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Causes of Death and Characteristics of Nonsurvivors Rescued during Recreational Mountain Activities in Japan between 2011 and 2015: A Descriptive Analysis

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ABSTRACT

Objectives: This study aimed to describe the cause of death and characteristics at the prehospital setting associated with care and rescue processes of nonsurvivors rescued in the mountain of Japan.

Design: Retrospective, descriptive analysis.

Setting: Pre-hospital setting of mountain search and rescue in Japan. Ten prefectural police headquarters that have over 10 cases of mountain death from 2011 to 2015.

Participants: Data were generated from the existing records. Of the total 6159 rescued subjects, 548 mountain deaths caused by recreational activities were included.

Results: Among the 548 mountain deaths, 83% were males, and major causes of death were trauma (49.1%), hypothermia (14.8%), cardiac death (13.1%), and avalanche-related death (6.6%). The alive rate at rescue team arrival in all nonsurvivors was 3.5%, with 1, 4, and 14 cases of cardiac, hypothermia, and trauma, respectively. Cardiac deaths occurred in 93.1% (67/72) of males and aged over 41 y, and 88.7% (63/71) were found on mountain trails. In hypothermia, callouts were made between 17:00 and 6:00 at 49% (40/81) and by persons not on-site in 59.7% (46/77). People with >6 h in trauma or >1 h in cardiac death already died upon rescue team arrival, but some with hypothermia after 6 h were alive.

Conclusion: This study is the first large-scale descriptive analysis of mountain nonsurvivors. The alive rate at rescue arrival in all mountain deaths was only 3.5%. These data showed that the circumstances related to onset and the process until the rescue team arrives have different characteristics depending on the cause of death. Survival may be enhanced by targeting better use of the time before rescue team arrival and by providing further education, particularly mountain rescue-related medical problems to rescuers including bystanders.

Keywords: prehospital, mountain rescue, accident & emergency medicine, medical education & training, quality in health care

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STRENGTHS AND LIMITATIONS OF THIS STUDY

► This study represents the first large-scale analysis of nonsurvivors rescued during recreational mountain activities.

► This study provides the alive rate of deaths on rescue team arrival, and the care and rescue processes of the prehospital setting time is evaluated for enhancing survival for each major cause of death.

► This research targeted only the Japanese population, and from a universal perspective of injury and illness, the results of this study can be generalized.; however, the generalization of the results may be limited since the topography, weather, and rescue systems vary depending on the country and mountain area.

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INTRODUCTION

Numerous people visit mountainous areas for recreational activities; in the 2016 official statistics of Japan, 11.37 million people aged over 10 years joined mountaineering in 2015.[1] Considering the topographic features, weather conditions, activity duration, and heavier and inadequate equipment, mountain activities can be physically demanding, leading to serious injuries or death. The mountain rescue team in Japan comprises police organizations. According to the National Police Agency report, the total callouts in 2015 were 3043, and 11% died (335/3043); thus, over 300 people die in Japan's mountainous areas annually.[2] Mountain fatalities were retrospectively studied, with trauma, acute altitude illness (AAI), hypothermia, avalanche burial, and sudden cardiac death (SCD) as the common causes.[3-6] However, few studies have examined the cause of death and the characteristics at the prehospital setting in recreational mountain activities internationally, particularly in Japan. We conducted a large-scale analysis of nonsurvivors rescued in Japan between 2011 and 2015. We aimed to clarify the causes and frequency of mountain deaths and identify the onset and rescue response circumstances and the prehospital setting time course to develop possible measures to strengthen the response and enhance survival chances during emergency situations in the mountain.

METHODS

Data source

After each mountain rescue mission, police officers record the event on the rescue report form, which is kept for the annual rescue report for 5 years. This report covers all rescued people in Japan. We collected such reports from police headquarters within all prefectures that had over 10 mountain death cases between January 2011 and December 2015 (the last 5 years in which records were kept as of 2016 when this study began). The head of police mountain rescue personnel in the included prefectures retrospectively answered our form with survey items such as age, sex, date and time of six points (start of activity, onset, callout, rescue team arrival, hospital arrival, and death confirmation), the mechanism, the number of groups, the person making the callout, presence or absence of any signs of life based on four points (at the onset, callout, rescue team arrival, and hospital arrival), implementation and type of medical intervention on-site, trigger of accident, cause of death, coexistence findings, information of onset and the found site such as weather, altitude, terrain features, mode of travel such as ascent, descent, ridge, rest, at the hut, sleeping, which did not contain individual-level identifying data. Any signs of life were considered "alive." The National Police Agency and the competent authority of each prefectural police headquarters approved the use of the abovementioned information for this study and mailed it to us. All postmortem examinations were done by physicians or coroners. Autopsies were not conducted because no crime and/or trouble were suspected.

Patient and public involvement

No patients or public were involved in the designing, conducting, reporting, or disseminating of this research.

Statistical analysis

Continuous data are expressed as median and interquartile range, whereas categorical variables are presented as counts and percentages. Proportions were compared using chi-square or Fisher's exact test, and the continuous data were compared using one-way analysis of variance or Kruskal–Wallis test. Furthermore, $P < 0.05$ was considered statistically significant. Data were stored using Excel 2019 (Microsoft, Seattle, WA, USA) and analyzed using EZR version 1.54 (Jichi Medical University, Saitama, Japan) modified R commander.

RESULTS

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Figure 1 illustrates the process of inclusion and exclusion of cases. After exclusion, 548 cases were analyzed, with 455 (83.0%) males and 95 (17.0%) females and a median age of 60 (46–68) and 62 (53–68) years, respectively.

Causes of death, its frequency, and alive cases at rescue team arrival

The overall fatality rate (number of death/number of callouts) (FR) was 10.2% (551/5422). Figure 2 (A) shows the cause of death and the number of alive victims during rescue team arrival. The causes of the majority of the deaths were the following: trauma (49.1%, 269), hypothermia (14.8%, 81), cardiac death (13.1%, 72), and avalanche-related death (6.6%, 36). During rescue team arrival, only 3.5% (19) were alive. Of these 19 alive cases, 14 (5.2% of 269), 4 (4.9% of 81), and 1 (1.4% of 71) exhibited trauma, hypothermia, and cardiac death, respectively.

Regional differences and FR

Figure 3 shows the differences between the north island (Hokkaido) and Japanese Alps range (Nagano, Toyama, Gifu) in terms of the cause of death, its frequency, and FR. The major cause of death was hypothermia in Hokkaido (FR: 4.1%, 32/784) and trauma in the Alps range (FR: 15.5%, 358/2308).

Table 1 Characteristics of four major causes of death in Japan from 2011 to 2015

		Trauma	**Hypothermia**	**Cardiac death**	**Avalanche-related**	**P value**
	n	269	81	72	36	
Sex	Male	213 (79.2)	70 (86.4)	67 (93.1)	32 (88.9)	0.022
	Female	56 (20.8)	11 (13.6)	5 (6.9)	4 (11.1)	0.022

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Age (years)	Median (IQR)	60 (47–67)	59 (43–68)	64.5 (58.8–71)	48 (39–58.3)	<0.001
Age group (years)	≤20	5 (1.9)	3 (3.7)	0 (0.0)	0 (0.0)	0.29
	21–40	44 (16.4)	15 (18.5)	0 (0.0)	11 (30.6)	<0.001
	41–60	98 (36.4)	26 (32.1)	29 (40.3)	18 (50.0)	0.286
	61–80	119 (44.2)	37 (45.7)	43 (59.7)	7 (19.4)	0.001
	≥81	3 (1.1)	0 (0.0)	0 (0.0)	0 (0.0)	0.548
Caller	By oneself	3 (1.1)	4 (5.2)	0 (0.0)	0 (0.0)	0.177
	Accompanied	91 (34.7)	18 (23.4)	26 (37.1)	17 (48.6)	0.194
	Passerby	77 (29.4)	9 (11.7)	27 (38.6)	9 (25.7)	0.015
	Not on-site	91 (34.7)	46 (59.7)	17 (24.3)	9 (25.7)	0.001
Group size	Solo	130 (48.3)	44 (54.3)	21 (29.2)	6 (16.7)	<0.001
	Group	139 (51.7)	36 (44.4)	51 (70.8)	30 (83.3)	<0.001
Contact location (multiple choices)	On trail	87 (41.0)	35 (49.3)	63 (88.7)	1 (2.9)	<0.001
	Hazardous	126 (59.2)	38 (53.5)	6 (8.5)	35 (100.0)	<0.001
Treatment	Done	18 (6.7)	7 (8.6)	24 (33.3)	0 (0.0)	<0.001

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Table 1 summarizes the characteristics stratified by the top four causes of death, namely, trauma, hypothermia, cardiac death, and avalanche, in 458 subjects. In cardiac death, male percentage was high (93.1%, 67/72), and all victims aged over 41 years ($P < 0.001$). Meanwhile, avalanche-related deaths were the youngest.

Type of trauma and avalanche-related injuries

Figure 4 shows the trauma types, avalanche-related injuries, and alive victim proportion during rescue arrival. The types of trauma included traumatic brain injury (TBI) (36.4%, 98/269), multiple injuries (35.7%, 96/269), cervical spine injury (7.4%, 20/269), chest injury (3.7%, 10/269), pelvic fracture (2.6%, 7/269), and others/undocumented (14.1%, 38/269), but only 7.1% (7/98), 2.1% (2/96), 5.0% (1/20), 0% (0/10), and 28.6% (2/7) were alive at rescue arrival, respectively. Avalanche-related death was mainly caused by asphyxia (84.6%, 22/26) followed by trauma (15.4%, 4/22). Unfortunately, none were alive when the rescue team arrived.

