAR activation, number of victims, location, climbing activity, incident cause, and most serious injury type. Incident cause, or at least the primary contributing factor, was determined from interviews with victims, belayers, and bystanders and through RMRG investigations of the incident scene. Injury types were determined from RMRG reports, and are based on first aid assessments made in the field. Fatal injuries for climbing accidents usually involved multisystems trauma, with the precise cause of death determined by the coroner some time after the SAR incident. Accurate cause of death information was not always obtained subsequent to the incident. We therefore include fatalities as their own injury category. When victim injuries were not specified they were classified as unknown. As some climbing rescues involve more than a single victim, data are presented and discussed by climbing victim rather than by climbing rescue.

Data were extracted based on the timing, climbing, and injury criteria, and descriptive statistics were calculated. Definitions specific to this investigation are provided in Table 1. We have compared our data with peer-reviewed data from North America[3,4,8,14] and an extensive dataset from Australia[2] to provide insights into potential differences in climbing incident trends beyond North America.

Results

CLIMBING INCIDENTS COMPARED WITH ALL SEARCH AND RESCUE ACTIVITY

Between 1998 and 2011, the RMRG has responded to 1857 SAR incidents involving 2198 victims. Climbing SAR incidents accounted for 345 incidents involving 428 (19.5%) victims (Table 2). Technical roped climbing and

Table 1. Definition of terms used in this investigation

Belay: "A system of using a rope to stop a fall if one should occur,"[12] by exerting friction on the rope. Also used to mean the place where the belayer is anchored.

Bouldering: "Climbing close to ground level, where an unchecked fall is not necessarily serious."[13] Undertaken without a rope and normally limited to short vertical distances.

Climbing: Any rock climbing activity; includes technical climbing with ropes and (rock) protection, bouldering, or scrambling. Includes climbers lost after completion of a climb.

Lead fall: A fall by a climber placing (rock) protection as they ascend a climb trailing a rope. Falls are generally arrested by a belayer and belay device below the climber.

Medical: Illness or injuries that are not from a traumatic event such as a fall.

Mountaineering: Climbing mountain peaks at higher elevations that may involve one or all methods of climbing, including technical roped climbing, unroped climbing, bouldering, and technical approaches to vertical terrain. Separated from other types of climbing because of the combination of many different types of climbing.

Rappel: Descending a rope by controlling speed with friction on the rope.[12] The climber is suspended by, and dependent on the rope.

Technical roped climbing: Climbing using specialized climbing shoes, harness, ropes, and removable or fixed rock protection.

Unroped climbing: Climbing without ropes or protection by experienced climbers (free soloers) or inexperienced scramblers.

Victim: An individual involved in an incident in which mountain rescue was called and provided some assistance. May not always involve an injury or evacuation.

Table 2. All search and rescue and climbing incidents (1998–2011)

Year	*SAR incidents*	*SAR victims*	*Climbing rescue incidents*	*Climbing rescue victims*	*Climbing rescue victims (%)*[a]
1998	118	166	32	35	21.0
1999	114	141	13	16	11.4
2000	128	155	28	30	19.4
2001	117	142	21	25	17.6
2002	131	157	27	38	24.2
2003	135	212	22	25	11.8
2004	131	168	25	35	20.8
2005	133	164	20	27	16.5
2006	140	159	19	20	12.6
2007	129	143	18	26	18.2
2008	143	176	31	37	21.0
2009	143	159	17	19	12.0
2010	149	126	43	53	42.0
2011	146	130	28	40	19.2
Total	1857	2198	345	428	100
Yearly average[b]	132.6 ± 11.0	150.0 ± 21.5	24.6 ± 7.6	30.5 ± 10.1	19.5 ± 8.5

SAR, search and rescue.
[a] Percentage of climbing victims relative to all SAR victims.
[b] Values are mean ± SD.

unroped climbing account for 11% and 6.5% of all SAR victims, respectively. Year-to-year variability in climbing incidents can be large, with 42% of all SAR victims involved in climbing incidents for 2010 compared with roughly 12% for 1999, 2003, and 2009.

VICTIM DEMOGRAPHICS

All age and gender data are presented in Table 3, including a comparison with the data from Australia[2] for the age distribution of victims.

