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Fatal non-avalanche snow burial in Japanese backcountry terrain: a case series of head-first burial in non–tree-well environments

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Abstract

Background Non-avalanche snow burial (NASB) is an increasingly recognized cause of asphyxial death in mountain environments. However, published reports remain limited and are largely confined to tree-well incidents in North America. Fatal NASB in non–tree-well environments remains poorly characterized. The aim of this study was to characterize the environmental settings, burial characteristics, and circumstances of discovery and recovery of fatal NASB in Japanese backcountry terrain.

Methods Prefectures containing areas meeting a nationally established snow-depth criterion were identified to define the geographic sampling frame. Prefectural police headquarters in all 24 identified prefectures were contacted to identify potentially fatal snow-burial cases between April 2021 and March 2026. Candidate cases were independently reviewed by two investigators and classified as NASB when avalanche involvement could be excluded with reasonable certainty. Demographic, environmental, burial-related, rescue, and clinical data were extracted.

Results Eight candidate cases were identified, six of which met the eligibility criteria for fatal NASB. Four occurred in Hokkaido, one in Nagano, and one in Toyama. None of the cases were consistent with tree-well burial; the burial environments included open slopes, terrain depressions, and forested terrain. Head-first burial was documented in all six cases, with the torso beneath the snow and only the lower extremities visible above the snow surface; for one case who was recovered approximately 50 days after the incident, the recorded extent of exposure reflected the condition at recovery rather than at burial. Two victims were skiing, three were snowboarding, and one was snowshoeing. Three victims were traveling alone, whereas the other three had become separated from their groups. Five victims were in cardiopulmonary arrest or confirmed dead at recovery, whereas one victim had signs of life but deteriorated during extrication. The recorded cause of death was asphyxia in five victims and hypoxemia in one.

Conclusions This study characterizes the environmental and burial settings of fatal NASB in Japanese backcountry terrain, with all six cases occurring in non–tree-well environments and with head-first burial observed in all cases. These findings broaden the geographic and environmental context in which fatal NASB should be considered and may inform backcountry risk assessment, first-aid education, and rescue training.

Keywords Non-avalanche snow burial · Snow immersion · Asphyxia · Mountain rescue · Backcountry

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Background

Asphyxia is the leading cause of death following avalanche burial and other forms of snow burial in mountain environments [1, 2]. In addition to avalanches, non-avalanche snow burial (NASB) has increasingly been recognized as a mechanism of fatal snow immersion, typically involving deep unconsolidated snow and often associated with tree wells [1–3]. A tree well is a deep snow depression surrounding the trunk of a large evergreen conifer that forms because the tree canopy intercepts snowfall, resulting in reduced snow accumulation adjacent to the trunk.

The proposed mechanisms of fatality associated with snow burial include upper airway obstruction, impaired gas exchange, hypoxia, hypercapnia, and progressive snow compaction around the face during struggling following head-first immersion [2]. However, the pathophysiology and environmental characteristics of fatal NASB remain incompletely understood because the available literature consists primarily of case reports and small-scale simulation studies.

Most published NASB cases originated from North America and involved predominantly tree-well environments [2]. In contrast, fatal NASB has rarely been described in Japan. In Japan, a survey of ski-area accidents revealed deaths attributed to asphyxiation, including suspected cases [4]; however, that series excluded incidents occurring in the backcountry or outside ski-area boundaries, and neither the contribution of non-avalanche snow burial nor the environmental characteristics of the incidents, including tree-well involvement, were described. The backcountry terrain of Japan is characterized by abundant snowfall, deep powder snow, and terrain features that include creeks, gullies, and depressions, yet the environmental settings associated with fatal NASB remain poorly characterized.

Therefore, the aim of this study was to characterize the environmental settings, burial characteristics, and circumstances of discovery and recovery in fatal NASB cases in Japanese backcountry terrain. To our knowledge, this series provides the first description of fatal NASB in the Japanese backcountry.

Methods

Study design and setting

In Japan, prefectural police headquarters maintain records of mountain rescue incidents involving public rescue agencies within their respective prefectures. Incidents within managed ski areas are handled by the private ski-area operators. Consequently, prefectural police records provide a systematic source for identifying mountain rescue incidents involving public rescue agencies outside managed ski-area boundaries. This study included fatal backcountry incidents that occurred between April 2021 and March 2026. The five-year study period was determined on the basis of the retention period of the relevant police mountain-rescue records.