Characteristics at the time of occurrence

In trauma death, the mechanisms of injury (excluding the undocumented) were fall (94%, 222/236) and falling rocks (3.0%, 7/236). The predominant injury was blunt trauma. Meanwhile, Figure 5 shows the characteristics of hypothermia. Hypothermia deaths were recorded every month and most frequently in May (26%, 20/81), followed by April (10.4%, 8/81), both spring months, and then in December (10.4%, 8/81), which is the winter month. The callout time peaked at 17:00 and was between 17:00 and 6:00 at 49% (40/81); those made by themselves and persons not on-site accounted for 5.2% (4/77) and 59.7% (46/77), respectively. Regarding cardiac death, the callout time peaked at 11:00 and was 7:00 to 13:00 in 70.8%. In addition, 88.7% (63/71) of cardiac death cases were found on mountain trails ($P < 0.001$), while 59.2% (126/223) of trauma cases and 53.5%

(38/71) of hypothermia cases were found at the hazardous areas such as snow, rock, and ice ($P < 0.001$) (Table 1).

Figure 2(B) shows the differences of time distribution from onset to rescue arrival between the top four causes. The proportion of within 1 h from the onset to rescue arrival was 17.1% (24/140) for trauma, 3.1% (2/67) for hypothermia, 50.0% (22/44) for cardiac death, and zero in avalanche.

On-site treatment

On-site treatment was done in 31.1% (59/190) of documented cases. The most applied treatment was cardiopulmonary resuscitation (CPR) followed by automated external defibrillators (AED) (applied with or without record of shock), rewarming, bleeding control, immobilization, and oxygen therapy (44, 7, 6, 4, 1, and 1, respectively). Of the 44 CPRs, 22, 11, 2, and 1 were cases of cardiac death, trauma, stroke, and drowning, respectively. In cardiac death, 75.9% (22/29) underwent CPR, and 6.8% (5/7), including a bystander, underwent AED. However, the CPR initiation and duration time, presence or absence of shock, and return of spontaneous circulation achievement were not specified in the record. Meanwhile, rewarming was provided in six hypothermia cases and zero trauma cases.

DISCUSSION

In Japan, the major cause of mountain deaths during the designated period was trauma followed by hypothermia, cardiac death, and then avalanche-related death. In our study, the alive rate of all nonsurvivors upon rescue team arrival was only 3.5%. In a mountainous prehospital setting, on-site physicians and technical support such as cardiac monitoring, which confirms death, are generally unavailable in Japan. Confirming death by the absence of vital signs is unreliable; hence, correctly recognizing death immediately after death is extremely difficult.[7] The classification of being alive can still be uncertain, thereby possibly affecting the number of alive subjects on rescue arrival.

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Highly frequented regions such as Nagano, and victims who were found skeletonized more than a few months later might also have influenced the results. However, our 5-year data showed no hitting peaks or troughs of fluctuating trends by year, and many factors affected the length of interval from callout to recovery. Factors such as terrain, weather, and search technique can greatly affect the outcome of mountain rescue. Thus, our results can be considered valid for the overall picture of mountain death in Japan for 5 years. The cause of death reported by international research varies by region. In Denali between 1903 and 2006, the main cause of death among the 96 included cases was trauma followed by hypothermia, AAI, and cardiac death (43, 44.8%; 16, 16.7%; 7, 7.3%; and 1, 1%, respectively).[5] In the Aconcagua Provincial Park between 2001 and 2012, death in 33 included cases was also mainly caused by trauma but followed by AAI, hypothermia, and cardiac death (9, 27.2%; 7, 21.2%; 5, 15.2%; 4, 12.1%, respectively).[6] In our study, trauma and hypothermia showed similar trends, but no AAI deaths were noted. The incidence of high-altitude pulmonary edema, which is fatal, is reportedly 0.3% at 3500 m altitude.[8] However, our study showed that Japan's mountains are not high enough to cause altitude-related deaths often. Even in Japan, the causes of death, its frequency, and FR were different by region. In the present study, the FR was not the mortality rate for the number of mountaineers because such number remains uncertain. This study intended to consider enhancing the survival by focusing on people that need rescue. The FR was clearly lower in the north island than in the Alps range (Fig. 3). In contrast to trauma and cardiac death, AAI and hypothermia gradually developed and progressed, which allowed survival for a longer time until rescue. This notion could be one of the reasons causing the regional differences in FR in Japan. Previously, the alive rate of all nonsurvivors on rescue team arrival was 7% (4/57) in Scottish mountain,[9] and 85% of rural trauma victims died at the prehospital setting in Norway,[10] with 2 years of observation period. Our 5-year results support that in remote environments, most deaths occur on the site before rescue team arrival.

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According to previous studies, the main mechanism of injury in the mountain associated with trauma is fall (59.6%).[5, 9, 11] In our study, 95% of trauma deaths were caused due to fall. Thus, fall is the major cause of death as well as the major mechanism of trauma. However, we could not collect the fall distance data in most of our cases. The larger the fall distance, the higher the risk of fatality.[3] Recently, major trauma has increased in the elderly, and its main mechanism is a fall of <2 m.[12] The pathophysiological response to trauma, anatomical and physiological fragility, and the potential higher serious comorbidities in older individuals, can increase the probability of major trauma from low-velocity mechanisms in this age group, which leads to a higher FR and early death compared with younger people.[13, 14] These findings can potentially impact the low alive rate at rescue arrival in the current study. The occurrence of cardiac death was higher in males >41 years old, similar to previous reports focusing on European Alps and obtaining 90%–95% of males aged over 34 years.[4] In our study, the time of collapse in an unwitnessed arrest was impossible to estimate, but at least 48.8% of the cases resulted in death within 1 h of onset, which corresponded to SCD.[15] Aging is a strong risk predictor of sudden cardiac arrest (SCA), which increases after the age of 35 years. Moreover, SCD is more common in males in all age groups.[16] The prevalence of SCD in the mountain can be attributed to such finding. Additionally, the incidence of sudden death is several times higher during exercise than at other times.[17] Unfortunately, in Japan, where many mountaineers are already in the middle age, SCD will continue to occur, considering the previous findings.

Regarding the time factors, the major causes of death were significantly different from the onset to rescue arrival (Fig. 2B). Concerning the time from the onset to callout, if signal is available, callout can be made in a short time in trauma-, cardiac death-, and avalanche-related accidents with apparent onset. In hypothermia, approximately half of the callout was made after around twilight. Previously, hypothermia deaths tended to occur as a result of injury and AAI.[5] In our study, secondary to trauma by 17.5% (14/81); thus, most of the hypothermia cases were primary because of prolonged exposure to heat loss, bad weather, and fasting. When hypothermia progresses to stage ≥2, the victims lose their judgment because of the decreased level of consciousness. Moreover, lone subjects were mostly males, and the onset of hypothermia was unclear. Consequently, making callouts on the site becomes impossible once the stage progresses. These views are the reasons why 59.7% of the callout was from a person who was not at the site, such as a family member, after recognizing that the casualty had not returned home. Therefore, the dispatch of the rescue team was delayed, and the hypothermia stage had further progressed. Additionally, most cardiac deaths occurred on a mountain trail, which shortened the required time to search and locate casualties. Conversely, searching for fall (trauma) and hypothermic casualties in places that require a technical rescue process was more time consuming. Regarding the time from the onset to rescue team arrival, our results revealed that at least 83% of trauma deaths took >60 min to be rescued, and no alive cases were rescued >6 h. In previous studies, an out-of-hospital time (OHT) exceeding 60 min was observed in 84% and 67% of mountain trauma and helicopter rescue cases, respectively,[11, 18] which led to an increased mortality rate in seriously injured patients.[19] Meanwhile, mountain rescue operations have a longer OHT (mean: 117.4 ± 142.9 min) associated with a prolonged treatment-free interval (TFI) than rescue operations in non-alpine areas (68.7 ± 28.6 min), but there was no difference in the hospital mortality.[11] Moreover, the mortality within the first hour of injury was high between 70% and 80% regardless of rurality.[10] In our study, though some casualties possibly had life-threatening injuries, we found alive cases even with a prolonged OHT. Factors that can contribute to survival other than a short OHT should be specified.

In cardiac death, despite an increased rate of rescue arrival within 1 h, only one patient remained alive. Survival from SCA is inversely related to the interval from collapse to definitive care,[20, 21] and in SCD, the best outcome reported was from the occurrence site with a publicly recognizable advanced emergency response system.[22] In this study, callouts by a companion or a passerby accounted for 52.1% (38/73), and the witnessed cardiac arrest was at least 24.7% (18/73). However, the current emergency response system in the mountain is far from obtaining better outcomes. Considering the on-site treatment, on-site interventions were greater than the alive subjects. Given that some cases had undetectable vital signs, death could hardly be confirmed.