INCIDENT LOCATION AND TIMING

Climbing incident timing is summarized in Table 4 and shows that more incidents occur in summer and autumn, followed by spring and then winter. August and December contain the most and least mean number of rescues, respectively. More than half of victims result from incidents occurring on weekends, with the midweek days accounting for the other half of climbing victims. Incident timing (time of SAR activation) is also statistically normally distributed (χ^2 test, $\alpha = 0.05$) with a median

Table 3. Victim demographics: age, gender (1998–2011)

Age (years)	*No. (%)*[a]	*% from Australia*[2]	*Gender*	*No. (%)*[b]
0–9	1 (0.5)	(0.0)	Male	295 (78)
10–19	61 (21)	(19.8)	Female	83 (22)
20–29	137 (46)	(47.6)		
30–39	45 (15)	(17.5)		
40–49	29 (10.0)	(10.4)		
50–59	13 (4.5)	(3.5)		
60–69	8 (2.5)	(1.2)		
70–79	1 (0.5)	(0.0)		

[a] Thirty-one percent of age data unknown. Percent calculated on known age data only.
[b] Twelve percent of gender data unknown. Percent calculated on known gender data only.

Table 4. Climbing incidents by season, weekend/weekday, and time of day (1998–2011)

Timing	*Climbing incidents (%)*	*Climbing victims (%)*	*Notes*[a]
Winter (Dec–Feb)	34 (10.0)	41 (9.5)	Rock fall: 2 at 5400 ft
Spring (Mar–May)	80 (23.0)	94 (22.0)	Rock fall: 8 at 5825 ft
Summer (Jun–Aug)	129 (37.5)	153 (36.0)	Rock fall: 8 at 8960 ft
Autumn (Sept–Nov)	102 (29.5)	140 (32.5)	Rock fall 1 at 8000 ft
Weekend	182 (53.0)	229 (53.0)	Unknown: 1 incident, 1 victim
Weekdays	162 (47.0)	198 (47.0)	
Midnight–6 AM	9 (2.5)	20 (4.5)	Unknown: 1 incident, 1 victim
6 AM–midday	55 (16.0)	58 (13.5)	
Midday–6 PM	195 (57.0)	215 (50.5)	
6 PM–midnight	84 (24.5)	134 (31.5)	

[a] Rock fall altitudes are averages for the season.

time of 3:30 PM (± 6.5 hours). Most incidents (85%) occur in the popular climbing areas around Boulder: Eldorado Canyon State Park, Boulder Canyon, and the Flatirons. The remaining incidents are on mountaineering routes, or in much less popular climbing areas.

CLIMBING ACTIVITY TYPE

Table 5 shows the distribution of climbing activities (technical roped, unroped, bouldering, bystanders, and mountaineering) for incidents and victims.

Table 5. Climbing incidents by activity (1998–2011)

Activity type	*Incidents (%)*	*Victims (%)*
Technical roped	190 (55)	247 (58)
Belay[a]	41	51
Unroped	120 (35)	145 (34)
Bouldering	24 (7)	26 (6)
Bystander (rock fall)[b]	5 (1.5)	4 (1)
Mountaineering	6 (2)	6 (1.5)
Total	345	428

[a] Belay is a subset of technical roped climbing.

[b] Bystander victims are less than incidents owing to one significant rock fall event that was a near miss.

Table 6. Technical climbing incidents by cause (1998–2011)

Technical climbing incident cause	*Incidents (%)*	*Victims (%)*
Lead fall	74 (39)	75 (30.5)
Second fall	3 (1.5)	3 (1)
Lost	19 (10)	47 (19)
Stranded	19 (10)	37 (15)
Belay	41 (21.5)	51 (20.5)
Lost control	8	8
Lower off	13	13
Rappel off	9	9
Rappel stuck	10	20
Knot untied	1	1
Anchor failure	6 (3)	6 (2.5)
Rock fall[a]	9 (5)	9 (3.5)
Dislocated shoulder	5 (2.5)	5 (2)
Seizure	1 (0.5)	1 (0.5)
Cardiac arrest	1 (0.5)	1 (0.5)
Unknown	12 (6.5)	12 (5)
Total	190	247

[a] There were 18 total rock fall incidents; however, only 9 victims were involved in technical roped climbing.