Case definitions

For this study, backcountry activity was defined as recreational travel on snow-covered mountain terrain outside managed ski-area boundaries, including travel on skis, a snowboard, or snowshoes. The terrain immediately adjacent to, but outside, a designated ski-area boundary was included. In this study, snow burial was defined as partial or complete burial of the body in snow to an extent capable of compromising breathing or preventing self-extrication. Fatal NASB was defined as death following burial in snow unrelated to avalanche release. Cases were classified as NASB only when the available evidence supported snow burial without avalanche release. The assessment of avalanche involvement was based on police investigative records and, where available, scene photographs. Because the exact time of the incident was unknown in most cases, it could not always be determined

from the conditions observed at discovery whether avalanche release had occurred at the time of burial. Cases in which any avalanche involvement could not be excluded with reasonable certainty were excluded.

Case identification

To define an objective and reproducible geographic sampling frame, prefectures containing areas meeting a nationally established snow-depth criterion were identified. Under these criteria, snow-covered regions are defined as areas in which the long-term average of the maximum snow depth in February is ≥ 50 cm [5, 6]. This criterion was used solely to define the geographic sampling frame rather than as a threshold for the occurrence of NASB. Twenty-four prefectures contained areas meeting this criterion. The respective prefectural police headquarters were contacted directly to identify fatal snow-burial cases occurring during backcountry or mountain activities during the study period; incidents clearly identified as avalanche-related were excluded at this initial screening stage. Mountain rescue incident records were maintained electronically, and personnel at each prefectural police headquarters reviewed the complete list of recorded mountain rescue incidents during the study period to identify potentially eligible cases, rather than relying on keyword searches or predefined incident categories. For each candidate case, information was obtained from the reporting prefectural police headquarters, with additional details clarified as needed through consultation with them. The classification of candidate cases as NASB was based on all available information, including rescue reports, scene investigations, witness accounts, police investigative records, and autopsy or postmortem findings when available. Because the term "tree well" was not used in the original records, the characteristics of tree-well burial were explained to personnel at the reporting prefectural police headquarters, who were asked to assess each case on the basis of scene records, terrain characteristics, and available photographs. Available scene photographs were also reviewed by the study investigators. Each candidate case was assessed independently by the two investigators.

Data collection

Demographic, environmental, burial-related, rescue, and clinical data were extracted from police rescue reports and related investigative records. The environmental variables included weather, altitude, terrain characteristics, snow depth, and recent snowfall. Burial environments were described on the basis of terrain features documented in the original investigative records and available scene photographs and were grouped after case review, for descriptive purposes only, as terrain depression, open slope, or forested terrain; when more than one feature was present, each case was assigned to a single category on the basis of the primary terrain feature associated with the burial. Meteorological records were also reviewed, when relevant, to assess changes in snow conditions between the incident and recovery periods. Burial-related variables included burial depth, body position, body exposure above the snow surface, equipment status (attachment of skis, snowboards, or snowshoes; helmet use; and avalanche transceiver carriage), and evidence of self-extrication attempts. In this study, head-first burial was defined as a burial configuration in which the head and torso were positioned deeper within the snow than the lower extremities, irrespective of the body's orientation relative to the slope or vertical axis. Rescue-related variables included group status, the circumstances of discovery, initial recovery status, and the number of resuscitation attempts. Clinical variables included the victim's condition at the time of discovery, recorded injuries, cause of death, and relevant autopsy or postmortem examination findings when available.

All the data were anonymized before analysis.

Because of the small number of cases, only descriptive analyses were performed.

Ethical considerations

This retrospective study was conducted in accordance with the principles of the Declaration of Helsinki and approved by the Institutional Review Board of Sapporo Kojinkai Memorial Hospital, which granted a waiver of

informed consent because of the retrospective nature of the study and the use of anonymized data (approval number 2026-21). The manuscript was prepared with reference to applicable items of the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines [7].

Language editing: ChatGPT (OpenAI) was used during manuscript preparation to assist with language editing and clarity. All AI-assisted suggestions were critically reviewed and revised by the authors, who take full responsibility for the content of the manuscript.