With correct implementation of first aid in blunt trauma, mortality potentially decreased by 4.5%.[23] In this study, 28.6% (2/7) had pelvic fracture and 7.1% (7/98) had TBI death after rescue arrival. Early diagnosis and treatment can possibly prevent death caused by pelvic exsanguination.[24] Pelvic binders were 70% effective in stabilizing the pelvis.[25] In severe TBI, basic airway management with oxygen administration obtained a better outcome than endotracheal intubation with oxygen administration for hypoxia prevention ($SaO2 \leq 94\%$).[26] Though our results cannot demonstrate statistical significance, they can encourage the implementation and education of these procedures for lifesaving in remote environments, with the background of current reported evidence. For hypothermia, on-site rewarming is safe and effective,[27] but the implementation rate on rescue arrival is low. Appropriate rewarming with mountain equipment showed good recovery at the site by nonmedical people when casualty transportation was difficult during a bad weather or at night.[28] In this study, even after 6 h from callout, alive cases were found. Early callout, first aid skill education, and dispatcher-assist rewarming might help shorten the TFI and increase the chances of survival. In our study, the CPR interventions were highest in cardiac death. Most SCAs were found on busy mountain trails where a bystander is likely to be present. However, the quality of chest compressions apparently decreases in 5–10 min at an altitude of 3454 m.[29] CPR implementation in the mountains is extremely restricted by technical issues such as the chest compression quality, AED availability, ventilation requirement, and human resources, as well as the safety of rescuers such as the bystander's advance age, the terrain, the longer interval from the onset to rescue arrival, and the weather. Moreover, dispatcher-assist CPR is effective in out-of-hospital cardiac arrest.[30] When heart attack is suspected, prompt callouts should be done to utilize the dispatch-assisted CPR instructions. Both the decisions to implement and to hold and terminate CPR should be supported.

Meanwhile, this study is limited by the retrospective analysis based on a nonstandardized report form from the regional rescue team. Some data were also missing. The emergency setting in the mountain that has restricted circumstances can hinder the recording of accurate prehospital time-stamped patient data. Future research needs to construct a standardized data collection system to reduce missing data in collaboration with the dispatcher center and hospitals and to collate with other topographical areas, considering the limited number of deaths.

In conclusion, the leading causes of death in the mountains in Japan are trauma, hypothermia, SCD, and avalanche-related deaths. The alive rate on rescue arrival in nonsurvivors was only 3.5%. No survival was observed in >6 hours in trauma and >1 hour in cardiac death cases, but a longer survival time was observed in cases of hypothermia. Early intervention into pelvic fracture and TBI, which have higher alive rate on rescue arrival, and major improvement in early recognition leading to early callout and initiation of effective rewarming in hypothermia cases can possibly enhance survival by shortening TFI. Heart attack cases mostly correspond to SCD; however, due to the obvious onset, occurrence on mountain trail, probable early callout, and easy locating, the time until rescue arrival can be better utilized for survival.

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ORIGINAL PROTOCOL

This study does not have an associated protocol.

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COMPETING INTERESTS

The authors declare no conflict of interest.

AUTHOR CONTRIBUTORS

K.O. and T.M. contributed to the conception and design. K.O. contributed to the acquisition and analysis. K.O. drafted the manuscript. K.O. and T.M. critically revised the manuscript, contributed to interpretation, gave final approval, and agreed to be accountable for all aspects of the work ensuring integrity and accuracy. K.O. and T.M. read and agreed for the publication of the final version of the manuscript.

ETHICAL STATEMENT

The National Police Agency and the competent authority of each prefectural police headquarters approved the use of the abovementioned information for this study and mailed it to us. Participant consent is waived due to retrospective nature of the study.

DATA AVAILABILITY STATEMENT

No additional data are available.

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FIGURE LEGENDS

Fig. 1. Flow diagram illustrating the inclusion and exclusion processes

Fig. 2. Cause of death, time distribution until rescue arrival, and the number of alive subjects between 2011 and 2015 in Japan

(A) The overall number of deaths and the number of alive subjects during rescue team arrival according to cause (B) Differences in time distribution and the number of alive subjects from the onset to rescue arrival between the top four causes of death

Fig. 3. Regional differences in the proportion of alive subjects on rescue arrival and in the cause of death

Fig. 4. (A) Types of trauma and the proportion of alive subjects (B) Causes of avalanche-related death

Fig. 5. Characteristics of nonsurvivors in hypothermia (A) Month of occurrence (B) Proportion of people who made the callout (C) Distribution of callout time

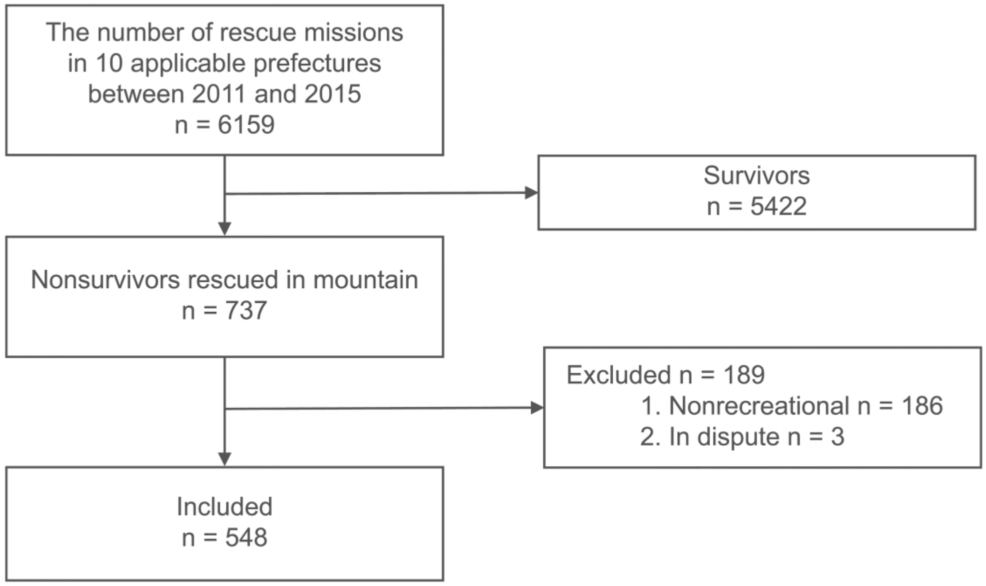

Fig. 1. Flow diagram illustrating the inclusion and exclusion processes

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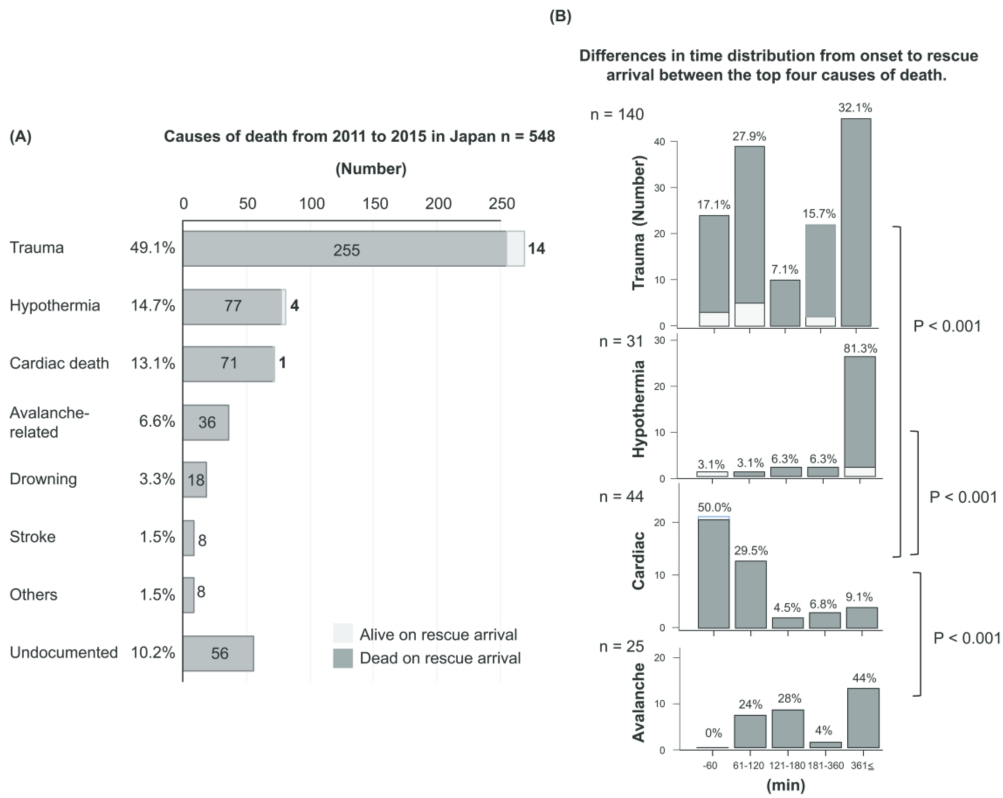

Fig. 2. Cause of death, time distribution until rescue arrival, and the number of alive subjects between 2011 and 2015 in Japan
(A) The overall number of deaths and the number of alive subjects during rescue team arrival according to cause (B) Differences in time distribution and the number of alive subjects from the onset to rescue arrival between the top four causes of death