Roped climbing

Table 6 shows the distribution of causes of technical roped climbing incidents and victims. For all rescues of persons involved in technical roped climbing, lead falls are the dominant cause, followed by belay incidents (discussed subsequently), and then by climbers who became lost during the descent—thus necessitating SAR assistance, predominantly after sunset. Of the 37 stranded climbers, 9 had ropes stuck during the climb or rappel, 10 were on climbs whose technical difficulty exceeded their ability, and 9 could not find suitable rappel anchors to descend. One unique incident involved a climber with his knee stuck in a crack feature of a climb. Falls by seconding climbers, failure of anchors, and medical conditions also contributed to technical roped climbing victims. We have one record of a lead climbing fall that resulted in a fatality in which the climber's rope was cut on a rock during the dynamic loading of the rope.[15]

Unroped climbing

Unroped climbing is the second most common climbing activity requiring rescue (Table 5), and most often leads to uninjured but stranded victims. It must be noted that incident reports sometimes do not record experience level; therefore, it is not always possible to differentiate between inexperienced scramblers and experienced free-solo climbers. Scramblers are generally not equipped

Table 7. Climbing fatality by climbing activity (1998–2011)

Activity type	*Victims (%)*
Unroped climbing	9 (39)
Lead fall	5 (21.5)
Lower off	3 (13)
Anchor failure	2 (8.5)
Rock fall	2 (8.5)
Mountaineering	2 (8.5)
Total	23

with specific rock climbing shoes or attire and typically have little technical climbing knowledge. In contrast, free-solo climbers more commonly are experienced climbers who choose to do technically challenging routes without the safety protection of a rope. As our dataset does not make the distinction between these groups, scramblers and free-solo climbers alike are considered unroped climbers. Unroped climbers are also the most common victims involved in fatal incidents (Table 7).

Belay- or rappelling-related incidents

Table 6 shows the details of belay-related incidents and victims. Belay and rappelling incidents in which the rope was not long enough for the climber to reach the ground accounted for 21 victims, 16 of whom had severe or fatal injuries and 3 of whom received severe rope burns while belaying. Only 8 victims resulted from a belayer losing control of the rope in which sufficient length of rope was available, whereas 20 victims were stranded on a climb as a result of an inability to continue to rappel, including ropes becoming stuck.

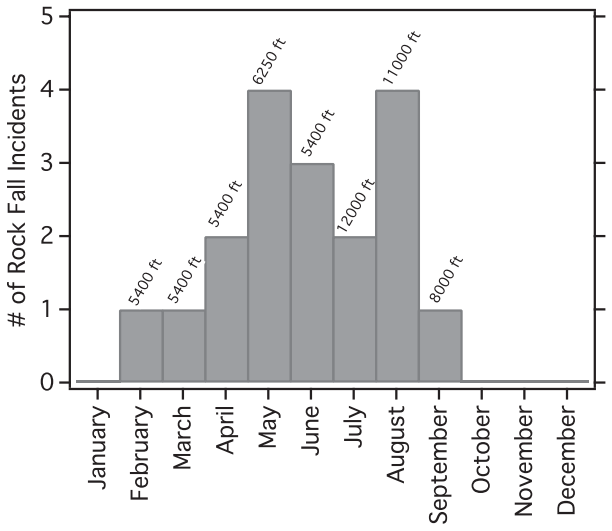

Figure 1. Rock fall incidents by month (each month labeled by average elevation [in feet] of the incident location).

Table 8. Injury types across all climbing incidents (1998–2011)

Injury type	*Victims (%)*
Uninjured[a]	186
Injured	242 (100)
Lower extremity	71 (29.5)
Upper extremity	6 (2.5)
Head	42 (17)
Spinal	30 (12.5)
Dislocated shoulder	5 (2)
Chest	6 (2.5)
Abdomen	3 (1.5)
Cardiac arrest	1 (0.5)
Seizure	1 (0.5)
Overdose	2 (1)
Fatality	23 (9.5)
Unknown	52 (21)
Total	428

[a] Uninjured victims not included in injury breakdown.

Rock fall incidents

Rock fall, in which climbers were hit by rock or fell off a climb as a result of falling rock, accounted for 15 victims. A further 3 victims hit by rock fall were bystander climbers, for a total of 4% of all climbing victims. Rock fall is an integral part of mountain geology and mostly a random occurrence; however, it can be triggered by climbing activity. Rock fall incidents have mostly occurred during the freeze–thaw cycles of spring (for lower elevations) and spring or early summer (for higher elevations; Figure 1). The Figure also shows the average elevation (feet above sea level) at which the incidents occurred. Boulder sits at 5400-feet elevation, whereas the highest peak in RMRG's primary response area is 13 500 feet. The incidents in February through June occurred at an average lower elevation than those in July, August, and September.