Results

All 24 prefectural police headquarters in the predefined geographic sampling frame responded to the inquiry. Eight candidate cases were identified. Independent eligibility assessments were concordant for all eight candidate cases. Two cases were excluded after detailed review because avalanche involvement could not be excluded. Six cases met the eligibility criteria for fatal NASB and were included in the study. Their clinical, environmental, and rescue characteristics are summarized in Table 1, and their geographic distribution is shown in Fig. 1.

Four cases occurred in Hokkaido, one occurred in Nagano, and one occurred in Toyama. The victims included four men and two women, in their 30s to 50s. Four victims were Japanese, one was Taiwanese, and one was Chinese. Recreational activities included skiing ($n=2$), snowboarding ($n=3$), and snowshoeing ($n=1$). Three incidents involved solo recreation, whereas the remaining victims were members of groups but became separated before burial. The available records revealed that two victims were inexperienced in their respective activities and unfamiliar with their equipment, whereas one was described as an experienced backcountry skier. The experience level was not documented for the remaining three victims. Avalanche transceivers were not carried in five cases, while carriage status was unknown in one case.

The burial environments included terrain depressions ($n=3$), open slopes ($n=2$), and forested terrain ($n=1$). None of the cases were consistent with tree-well burial. In Case 2, the open-slope environment at the time of discovery is shown in Fig. 2A. The victim was discovered approximately 50 days after the incident, after snowmelt had exposed part of one lower extremity and the attached snowboard. The victim was found with the head downhill. The body posture appeared to have been preserved, with both upper extremities flexed and the hands positioned in front of the chest. The helmet, backpack, gloves, goggles, and balaclava remained in place. However, the victim may have shifted downslope as the surrounding snow melted; therefore, the original orientation of the body within the snowpack could not be determined. Head-first burial was documented in all six cases. In each case, the torso remained buried beneath the snow, with at least one part of the lower extremities exposed above the surface; in five cases, this reflected the burial configuration at discovery, whereas in Case 2, the observed exposure followed substantial snowmelt. Skis, a snowboard, or snowshoes remained attached in five cases; equipment status was undocumented in one. Two victims were wearing helmets, three were not, and helmet status was unknown in one case. Weather and recent snowfall at the time of the incidents could not be reliably determined in most cases because the exact time of occurrence was unknown. In Case 6, however, police records documented heavy snowfall the day before the incident, although the amount of snowfall was not recorded. Similarly, uncertainty regarding the exact time of burial precluded reliable determination of the duration from burial to discovery or extrication. Snow depth was not consistently documented in the investigative records. Burial depth was documented only in Cases 2 and 6. In Case 6, the victim was buried to a depth of approximately 150 cm, with branches present within the burial site (Fig. 2B). Evidence of self-extrication attempts was documented only in Case 6 and could not be determined in the other cases.

The circumstances of recovery varied. Three victims were discovered by members of the public who happened to be recreating in the backcountry, one was found by ski patrol personnel in the backcountry terrain adjacent to a managed ski area, and one (Case 1) was discovered by a friend whose search was guided by smartphone location information. In one additional case, the victim was not located despite search efforts that were guided by the location of a smartphone left in a parked vehicle. The victim was recovered approximately 50 days later

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Table 1 Characteristics of fatal non-avalanche snow burial cases in Japan

Case	Month	Region	Age/Sex	Nationality	Activity	Group status	Burial environment and altitude	Burial characteristics	Body part(s) exposed above snow	Equipment status	Discovered by	Initial recovery	Recorded cause of death	Relevant findings[d]
1	February	Hokkaido	50s/F	Japanese	Snowshoes	Solo	Terrain depression beside rock below cliff (831 m)	Head-first	Part of the lower extremities[a]	Snowshoes attached; no helmet; avalanche transceiver unknown	Layperson (friend); smartphone location information	Found dead; CPR not documented	Asphyxia[b]	Conjunctival petechiae; Pulmonary edema
2	February	Hokkaido	30s/F	Japanese	Snowboard	Solo	Open slope adjacent to birch forest (867 m)	Head-first; ~1 m burial	One lower leg (when found after 50 days)	Snowboard attached; helmet worn; no avalanche transceiver	Search team; aerial search after smartphone left in vehicle identified the point of departure	Found dead after 50 days	Asphyxia[b]	Conjunctival petechiae
3	January	Hokkaido	40s/M	Taiwanese	Snowboard	Group (separated)	Terrain depression within birch forest (604 m)	Head-first	Both lower legs	Not documented; helmet worn; no avalanche transceiver	Layperson	Extricated; CPA; CPR unsuccessful	Asphyxia[b]	Conjunctival petechiae; Pulmonary edema
4	April	Hokkaido	30s/M	Japanese	Ski	Group (separated)	Open slope (1,438 m)	Head-first; upper body buried	Legs to the thighs	Skis attached; helmet status unknown; no avalanche transceiver	Layperson	Extricated; CPA; CPR unsuccessful	Asphyxia[b]	Conjunctival petechiae

