RISK MANAGEMENT TRENDS IN U.S. BACKCOUNTRY AVALANCHE ACCIDENTS: SKIERS AND SNOWBOARDERS

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ABSTRACT: Winter backcountry use in the United States has soared over the past decade while avalanche fatalities have remained relatively constant. Researchers have suggested this discrepancy is due in part to the success of public safety messaging, avalanche education and improved safety equipment. However, little is known about which components of safety messaging have played a role in accident reduction. This study examined five decades of risk management behaviors recommended in eight avalanche safety messages. All of the suggested behaviors reduced fatalities but our findings indicate there is room for improvement in messages regarding solo travel, terrain traps, the role of avalanche forecasts in decision making, group management and preparing for trauma. This paper provides specific suggestions for augmenting existing messages to further reduce avalanche fatalities.

KEYWORDS: Education, fatalities, accidents, trends, risk reduction, risk management

1. INTRODUCTION

Fifty years ago, recreational travel in avalanche terrain was very different than it is today. Equipment was rudimentary and relatively few people traveled in the winter backcountry. Avalanche education was just emerging and generally advised avoiding steeper slopes during periods of elevated hazard (e.g. Fraser, 1966; Perla and Martinelli, 1975; LaChappelle, 1978).

Today, avalanche safety messaging emphasizes risk management rather than simple avoidance. Eight key practices have emerged as guidance for backcountry avalanche safety and now form the basis for most avalanche education and public messaging.

Our goal was to identify the roles these safety practices have played in fifty years of fatal avalanche accidents and pinpoint areas for improving safety messaging and avalanche education.

2. BACKGROUND

Over the last two decades, avalanche fatalities in the United States have not kept pace with the rise in backcountry recreation. Birkeland et al. (2017) conservatively estimated an 8-fold increase in winter backcountry use since 1995 and demonstrated avalanche fatalities have remained statistically constant at approximately 1995 levels. Researchers have attributed this disparity to improvements in safety equipment, proliferation of high-quality avalanche forecasts and widespread avalanche education.

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Various studies have explored the effects of avalanche education on behaviors, beliefs, knowledge, risk perception, confidence, and decision-making (Jekich et al., 2016; Ng et al., 2017; Nichols et al., 2018; Silverton et al., 2007; Greene et al., 2022). Landrø et al. (2022) reported increased precision in assessing avalanche risk factors with more avalanche education. Nichols et al. (2018) noted those with avalanche training were more likely to carry safety gear. McNeil et al. (2023) found participants perceived an increase in their own risk management proficiency after attending an avalanche course.

Several studies have assessed trends in avalanche accidents over time (Jekich et al., 2016; Spencer and Ashley, 2011). Greene and Logan (2022) found a shift to higher levels of experience across the 2020 pandemic shutdown in Colorado avalanche accidents.

Missing from the literature are explorations of how avalanche education and safety messaging affect U.S. fatality rates. The need to understand these effects and identify opportunities to improve safety messaging were key motivations in conducting this study.

3. DATA AND METHODS

3.1 Accident data sources

We utilized public records of avalanche accidents available through the Colorado Avalanche Information Center (CAIC), the Cyberspace Snow and Avalanche Center (CSAC), and volumes of the *Snowy Torrents* covering the years 1972 to 2004. We also obtained supplemental details of fatal accidents from avalanche center archives and

online media sources. When we found inconsistencies in accident accounts, we gave precedence to official accident reports.

3.2 Coding

We examined fatal avalanche accidents among backcountry skiers and snowboarders in the United States between 1974 and May 2024. We omitted accidents where risk management might not be representative of typical backcountry avalanche practices including accidents in the side country, guided or club outings and operational activities. We defined avalanche seasons using the interval October 1 to September 30.

We iteratively identified coding variables that we found to be indicative of specific risk management behaviors. We also examined emergent risk failure themes across five phases of risk management: education, pre-trip preparation, exposure, active mitigation and accident response. We tabulated themes by frequency across the five decades of the study.

3.3 Analysis

Our analysis was exploratory and organized around eight common principles of avalanche risk management. We identified trends using a 5-year moving average typical in reporting avalanche accident rates (Birkeland et al, 2017).

In order to ensure we were assessing similar cohorts of backcountry users we categorized accident parties by their proficiency in risk management using a behavioral scale similar to Greene and Logan (2022):

Risk unaware (RU) parties did not recognize avalanche hazard, took no reported actions to mitigate their exposure and exhibited only ad-hoc rescue skills. Reports often stated that these groups had no avalanche knowledge.

Risk aware (RA) parties appeared to be conceptually aware of avalanche hazard. This group included parties who were warned about the hazard or had been exposed to avalanche awareness messaging. Similar to unaware groups these parties exhibited no evidence of avalanche avoidance or rescue skills.