Climber injuries

Table 8 shows the distribution of victim injuries; 56.5% sustained 1 or more injuries, whereas 43.5% were uninjured. Of the nonfatal injuries, those affecting a lower extremity dominated followed by head, spinal, and upper extremity injuries, respectively. Medical issues such as seizures, cardiac arrest, and substance abuse while climbing also contribute to the injury distribution (Tables

6 and 8). Table 7 presents the climbing activity for fatalities, unroped climbing being the dominant activity.

Discussion

In Boulder County, the fraction of climbing-related incidents relative to all SAR incidents (see Table 2) is comparable to Yosemite National Park (442 climbing victims in 10 years and 19% of SAR incidents[14]). The popularity of climbing areas such as Eldorado Canyon and Yosemite Valley provides for higher rates of incidents compared with other locations. For example, data averaged across all US National Parks suggest that just 3% of SAR incidents are for technical roped climbing.[4] Hikers accounted for 45% of RMRG SAR victims each year. In comparison hikers comprised 52% of SAR victims for Yosemite National Park[14] and 48% of SAR rescues (victim number not reported) for all of the US National Parks.[4]

Victims were predominantly male and between the ages of 20 and 29 years; the age demographics observed matched the distribution in Australia, which was the only study reporting similar data[2] (comparison presented in Table 3). The RMRG reported fewer technical roped climbing victims compared with Australia,[2] and similar numbers compared with all US National Parks.[4] For the RMRG, one third of all technical roped climbing victims were a result of a lead fall or second fall (dominated by lead fall incidents), compared with 64% in Australia.[2] The higher rate of unroped climbing incidents in Boulder may account for some of this difference (34% compared with 11% in Australia[2]). The higher incidence of unroped climbing incidents may possibly be related to the presence of and ease of access to technically less difficult climbs close to the City of Boulder. Unroped climbing most often leads to stranded, uninjured victims; however, unroped climbing was the dominant cause of climbing fatalities (Table 7), with Boulder showing similar results to the 36% unroped climbing fatality rate from Australia.[2] Although the RMRG data cannot readily distinguish between experienced free-solo unroped climbers and inexperienced scramblers, this distinction is an important one—particularly when determining the underlying cause behind unroped climbing and potential prevention strategies. Fatalities from all types of climbing comprised 5.5% of climbing victims for the RMRG. Similarly, Yosemite National Park reported a 6% climbing fatality rate.[3] The higher rate of fatalities reported from Australia, 14%, was inferred from publications and included incidents in which injuries were serious, severe, or fatal,[2] and may overrepresent actual deaths. Sedgman[2] reports a larger lead fall fatality contribution of 40%, compared with 21.5% in our evaluation, likely attributable to the higher rate of unroped climbing incidents in Boulder. For reference, the British Health and Safety Executive[16] reports that the climbing fatality risk is 1 in 320 000 climbs.

Anchor failure contributed to just 2.5% of technical roped climbing victims for the RMRG. Notable anchor failures include the movement of an approximately 250-kg boulder that had been slung with webbing, the failure of a top-rope anchor as a result of the climbing rope being threaded directly through the anchor webbing, and the failure of an anchor built from webbing spliced together using masking tape,[17] a common method used by manufactures when linking two ends of webbing together on a spool. The RMRG does not have any records of bolted anchor failures, although one incident involved the failure of rock surrounding a removable mechanical device used as an anchor. Data from both Yosemite National Park and Australia report anchor failures as the cause of climbing incidents as 1% or less.[2,3]

Belay-related climbing incidents (51 individuals) included 8 belayers losing control of the rope while lowering and 20 climbers stuck on rappel. Both of these causes point to inadequate attentiveness and technical skills. Insufficient rope length on lowering and rappel accounted for 22 victims. The most effective prevention measure for belay incidents—regardless of experience, equipment, or familiarity with the climb—is to control both ends of the rope. This can easily be accomplished in a variety of ways, such as tying the two ends together. On 2 of the incidents (one of which was a fatality), a rappel failure occurred when the climber knew the rope had sufficient length to reach the ground, but the rope ends were not even; this resulted in a fall once the climber rappelled past the short end of the rope. Other simple safety measures include rappelling with backups, such as a prusik or other autoblock device, and consulting the latest available information about fixed anchors. Easily identifiable rope middle marks may help prevent rappelling incidents as well.