Table 1 (continued)

Case	Month	Region	Age/Sex	Nationality	Activity	Group status	Burial environment and altitude	Burial characteristics	Body part(s) exposed above snow	Equipment status	Discovered by	Initial recovery	Recorded cause of death	Relevant findings[d]
5	February	Nagano	40s/M	Chinese	Snowboard	Group (separated)	Terrain depression below cliff during tree run (1,900 m)	Head-first	Part of the lower extremities[a]	Snowboard attached; no helmet; no avalanche transceiver	Ski patrol	Found in CPA; CPR not documented	Asphyxia[b]	Detailed findings not available
6	January	Toyama	40s/M	Japanese	Ski	Solo	Forested terrain with terrain depression (1,050 m)	Head-first; ~150 cm burial; branches within the snow	Both lower legs	Skis attached; no helmet; no avalanche transceiver	Layperson	Initially, alive; deteriorated to CPA during extrication; CPR unsuccessful	Hypoxemia[c]	Conjunctival petechiae; abrasions on the dorsum of both hands; no major trauma

CPA, cardiopulmonary arrest; CPR, cardiopulmonary resuscitation

[a] Extent could not be determined from the original records

[b] Autopsy performed

[c] External examination with postmortem computed tomography (autopsy imaging computed tomography; AI-CT)

[d] Only findings relevant to asphyxia or the exclusion of alternative causes are shown. Foreign bodies in airways and major trauma were absent unless otherwise indicated

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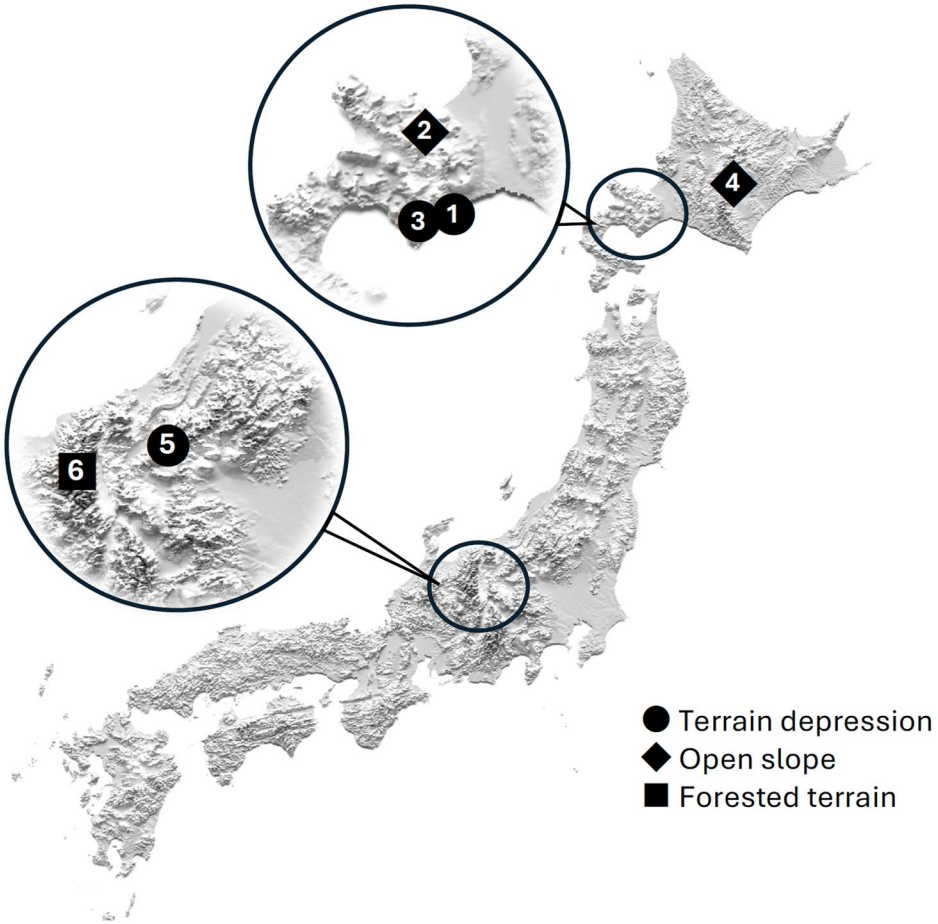