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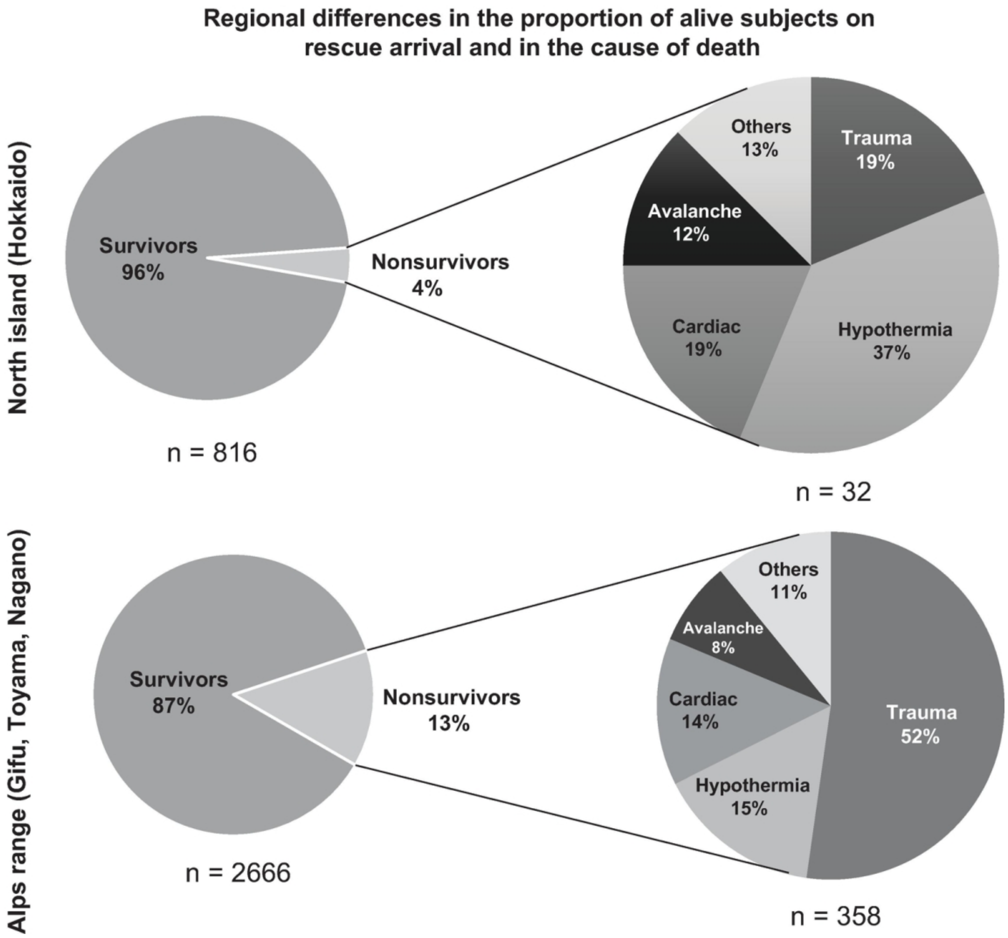

Fig. 3. Regional differences in the proportion of alive subjects on rescue arrival and in the cause of death

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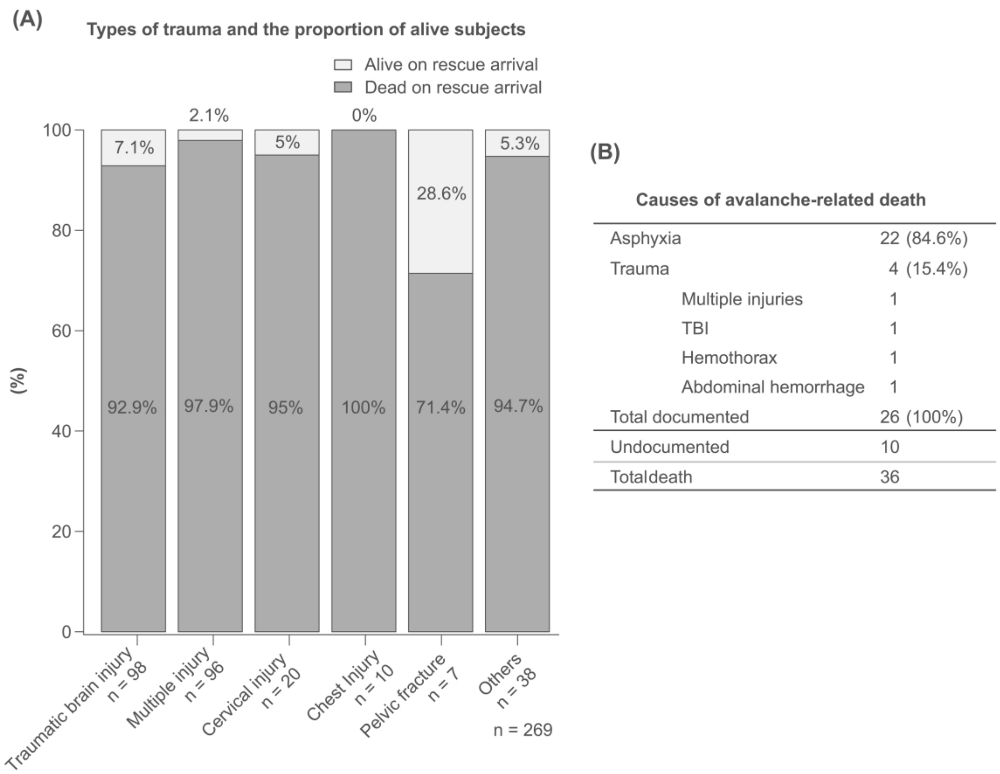

Asphyxia	22 (84.6%)
Trauma	4 (15.4%)
Multiple injuries	1
TBI	1
Hemothorax	1
Abdominal hemorrhage	1
Total documented	26 (100%)
Undocumented	10
Totaldeath	36

Fig. 4. (A) Types of trauma and the proportion of alive subjects (B) Causes of avalanche-related death

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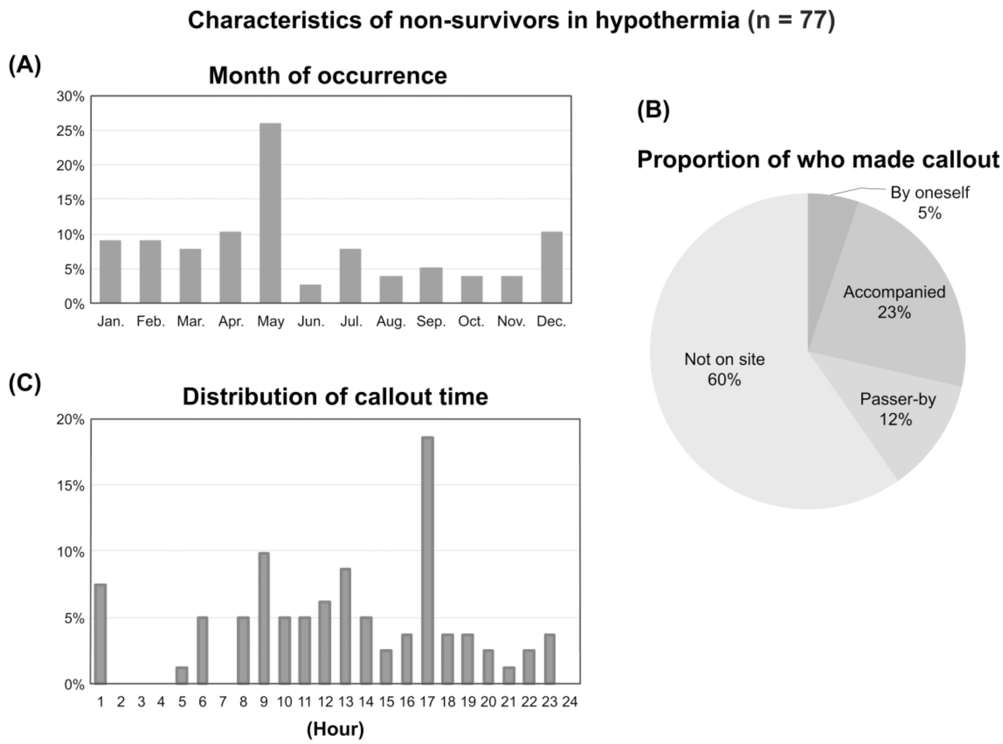

Fig. 5. Characteristics of nonsurvivors in hypothermia (A) Month of occurrence (B) Proportion of people who made the callout (C) Distribution of callout time

180x132mm (600 x 600 DPI)

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	4,5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4,5
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	Not applicable
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4,5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*4,5*
Bias	9	Describe any efforts to address potential sources of bias	4,5
Study size	10	Explain how the study size was arrived at	4,5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	4,5
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	5
		(*b*) Describe any methods used to examine subgroups and interactions	4,5
		(*c*) Explain how missing data were addressed	4,5
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	Not applicable
		(*e*) Describe any sensitivity analyses	4,5

Continued on next page

Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6
		(b) Give reasons for non-participation at each stage	6
		(c) Consider use of a flow diagram	Fig.1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	6
		(b) Indicate number of participants with missing data for each variable of interest	6, Figure
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	Not applicable
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	Not applicable
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Not applicable
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	6-9
Discussion			
Key results	18	Summarise key results with reference to study objectives	9
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	9,10,14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	10-14
Generalisability	21	Discuss the generalisability (external validity) of the study results	10-14
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Not applicable

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

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Causes of Death and Characteristics of Nonsurvivors Rescued during Recreational Mountain Activities in Japan between 2011 and 2015: A Retrospective Analysis

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Word count: 3,116

ABSTRACT

Objectives: This study aimed to describe the cause of death and characteristics at the prehospital setting associated with care and rescue processes of nonsurvivors rescued in the mountain of Japan.