Rock fall incidents contributed to 4.5% of all RMRG climbing victims. More than half of these incidents occurred in well-established climbing areas on regularly climbed routes. Although there is no certain method for identifying loose holds, a climber can qualitatively test a hold by tapping or pulling on the hold before weighting it. Increased caution during warm periods after freezing conditions is prudent. Additionally, belayers and others not actively climbing should try to avoid exposing themselves to areas directly below or in the fall line of active climbers. Five of the incidents involved rock releasing from steep slopes (rather than on climbs themselves) at climbing areas or on popular mountaineering routes; most of these incidents were during the prime freeze–thaw cycle. One notable rock fall incident involved a lead climber who pulled a large rock off the face of the

climb, resulting in his own internal injuries and his belayer sustaining multiple critical traumatic injuries.[18] Interestingly, this loose rock had been identified as a potential danger on a climber's Internet forum in the months before that incident.

One hundred eighty-six (43.5%) RMRG climbing victims were uninjured, and therefore were lost or stranded on a climb or during the descent. These climbers became stuck most often as a result of inexperience with the climbing route or descent, or when the route difficulty exceeded their ability. In many cases prevention was possible by individual self-education and preparation, including consulting guidebooks before the climb, or carrying route descriptions and headlamps while engaging in the climb.

Injury patterns can be compared with 2 comprehensive studies of rock climbing injuries. The study by Nelson and McKenzie[8] analyzed rock climbing injuries treated within hospitals, whereas the study by Bowie et al[3] analyzed rock climbing injuries from the medical clinic in Yosemite National Park. Comparing all climbing rescues, Boulder and Yosemite National Park show similar rates of upper extremity injuries—2.5% in Boulder and 6% from Yosemite[3]—and yet these numbers differ substantially (29.2%) from the study by Nelson and McKenzie.[8] This difference is likely owing to upper extremity injuries being more conducive to self-rescue and companion rescue (although still possibly requiring treatment at a hospital), rather than requiring SAR assistance. Victims suffering lower extremity injuries accounted for 29.5% of injured victims in this analysis and 28% in Yosemite,[3] compared with 46.3% from Nelson and McKenzie.[8] Conversely, head injuries account for 17% of injuries here, compared with 8% in Yosemite[3] and 12.2% in hospital admissions.[8] Our data specify a significant number of suspected spinal injuries (12.5%) that is much higher than other reports. This is likely related to suspected injury determined in the field as opposed to confirmed injuries from clinic and hospital reports. For the awareness of climbers, it should be noted that lower extremity, head, and spinal injuries make up 59% of climbing injuries—all of which are injuries that make self and companion rescue unlikely as a result of pain, victim level of consciousness, and a high likelihood for the chance of exacerbating the injuries. Calling for organized SAR assistance early is pivotal to getting the victim to definitive care as soon as possible.

LIMITATIONS

This study is limited by the information available to the RMRG at the time the report was completed. Information such as incident cause, victim experience, length of fall, and events leading up to the incident may never become available to the RMRG or may vary according to eyewitness accounts. In addition, the primary medical diagnosis may change from prehospital to hospital care (eg, the deterioration in a pulmonary injury en route to the hospital after SAR evacuation). This dataset contains information for rock climbing incidents when SAR was requested. It is certain that many minor and repetitive-use climbing injuries are not reported to SAR as these incidents do not warrant a call for rescue. The experience level of victims, difficulty of climb, and helmet use were sparsely recorded and are not included. Additionally, time of SAR activation may occur minutes to hours after the actual climbing incident, and may not always be an accurate reflection of when the incident occurred—especially for lost or stranded climbers, or climbers in remote locations where alerting for SAR assistance is limited.

Conclusions

The data presented here provide a comprehensive overview of rock climbing incidents requiring SAR assistance for one of the more popular climbing areas in North America. This analysis provides valuable insights into possible preventive measures and preemptive technical and medical training for individuals involved in climbing incidents.

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