Fig. 1 Geographic distribution and burial environments of fatal non-avalanche snow burial cases in Japan. Numbers indicate case numbers. Circles indicate terrain-depression–associated burial, diamonds indicate open-slope immersion, and squares indicate burial in forested terrain. Insets show enlarged views of areas with closely spaced cases

during an aerial search. Five victims were found to be in cardiopulmonary arrest or were confirmed dead at the time of recovery. One victim was found to have signs of life but deteriorated during extrication and had no signs of life at the completion of extrication. Resuscitation attempts were unsuccessful in all cases in which CPR was performed. The recorded cause of death was asphyxia in five victims and hypoxemia in one victim. Among the five cases for which detailed postmortem findings were available, conjunctival petechiae were documented in all five and pulmonary edema in two; no major trauma or airway foreign bodies were identified in any of these cases. Relevant postmortem findings are summarized in Table 1.

Discussion

This study characterized the environmental settings, burial characteristics, and circumstances of discovery and recovery of fatal NASB in Japanese backcountry terrain. All six cases occurred in non–tree-well environments, including open slopes, terrain depressions, and forested terrain. Notably, head-first burial was documented in all six cases, with the torso beneath the snow and at least one part of the lower extremities exposed above the snow surface. The recorded cause of death was asphyxia in five cases and hypoxemia in one.

NASB has been classically associated with tree wells in studies originating from North America; however, fatalities have also been reported following snow burial without the involvement of tree wells. Citing the largest available dataset collected by Baugher, Van Tilburg reported that 65% of NASB-associated deaths were due to tree wells and 35% were due to open-slope deep snow burial [3].