Design: Retrospective analysis.

Setting: Prehospital setting of mountain searches and rescues in Japan. A total of 10 prefectural police headquarters with >10 cases of mountain death from 2011 to 2015.

Participants: Data were generated from the existing records. Of the total 6,159 rescued subjects, 548 mountain deaths were caused by recreational activities.

Results: Among the 548 mountain deaths, 83% were men, and major causes of death were trauma (49.1%), hypothermia (14.8%), cardiac death (13.1%), and avalanche-related death (6.6%). The alive rate at rescue team arrival in all nonsurvivors was 3.5%, with 1, 4, and 14 cases of cardiac, hypothermia, and trauma, respectively. Cardiac deaths occurred in 93.1% (67/72) of men and individuals aged >41 years, and 88.7% (63/71) were found on mountain trails. In hypothermia, callouts were made between 17:00 and 6:00 at 49% (40/81) and by persons not on-site in 59.7% (46/77). People with >6 h in trauma or >1 h in cardiac death already died upon rescue team arrival, but some with hypothermia after 6 h were alive.

Conclusion: This study is one of the first large-scale retrospective analyses of prehospital nonsurvivors in mountain emergencies. The alive rate at rescue arrival in all mountain deaths was only 3.5%. These data showed that the circumstances related to onset and the process until the rescue team arrives have different characteristics depending on the cause of death. Survival may be enhanced by targeting better use of the time before rescue team arrival and by providing further education, particularly mountain rescue-related medical problems to rescuers including bystanders.

Keywords: prehospital, mountain rescue, accident & emergency medicine, medical education & training, quality in health care

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STRENGTHS AND LIMITATIONS OF THIS STUDY

►This study is one of the first large-scale analyses of prehospital nonsurvivors who were rescued during recreational mountain activities.

►This study provides the alive rate of deaths on rescue team arrival, and the care and rescue processes of the prehospital setting time is evaluated for enhancing survival for each major cause of death.

►This research targeted the rescued people in Japan, and from a universal perspective of injury and illness, the results of this study can be generalized; however, the generalization of the results may be limited since the topography, weather, and rescue systems vary depending on the country and mountain area.

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INTRODUCTION

Numerous people visit mountainous areas for recreational activities; in the 2016 official statistics of Japan, 11.37 million people aged >10 years joined mountaineering in 2015.[1] Considering the topographic features, weather conditions, activity duration, and heavy and/or inadequate equipment, mountain activities can be physically demanding and lead to serious injuries or death. The mountain rescue team in Japan comprises police organizations. According to the National Police Agency report, the total callouts in 2015 were 3,043, of which 11% died (335/3,043). Considering this information, >300 people die in Japan's mountainous areas annually.[2] Mountain fatalities were retrospectively studied, and trauma, acute altitude illness (AAI), hypothermia, avalanche burial, and sudden cardiac death (SCD) were the most common causes.[3-6] However, few studies have examined the cause of death and the characteristics at the prehospital setting in recreational mountain activities internationally[3,7] or in Japan. We conducted a large-scale analysis of nonsurvivors rescued in Japan between 2011 and 2015. We aimed to clarify the causes and frequency of mountain deaths and identify the onset and rescue response circumstances and the prehospital setting time course to develop possible measures to strengthen the response and enhance survival chances during emergency situations in the mountain.

METHODS

Data source

After each mountain rescue mission, police officers record the event on the rescue report form, which is kept for the annual rescue report for 5 years. This report covers all rescued people in Japan. We collected such reports from police headquarters within all prefectures that had over 10 mountain death cases between January 2011 and December 2015 (the last 5 years in which records were kept as of 2016 when this study began). The head of police mountain rescue personnel in the included prefectures retrospectively obtained data from the documented information survey items, such as

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age; sex; date and time of six points (start of activity, onset, callout, rescue team arrival, hospital arrival, and death confirmation); the mechanism; number of groups; person making the callout; presence or absence of any signs of life based on four points (at the onset, callout, rescue team arrival, and hospital arrival); implementation and type of medical intervention on-site; trigger of accident; cause of death; coexistence findings; information of onset and the found site such as weather, altitude, terrain features; and mode of travel such as ascent, descent, ridge, rest, at the hut, sleeping, which did not contain individual-level identifying data. Any signs of life were considered "alive." The National Police Agency and the competent authority of each prefectural police headquarters approved the use of the abovementioned information for this study and mailed it to us. All postmortem examinations were done by physicians or coroners. Autopsies were not conducted, because no crime and/or trouble were suspected.

Patient and public involvement

No patients or public were involved in the designing, conducting, reporting, or disseminating of this research.

Statistical analysis

Continuous data are expressed as median and interquartile range, whereas categorical variables are presented as counts and percentages. Proportions were compared using chi-square or Fisher's exact test, and the continuous data were compared using one-way analysis of variance or Kruskal–Wallis test. Furthermore, $P < 0.05$ was considered statistically significant. Data were stored using Excel 2019 (Microsoft, Seattle, WA, USA) and analyzed using EZR version 1.54 (Jichi Medical University, Saitama, Japan) modified R commander.

RESULTS

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Figure 1 illustrates the process of inclusion and exclusion of cases. After exclusion, 548 cases were analyzed, with 455 (83.0%) men and 95 (17.0%) women and a median age of 60 (46–68) years and 62 (53–68) years, respectively.

Causes of death and alive rate at rescue team arrival

The overall fatality rate (number of death/number of callouts) (FR) was 12.0% (737/6,159). Figure 2 (A) shows the cause of death and the number of alive victims during rescue team arrival. The causes of the majority of the deaths were the following: trauma (49.1%, 269), hypothermia (14.8%, 81), cardiac death (13.1%, 72), and avalanche-related death (6.6%, 36). During rescue team arrival, only 3.5% (19) were alive. Of these 19 alive cases, 14 (5.2% of 269), 4 (4.9% of 81), and 1 (1.4% of 71) exhibited trauma, hypothermia, and cardiac death, respectively.

Regional differences in mortality outcomes

Figure 3 shows the differences between the north island (Hokkaido) and Japanese Alps range (Nagano, Toyama, Gifu) in terms of the cause of death, its frequency, and FR. The major cause of death was hypothermia in Hokkaido (FR: 4.1%, 32/784) and trauma in the Alps range (FR: 15.5%, 358/2308).

Table 1. Characteristics of four major causes of death in Japan from 2011 to 2015

		Trauma	**Hypothermia**	**Cardiac death**	**Avalanche-related**	**P value**
	n	269	81	72	36	
Sex	Male	213 (79.2)	70 (86.4)	67 (93.1)	32 (88.9)	0.022
	Female	56 (20.8)	11 (13.6)	5 (6.9)	4 (11.1)	0.022

Age (years)	Median (IQR)	60 (47–67)	59 (43–68)	64.5 (58.8–71)	48 (39–58.3)	<0.001
Age group (years)	≤20	5 (1.9)	3 (3.7)	0 (0.0)	0 (0.0)	0.29
	21–40	44 (16.4)	15 (18.5)	0 (0.0)	11 (30.6)	<0.001
	41–60	98 (36.4)	26 (32.1)	29 (40.3)	18 (50.0)	0.286
	61–80	119 (44.2)	37 (45.7)	43 (59.7)	7 (19.4)	0.001
	≥81	3 (1.1)	0 (0.0)	0 (0.0)	0 (0.0)	0.548
Caller	By oneself	3 (1.1)	4 (5.2)	0 (0.0)	0 (0.0)	0.177
	Accompanied	91 (34.7)	18 (23.4)	26 (37.1)	17 (48.6)	0.194
	Passerby	77 (29.4)	9 (11.7)	27 (38.6)	9 (25.7)	0.015
	Not on-site	91 (34.7)	46 (59.7)	17 (24.3)	9 (25.7)	0.001
Group size	Solo	130 (48.3)	44 (54.3)	21 (29.2)	6 (16.7)	<0.001
	Group	139 (51.7)	36 (44.4)	51 (70.8)	30 (83.3)	<0.001
Contact location (multiple choices)	On trail	87 (41.0)	35 (49.3)	63 (88.7)	1 (2.9)	<0.001
	Hazardous	126 (59.2)	38 (53.5)	6 (8.5)	35 (100.0)	<0.001
Treatment	Done	18 (6.7)	7 (8.6)	24 (33.3)	0 (0.0)	<0.001

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Table 1 summarizes the characteristics stratified by the top four causes of death, namely, trauma, hypothermia, cardiac death, and avalanche, in 458 subjects. In cardiac death, the percentage of male victims was high (93.1%, 67/72), and all victims aged >41 years ($P < 0.001$). Meanwhile, avalanche-related deaths were the youngest.