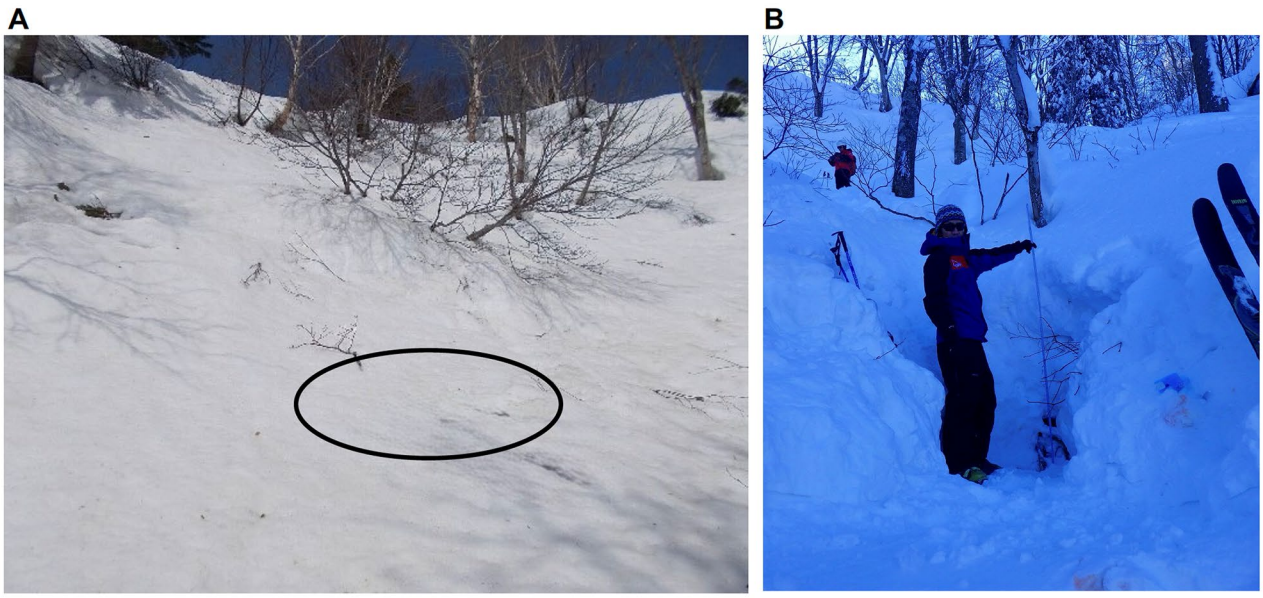


Fig. 2 Examples of non–tree-well environments associated with fatal non-avalanche snow burial. (**A**) Discovery site in Case 2, showing an open snow-covered slope with birch trees and dwarf pine (*Pinus pumila*). The circle indicates the approximate location where part of one lower extremity and the attached snowboard were visible at discovery. The visible lower extremity and snowboard were digitally removed to protect privacy. (**B**) Excavation site in Case 6 in a beech forest after removal of the victim, showing an approximately 150-cm-deep cavity with branches extending into the buried space. A rescuer standing in the cavity holds a probe indicating the approximate depth

Tree wells are particularly common in the mature evergreen conifer forests of western North America, where abundant seasonal snowfall favors their development. These forest and snow conditions may partly explain the predominance of tree-well NASB in this region [8, 9].

In contrast, many snow-covered mountain areas in Japan are characterized by deciduous broad-leaved forests, including Japanese beech and oak, and their leafless winter canopies intercept less snowfall than evergreen conifer canopies do. These differences in forest composition and canopy structure may contribute to differences in tree-well formation and represent one possible explanation for the absence of tree-well burial in this series [10, 11].

Although fatal non–tree-well NASB has been reported previously in North America, the present series extends the understanding of NASB by documenting the specific environments in which fatal cases occurred in Japanese backcountry terrain, including terrain depressions, open slopes, and forested terrain without tree-well involvement.

The consistent head-first configuration raises the possibility that terrain permitting head-first entry and upper-body burial, rather than tree-well formation itself, may be an important feature of fatal NASB. However, given the small number of cases, whether this consistent head-first burial pattern is generalizable to fatal NASB more broadly remains uncertain. Tree wells may represent one environment associated with fatal NASB in North America, whereas terrain depressions and other non–tree-well features may represent alternative environmental settings in which fatal NASB can occur in Japanese backcountry terrain. The environments shown in Fig. 2 provide examples of these contrasting settings, including an open slope with birch and dwarf pine (*Pinus pumila*) in Case 2 and a beech forest in Case 6. Notably, the occurrence of Case 6 within a beech forest illustrates that forested NASB should not necessarily be equated with tree-well burial. Taken together, these observations suggest that consideration of potential NASB hazards in Japanese backcountry terrain should not be limited to tree-well environments but should also include non–tree-well terrain features that may permit head-first snow immersion.

The geographic distribution of cases revealed that four of the six fatal NASB cases occurred in Hokkaido, the northernmost island of Japan. The only case that occurred in April was also recorded in Hokkaido. Although no

conclusions can be drawn regarding regional incidence because of the small number of cases, this distribution may partly reflect Hokkaido's prolonged cold and heavy-snow conditions, which may favor the prolonged persistence of dry, unconsolidated snow [12, 13]. However, regional differences in backcountry participation and exposure may also have contributed. These possibilities could not be directly evaluated in this study and warrant further investigation incorporating snowpack characteristics and regional exposure data. Previous studies in North America have also suggested that snow-immersion accidents are more frequent early in the winter season, when the snowpack is loose and the bases of tree wells have not been consolidated [14]. Although the burial environments in our series differed from those in classic tree-well accidents, poorly consolidated snow may represent a common environmental factor that increases the risk of immersion and self-extrication failure.

These published literature on NASB is limited; consequently, the 2024 Wilderness Medical Society guidelines are based primarily on case reports, a review article, and a small simulation study [2, 3, 14, 15]. Although fatal asphyxiation can occur rapidly, the exact mechanisms and time course leading to death remain poorly understood. The results of the simulation study suggest that victims who struggle or remove their skis or snowboards may sink deeper into the snow. Furthermore, in an inverted position, body movements, body weight, and the funnel effect of a hooded jacket may result in progressive snow accumulation, reduce the available air space around the face, and make self-extrication difficult [2, 14]. In a previous snow immersion simulation study, all three participants who successfully self-extricated were able to bend 90° at the waist, suggesting that the ability to flex at the waist may influence self-extrication [14].