Type of trauma and avalanche-related injuries

Figure 4 shows the trauma types, avalanche-related injuries, and alive victim proportion during rescue arrival. The types of trauma included traumatic brain injury (TBI) (36.4%, 98/269), multiple injuries (35.7%, 96/269), cervical spine injury (7.4%, 20/269), chest injury (3.7%, 10/269), pelvic fracture (2.6%, 7/269), and others/undocumented (14.1%, 38/269), but only 7.1% (7/98), 2.1% (2/96), 5.0% (1/20), 0% (0/10), and 28.6% (2/7) were alive at rescue arrival, respectively. Avalanche-related death was mainly caused by asphyxia (84.6%, 22/26) followed by trauma (15.4%, 4/22). Unfortunately, none were alive when the rescue team arrived.

Characteristics at the time of occurrence

In trauma death, the mechanisms of injury (excluding the undocumented) were fall (94%, 222/236) and falling rocks (3.0%, 7/236). The predominant injury was blunt trauma. Meanwhile, Figure 5 shows the characteristics of hypothermia. Hypothermia deaths were recorded every month and most frequently in May (26%, 20/81), followed by April (10.4%, 8/81), both spring months, and then in December (10.4%, 8/81), which is the winter month. The callout time peaked at 17:00 and was between 17:00 and 6:00 at 49% (40/81); those made by themselves and persons not on-site accounted for 5.2% (4/77) and 59.7% (46/77), respectively. Regarding cardiac death, the callout time peaked at 11:00 and was 7:00 to 13:00 in 70.8%. In addition, 88.7% (63/71) of cardiac death cases were found on mountain trails ($P < 0.001$), while 59.2% (126/223) of trauma cases and 53.5%

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(38/71) of hypothermia cases were found at the hazardous areas such as snow, rock, and ice ($P < 0.001$) (Table 1).

Figure 2(B) shows the differences of time distribution from onset to rescue arrival between the top four causes. The proportion of within 1 h from the onset to rescue arrival was 17.1% (24/140) for trauma, 3.1% (2/67) for hypothermia, 50.0% (22/44) for cardiac death, and zero in avalanche.

On-site treatment

On-site treatment was done in 31.1% (59/190) of documented cases. The most applied treatment was cardiopulmonary resuscitation (CPR) followed by automated external defibrillators (AED) (applied with or without record of shock), rewarming, bleeding control, immobilization, and oxygen therapy (44, 7, 6, 4, 1, and 1, respectively). Of the 44 CPRs, 22, 11, 2, and 1 were cases of cardiac death, trauma, stroke, and drowning, respectively. In cardiac death, 75.9% (22/29) underwent CPR, and 6.8% (5/7), including a bystander, underwent AED. However, the CPR initiation and duration time, presence or absence of shock, and return of spontaneous circulation achievement were not specified in the record. Meanwhile, rewarming was provided in six hypothermia cases (three were initiated by bystanders) and zero trauma cases.

DISCUSSION

In Japan, the major cause of mountain deaths during the designated period was trauma followed by hypothermia, cardiac death, and then avalanche-related death. In our study, the alive rate of all nonsurvivors upon rescue team arrival was only 3.5%. In a mountainous prehospital setting, on-site physicians and technical support such as cardiac monitoring, which confirms death, are generally unavailable in Japan. Confirming death by the absence of vital signs is unreliable; hence, correctly recognizing death immediately after death is extremely difficult.[8] The classification of being alive can still be uncertain, thereby possibly affecting the number of alive subjects on rescue arrival. In

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addition, although all deaths were confirmed by physicians or coroners, autopsy was not performed for all, which may influence the cause of death of an unwitnessed cardiac arrest. Highly frequented regions such as Nagano, and victims who were found skeletonized more than a few months later might also have influenced the results. However, our 5-year data showed no hitting peaks or troughs of fluctuating trends by year, and many factors affected the length of interval from callout to recovery. Factors such as terrain, weather, and search technique can greatly affect the outcome of mountain rescue. Thus, our results can be considered valid for the overall picture of mountain death in Japan for 5 years. The cause of death reported by international research varies by region. In Denali between 1903 and 2006, the main cause of death among the 96 included cases was trauma followed by hypothermia, AAI, and cardiac death (43, 44.8%; 16, 16.7%; 7, 7.3%; and 1, 1%, respectively).[5] In the Aconcagua Provincial Park between 2001 and 2012, death in 33 included cases was also mainly caused by trauma but followed by AAI, hypothermia, and cardiac death (9, 27.2%; 7, 21.2%; 5, 15.2%; 4, 12.1%, respectively).[6] In our study, trauma and hypothermia showed similar trends, but no AAI deaths were noted. The incidence of high-altitude pulmonary edema, which is fatal, is reportedly 0.3% at 3,500 m altitude.[9] However, our study showed that Japan's mountains are not high enough to cause altitude-related deaths often. Even in Japan, the causes and frequency of death and the FR differed by region. In the present study, the FR was not the mortality rate for the number of mountaineers because such number remains uncertain. This study intended to consider enhancing the survival by focusing on people that need rescue. The FR was clearly lower in the north island than in the Alps range (Fig. 3). In contrast to trauma and cardiac death, hypothermia gradually developed and progressed, which allowed survival for a longer time until rescue. This notion could be one of the reasons causing the regional differences in FR in Japan. Previously, the alive rate of all nonsurvivors on rescue team arrival was 7% (4/57) in Scottish mountain,[10] and 85% of rural trauma victims died at the prehospital setting in

Norway,[11] with 2 years of observation period. Our 5-year results support that in remote environments, most deaths occur on the site before rescue team arrival.

According to previous studies, the main mechanism of injury associated with trauma in the mountains is a fall (59.6%).[5,10,12] In our study, 95% of trauma deaths were caused due to falls. Therefore, falls are the major cause of death and the major mechanism of trauma. The larger the fall distance, the higher the risk of fatality;[3] however, we could not obtain data regarding the fall height for most of the victims; these data could enhance our study's contributions to the field. Recently, the incidences of major trauma have increased in the elderly, and the main mechanism is a fall from a height of >2 m.[13] The pathophysiological response to trauma, anatomical and physiological fragility, and potential higher serious comorbidities in older individuals can increase the probability of major trauma from low-velocity mechanisms in this age group, which leads to a higher FR and early death than those in younger people.[14,15] These findings potentially impact the low alive rate at rescue arrival in the current study. The occurrence of cardiac death was higher in men aged >41 years; this was similar to previous reports focusing on the European Alps, in which 90%–95% were males, all aged >34 years.[4]In our study, the time of collapse in an unwitnessed arrest was impossible to estimate, but at least 48.8% of the cases resulted in death within 1 h of onset, which corresponded to SCD.[16] Aging is a strong risk predictor of sudden cardiac arrest (SCA), which increases after the age of 35 years. Moreover, SCD is more common among men rather than women in all age groups.[17] The prevalence of SCD in mountain fatalities can be attributed to such finding. Additionally, the incidence of sudden death is several times higher during exercise than at other times.[18] Unfortunately, in Japan, where many mountaineers are already in middle age, SCD will continue to occur, according to previous findings.

Regarding the time factors, the major causes of death were significantly different from the onset to rescue arrival (Fig. 2B). Concerning the time from the onset to callout, if signal is available, callout can be made in a short time in trauma-, cardiac death-, and avalanche-related accidents with apparent onset. In hypothermia, approximately half of the callout was made after around twilight. Previously, hypothermia deaths tended to occur as a result of injury.[5] In our study, secondary to trauma by 17.5% (14/81); thus, most of the hypothermia cases were primary because of prolonged exposure to heat loss, bad weather, and fasting. When hypothermia progresses to stage ≥2, the victims lose their judgment because of the decreased level of consciousness. Moreover, lone subjects were mostly men, and the onset of hypothermia was unclear. Consequently, making callouts on the site becomes impossible once the stage progresses. These views are the reasons why 59.7% of the callout was from a person who was not at the site, such as a family member, after recognizing that the casualty had not returned home. Therefore, the dispatch of the rescue team was delayed, and the hypothermia stage had further progressed. Additionally, most cardiac deaths occurred on a mountain trail, which shortened the required time to search and locate casualties. Conversely, searching for fall (trauma) and hypothermic casualties in places that require a technical rescue process was more time consuming. Regarding the time from the onset to rescue team arrival, our results revealed that at least 83% of trauma deaths took >60 min to be rescued, and no alive cases were rescued >6 h. In previous studies, an out-of-hospital time (OHT) exceeding 60 min was observed in 84% and 67% of mountain trauma and helicopter rescue cases, respectively,[12,19] which led to an increased mortality rate in seriously injured patients.[20] Meanwhile, mountain rescue operations have a longer OHT (mean: 117.4 ± 142.9 min) associated with a prolonged treatment-free interval (TFI) than rescue operations in nonalpine areas (68.7 ± 28.6 min), but there was no difference in the hospital mortality.[12] Moreover, the mortality within the first hour of injury was high between 70% and 80% regardless of rurality.[11] In our study, though some casualties possibly had life-threatening injuries, we found alive cases even with a prolonged OHT. Factors that can contribute to survival other than a short OHT should be specified.

In the cardiac death group (nonsurvivors), only one victim was alive when the rescue team arrived, despite an increased rate of rescue team arrival within 1 h. Survival from SCA is inversely

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correlated with the interval from collapse to definitive care,[21,22] and in SCD, the best outcome reported was from the occurrence site with a publicly recognizable advanced emergency response system.[23] In the present study, 52.1% (38/73) callouts were made by a companion or a passerby and at least 24.7% (18/73) of cardiac arrest incidences were witnessed. However, the current emergency response system in the mountains has to overcome various hurdles before better outcomes can be achieved.