In five cases, at least one part of the lower extremities remained exposed above the snow surface while the torso remained buried. In Case 2, the extent of exposure was documented only at recovery approximately 50 days after the incident and therefore may not reflect the original burial configuration. The configuration observed in the other cases shares features with those associated with difficulty in self-extrication in the simulation study. In Case 2, the preserved posture provides additional information on body configuration; however, whether the victim retained sufficient mobility to adopt a posture favorable for self-extrication cannot be determined.

In avalanche burial, victims are recovered in a wide variety of body positions, with approximately 45% found face down, 24% on their backs, 16% sitting or standing, and 15% on their sides [16]. In contrast, head-first burial has been described in reported NASB cases. Progressive ventilatory impairment, rebreathing, hypoxia, and hypercapnia, which are central mechanisms of avalanche snow-burial asphyxia [17], may also be relevant in NASB. A recent simulation study found a faster decline in SpO_2 during simulated tree-well than avalanche burial, although the mechanism and the specific contribution of head-down positioning remain uncertain [18]. Whether and how head-first burial influences self-extrication or the progression of respiratory compromise in actual NASB therefore remain unclear.

Postmortem findings were also consistent with an asphyxial mechanism. Among the five cases for which detailed postmortem findings were available, conjunctival petechiae were documented in all five, and pulmonary edema was observed in two. Although these findings may occur in asphyxial deaths, they are nonspecific and cannot independently establish asphyxia. The etiology of pulmonary edema could not be determined from the available records. No major traumatic injuries or airway foreign bodies providing an alternative explanation for death were identified. Taken together, the postmortem findings, the burial circumstances and recorded causes of death were compatible with an asphyxial mechanism associated with snow burial.

The only victim found with signs of life at the time of discovery (Case 6) may provide additional insight into the pathophysiology and progression of fatal snow-burial asphyxia. Despite head-first burial, spontaneous breathing and vocalization were reportedly present when the victim was first discovered, indicating that complete airway obstruction was not present at that time. The victim subsequently progressed to cardiac arrest during extrication. Positional asphyxia, in which body position itself mechanically compromises ventilation, is one possible mechanism to consider in head-first burial. However, the preserved spontaneous breathing and vocalization in Case 6 suggest that positional impairment of ventilation alone is unlikely to explain the clinical course.

In avalanche burial, asphyxia may result from partial or complete airway obstruction, rebreathing of expired air, and impaired ventilation, with progressive hypoxia and hypercapnia occurring even when the airway is not

completely obstructed [1, 17]. Similar mechanisms may have contributed in Case 6, although their relative contributions cannot be determined from the available records.

Figure 2B illustrates the approximately 150-cm-deep buried space in a beech forest, with branches extending into the space surrounding the victim. Abrasions on the dorsum of both hands may be consistent with contact during attempts at self-extrication and raise the possibility that some upper-extremity movement occurred. Whether these branches restricted movement, preserved air spaces, influenced ventilation or self-extrication, or affected subsequent extrication cannot be determined.

The reported cause of death was hypoxemia, which represents a physiological consequence rather than a specific mechanism of death. In the context of the burial circumstances and the absence of an alternative fatal injury, the clinical course was consistent with snow-burial asphyxia.

The non–tree-well burial configurations observed in this series may also have implications for rescue techniques. Current NASB guidelines provide recommendations regarding prevention, self-extrication, and victim location, but do not address specific rescuer extrication techniques for different burial configurations [2]. In contrast, specific rescue techniques have been developed for tree-well burial. The T-Rescue method, for example, was developed around the characteristic geometry of an inverted victim in a tree well [19, 20]. Whether such tree-well–specific techniques are applicable to the non–tree-well burial configurations observed in the present series remains unknown. The contrasting environments shown in Fig. 2 highlight the need to determine whether the most appropriate approach to excavation and airway access differs according to the surrounding terrain and burial configuration.

In the case series reported by Cadman, all victims had advanced skiing or snowboarding skills [15]. In the present series, among the three victims for whom experience level was documented, two were classified as inexperienced and one as experienced. Thus, the cases in this series were not limited to experienced backcountry users.

Previous NASB literature has emphasized the importance of rapid rescue, and the buddy system is often recommended as a means of improving the likelihood of timely rescue. However, the cases in our series also illustrate that simply recreating as part of a group may not ensure timely recognition of burial when group members become separated. Traveling alone or failing to maintain awareness of companions' whereabouts may delay recognition of burial and subsequent rescue, potentially increasing the risk of a fatal outcome. Additionally, under poor visibility or deep-snow conditions, a buried victim may be difficult to detect, and even exposed body parts may not be readily visible. Although avalanche transceivers may be less necessary when a buried victim can be readily identified visually, they may facilitate victim localization when snow, terrain, or poor visibility makes visual detection difficult. However, their impact on rescue time and survival in NASB remains uncertain. Smartphone-derived location information assisted in locating one confirmed NASB victim and one of the two excluded snow-burial victims in this series, whereas in another case, location information from a smartphone left in a parked vehicle did not lead to localization of the victim. Current wilderness medicine guidelines state that there are no data on the use of mobile phones in NASB [2]. Although the effectiveness of smartphone-based location tracking cannot be evaluated in the present case series, these observations suggest that smartphone-derived location data may provide useful supplementary information for locating missing persons in backcountry snow-burial incidents when the device remains with the victim.

Further studies incorporating detailed snowpack characteristics, burial circumstances, exposure data, and physiological measurements are needed to clarify how environmental conditions and burial mechanisms contribute to fatal NASB. Further research should also evaluate the applicability of rescue approaches across different burial environments and configurations. Such evidence could inform more specific prevention and rescue strategies.

Limitations

This study has several limitations. First, the small sample size and retrospective design limited the ability to perform detailed clinical, environmental, and rescue-related analyses and the generalizability of the observed findings. Furthermore, only fatal cases were included, and neither the case fatality rate of NASB nor its proportion

among all fatal backcountry incidents could be estimated. Without activity-specific backcountry exposure data, the relative risk of NASB among skiing, snowboarding, and snowshoeing could not be determined. Because victims were generally not initially discovered by medical personnel, detailed observations of burial circumstances and physiological status at the time of discovery were limited. The exact time of burial was unknown in most cases, precluding reliable assessment of burial duration and its relationship with survival. Assessment of tree-well involvement was retrospective and based on available scene records, terrain characteristics, and photographs rather than a standardized prospective on-site assessment. Finally, the proposed pathophysiological mechanisms were inferred from scene investigations, previous simulation studies, and the relevant literature rather than from direct physiological measurements obtained during burial.

Conclusions

In this series, fatal NASB in Japanese backcountry terrain occurred in non–tree-well environments, including open slopes, terrain depressions, and forested terrain, with head-first burial observed in all six cases. This study characterizes the environmental and burial settings of fatal NASB in Japanese backcountry terrain and broadens the geographic and environmental context in which this phenomenon should be considered. These findings may have implications for backcountry risk assessment, first-aid education, and rescue training. Avoiding solo travel and maintaining awareness of companions' whereabouts may facilitate prompt recognition and rescue in the event of burial.

Larger case series and studies integrating environmental characteristics, snowpack conditions, and physiological investigations are needed to determine whether head-first burial represents a consistent feature of fatal NASB, to better define its mechanisms and risk factors, and to support evidence-based prevention strategies.

Abbreviations

NASB	Non-avalanche snow burial
SpO_2	Peripheral oxygen saturation
CPA	Cardiopulmonary arrest
CPR	Cardiopulmonary resuscitation

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Author contributions KO and TM contributed to the conception and design of the study and to the analysis and interpretation of the data. KO contributed to data acquisition and drafted the manuscript. TM critically revised the manuscript. Both authors read and approved the final manuscript.

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Data availability No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate This retrospective study was conducted in accordance with the principles of the Declaration of Helsinki and was approved by the Institutional Review Board of Sapporo Kojinkai Memorial Hospital (approval number 2026-21). The requirement for informed consent was waived by the IRB because of the retrospective nature of the study and the use of anonymized data. Permission for the retrospective use of anonymized rescue records was obtained from the participating prefectural police headquarters.

Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

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