Considering on-site treatment, the number of on-site interventions was greater than that of the alive subjects. Given that some cases had undetectable vital signs, death could hardly be confirmed. With correct implementation of first aid in blunt trauma, mortality potentially decreased by 4.5%.[24] In the present study, 28.6% (2/7) had pelvic fracture, and 7.1% (7/98) had TBI death after rescue arrival. Early diagnosis and treatment may prevent death caused by pelvic exsanguination.[25] Pelvic binders were 70% effective in stabilizing the pelvis.[26] In severe TBI, basic airway management with oxygen administration obtained a better outcome than endotracheal intubation with oxygen administration for hypoxia prevention ($SaO_2 \leq 94\%$).[27,28] Despite the fact that our results do not demonstrate statistical significance, they encourage the implementation of and training on these procedures for lifesaving in remote environments considering the background of reported evidence. For hypothermia, on-site rewarming is safe and effective,[29] but the implementation rate on rescue arrival is low. Appropriate rewarming with mountain equipment showed good recovery at the site by nonmedical persons when casualty transportation was difficult during bad weather or at night.[30] In this study, even after 6 h from callout, alive cases were found. Early callout, first-aid skill education, and dispatcher-assisted rewarming contribute to a shortened TFI and increase the chances of survival. In our study, CPR interventions were highest in cardiac death. Most SCAs were found on busy mountain trails where a bystander is likely to be present. However, the quality of chest compressions apparently decreases in 5–10 min at an altitude of 3,454 m.[31] CPR implementation in the mountains is restricted by various technical issues, including chest compression quality, AED availability, ventilation requirement, and human resources, as well as the safety of rescuers, such as the bystander's advance age, the terrain, the longer interval from onset to rescue arrival, and the weather. Moreover, dispatcher-assisted CPR is effective in treating out-of-hospital cardiac arrest.[32] When heart attack is suspected, prompt callouts should be made to utilize dispatch-assisted CPR instructions. The decisions to implement, hold, and terminate CPR should be supported.

The limitation of this study lies in its retrospective nature; analyses were performed based on data extracted from the information recorded in each regional format. Police record formats are unified by region, but not nationwide. Although the facts of field activities by rescue teams are recorded, the emergency setting in the mountain that has restricted circumstances can hinder the recording of accurate prehospital time-stamped patient data. For this reason, some data were missing. Future research needs to construct a standardized data collection system to reduce missing data in collaboration with the dispatcher center and hospitals and to collate with other topographical areas, considering the limited number of deaths.

In conclusion, the leading causes of death in the mountains in Japan are trauma, hypothermia, SCD, and avalanche-related deaths. The alive rate on rescue arrival in nonsurvivors was only 3.5%. No survival was observed in >6 h in trauma and >1 h in cardiac death cases, but a longer survival time was observed in cases of hypothermia. Early intervention into pelvic fracture and TBI, which have higher alive rate on rescue arrival, and major improvement in early recognition leading to early callout and initiation of effective rewarming in hypothermia cases can possibly enhance survival by shortening TFI. Heart attack cases mostly correspond to SCD; however, due to the obvious onset, occurrence on mountain trail, probable early callout, and easy locating, the time until rescue arrival can be better utilized for survival.

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ORIGINAL PROTOCOL

This study does not have an associated protocol.

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COMPETING INTERESTS

The authors declare no conflict of interest.

AUTHOR CONTRIBUTORS

K.O. and T.M. contributed to the conception and design. K.O. contributed to the acquisition and analysis. K.O. drafted the manuscript. K.O. and T.M. critically revised the manuscript, contributed to interpretation, gave final approval, and agreed to be accountable for all aspects of the work to ensure integrity and accuracy. K.O. and T.M. read and agreed to the publication of the final version of the manuscript.

ETHICAL STATEMENT

The National Police Agency and the competent authority of each prefectural police headquarters approved the use of the abovementioned information for this study and mailed it to us. Participant consent was waived owing to the retrospective nature of the study.

DATA AVAILABILITY STATEMENT

No additional data are available.

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FIGURE LEGENDS

Fig. 1. Flow diagram illustrating the inclusion and exclusion processes

Fig. 2. Cause of death, time distribution until rescue arrival, and the number of alive subjects between 2011 and 2015 in Japan

(A) The overall number of deaths and the number of alive subjects during rescue team arrival according to cause (B) Differences in time distribution and the number of alive subjects from the onset to rescue arrival between the top four causes of death

Fig. 3. Regional differences in the proportion of alive subjects on rescue arrival and in the cause of death

Fig. 4. (A) Types of trauma and the proportion of alive subjects (B) Causes of avalanche-related death

Fig. 5. Characteristics of nonsurvivors in hypothermia

(A) Month of occurrence (B) Proportion of people who made the callout (C) Distribution of callout time

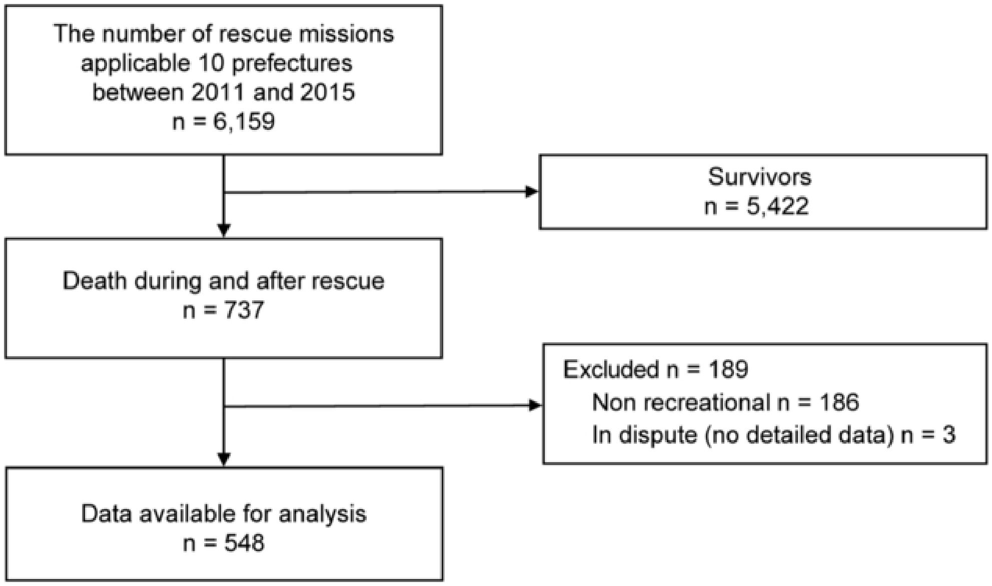


Fig. 1. Flow diagram illustrating the inclusion and exclusion processes

27x16mm (600 x 600 DPI)

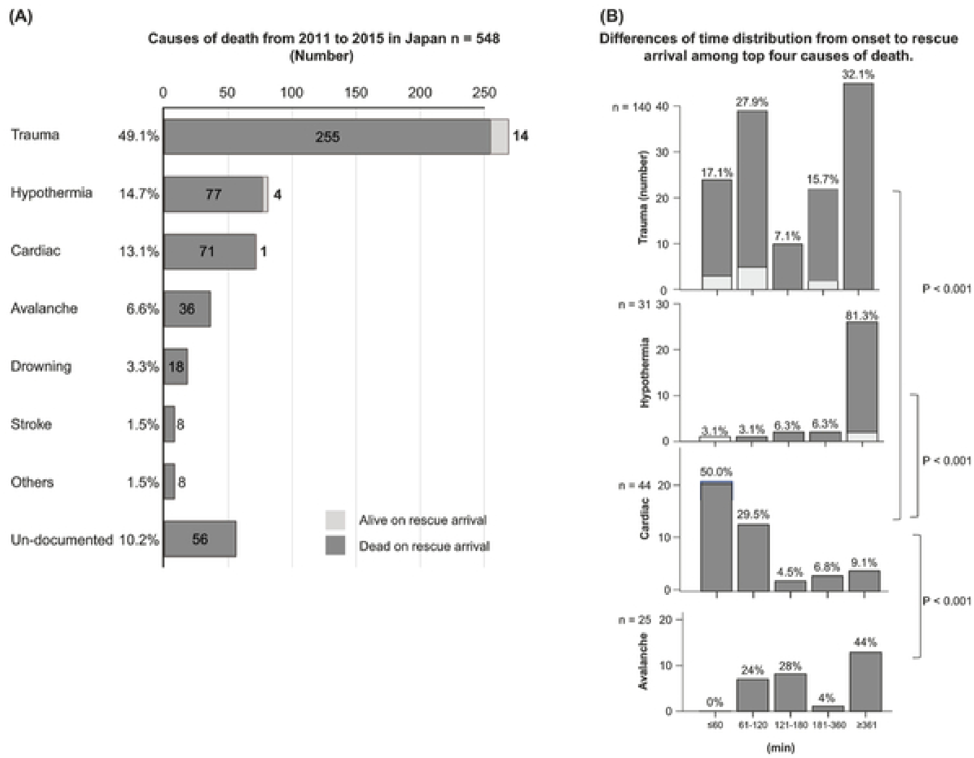


Fig. 2. Cause of death, time distribution until rescue arrival, and the number of alive subjects between 2011 and 2015 in Japan
(A) The overall number of deaths and the number of alive subjects during rescue team arrival according to cause (B) Differences in time distribution and the number of alive subjects from the onset to rescue arrival between the top four causes of death

25x20mm (600 x 600 DPI)

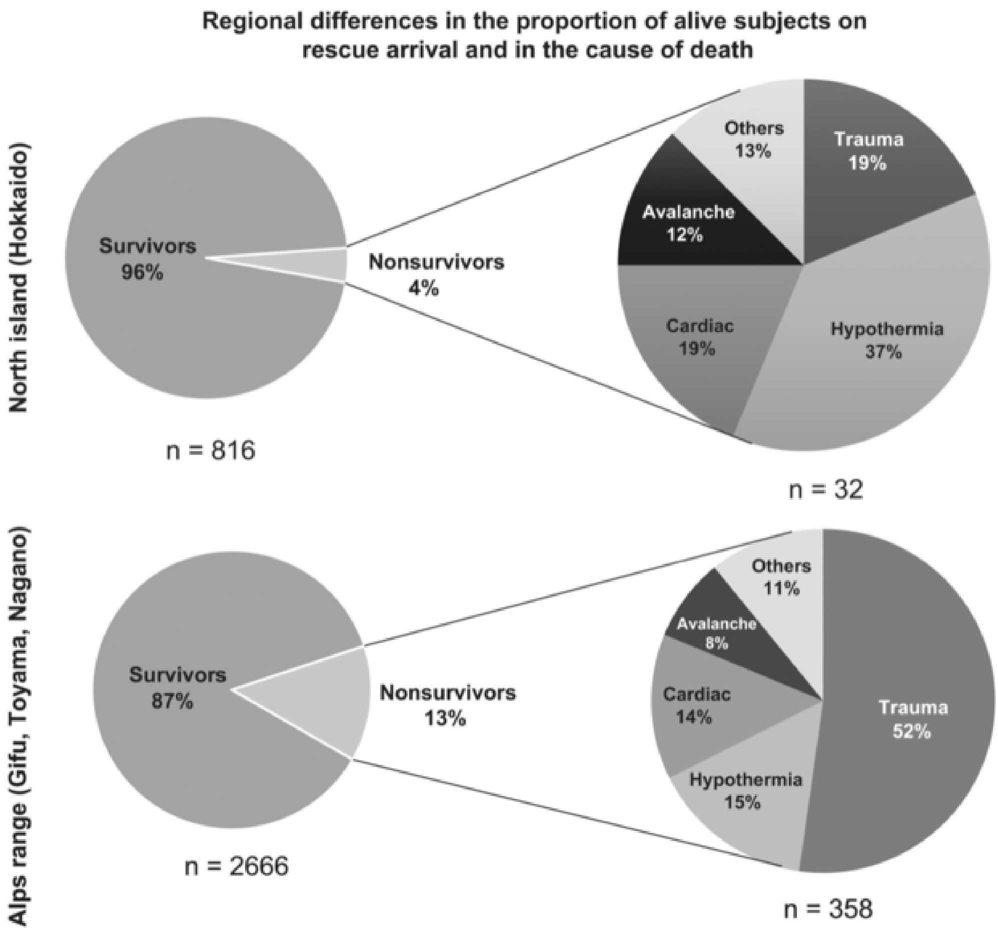
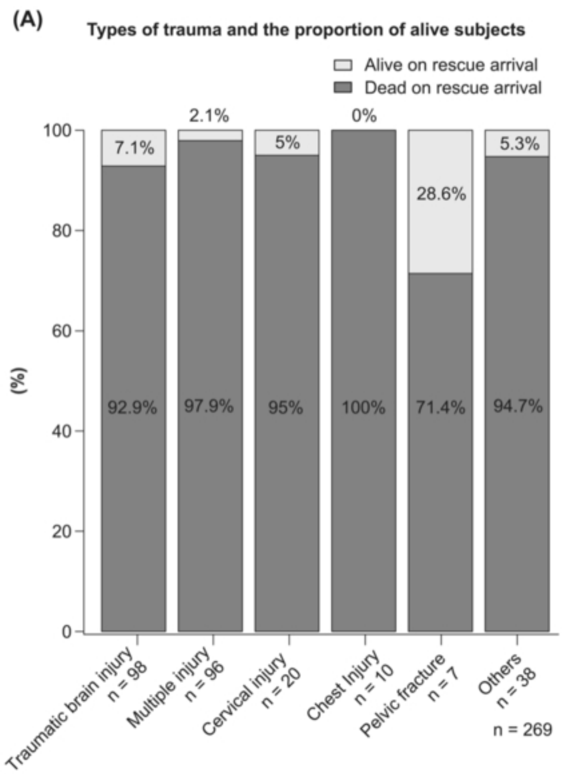


Fig. 3. Regional differences in the proportion of alive subjects on rescue arrival and in the cause of death

26x24mm (600 x 600 DPI)



(B)

Causes of avalanche-related death

Asphyxia	22 (84.6%)
Trauma	4 (15.4%)
Multiple injuries	1
TBI	1
Hemothorax	1
Abdominal hemorrhage	1
Total documented	26 (100%)
Undocumented	10
Totaldeath	36

Fig. 4. (A) Types of trauma and the proportion of alive subjects (B) Causes of avalanche-related death

31x24mm (600 x 600 DPI)

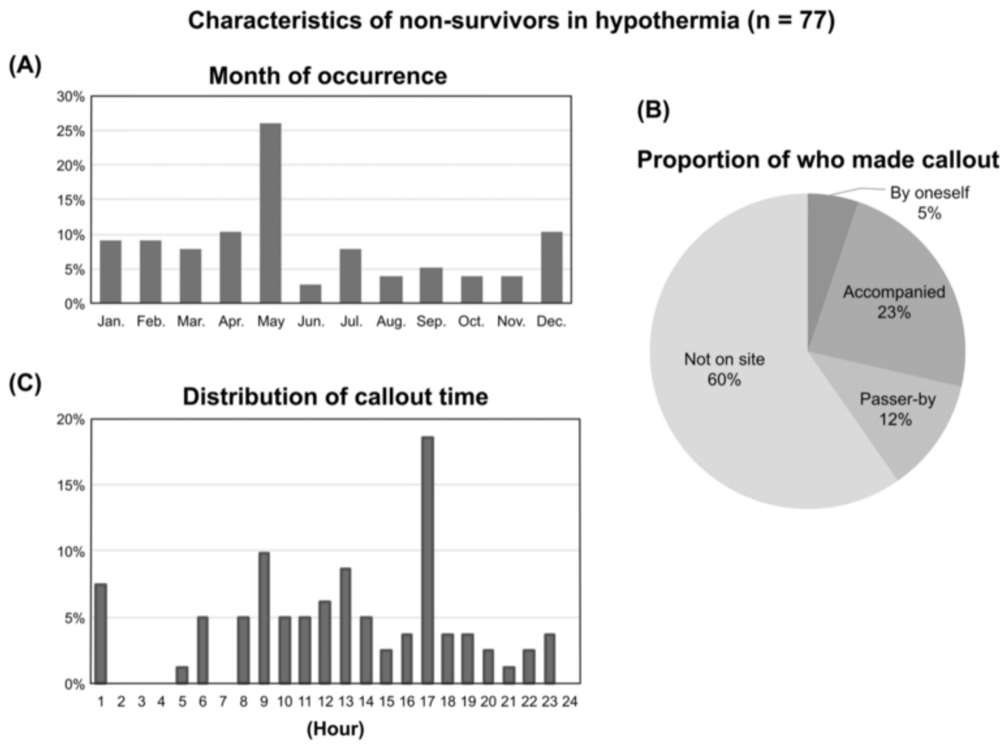


Fig. 5. Characteristics of nonsurvivors in hypothermia
(A) Month of occurrence (B) Proportion of people who made the callout (C) Distribution of callout time

32x24mm (600 x 600 DPI)

STROBE Statement—checklist of items that should be included in reports of observational studies

	Item No	Recommendation	Page No
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	4
Methods			
Study design	4	Present key elements of study design early in the paper	4,5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	4,5
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	Not applicable
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	4,5
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	*4,5*
Bias	9	Describe any efforts to address potential sources of bias	4,5
Study size	10	Explain how the study size was arrived at	4,5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	4,5
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	5
		(*b*) Describe any methods used to examine subgroups and interactions	4,5
		(*c*) Explain how missing data were addressed	4,5
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed *Cross-sectional study*—If applicable, describe analytical methods taking account of sampling strategy	Not applicable
		(*e*) Describe any sensitivity analyses	4,5

Continued on next page

Results

Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	6
		(b) Give reasons for non-participation at each stage	6
		(c) Consider use of a flow diagram	Fig.1
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	6
		(b) Indicate number of participants with missing data for each variable of interest	6, Figure
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	Not applicabl e
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	Not applicabl e
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Not applicabl e
		(*b*) Report category boundaries when continuous variables were categorized	
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	6-9

Discussion

Key results	18	Summarise key results with reference to study objectives	9
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	9,10,14
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	10-14
Generalisability	21	Discuss the generalisability (external validity) of the study results	10-14

Other information

Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	Not applicabl e

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.