Risk managing (RM) parties were either reported to have some level of formal avalanche education, took deliberate steps to mitigate their exposure or exhibited some level of competence at companion rescue. A necessarily large cohort, this class of users spanned many levels of proficiency across years when avalanche education and rescue practices were evolving.

When we found insufficient source data to identify an accident party's risk management skills we classified their skills as **Unknown (U)**.

We found these categories to be repeatable during our coding process.

4. RESULTS, DISCUSSION AND APPLICATIONS

This section organizes our findings around each of the eight avalanche safety messages. Percentages reflect the data screening criteria described in Section 3.2. Section headings indicate if the results apply to all accident parties (All) or risk managing (RM) accident parties only.

4.1 General statistics - All

Results – We examined 240 accidents involving 424 people caught and 285 people killed. Triggers were 74% skiers, 17% snowboarders, 5% natural and 4% unknown. Thirty-four percent of victims died of trauma, 39% died of asphyxia and in 27% of cases the cause of death was not reported. Risk management types were 11% unaware (RU), 13% aware of the hazard (RA), 56% actively mitigating (RM) and 21% unknown (U). **Figure 1a** shows the distribution of these risk management categories over time.

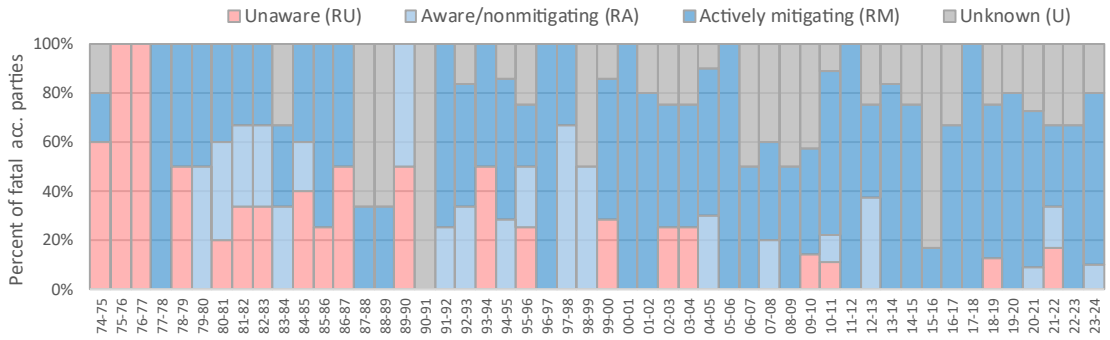
Discussion - Risk management behavior among these fatal avalanche parties began strengthening in the 1990s and appears to be gradually increasing. RM parties have become more common and RU parties are becoming rare. This trend mirrors the growing availability of avalanche education (Lovejoy, 2012) and public warnings about avalanche conditions (Birkeland et al. 2017).

Applications – The increasing proportion of fatal accidents occurring to RM parties indicates that the modern avalanche victim has more skills than in the past. Many accidents appear to be the result of failed attempts at risk management.

The following sections examine how these failures are reflected in fatality trends and how messaging can be improved to reduce these failures.

4.2 "Carry rescue gear" - All

Results - Avalanche transceivers were the most consistently reported item of rescue equipment in accident records. First appearing in our data set in 1979, transceiver presence in fatal accidents began rising in the 1980s and has stabilized around 80% in recent years (**Figure 1b**).



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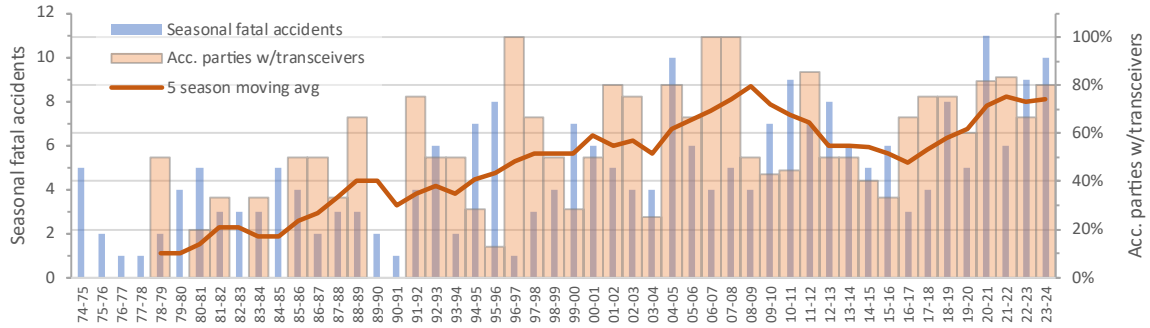

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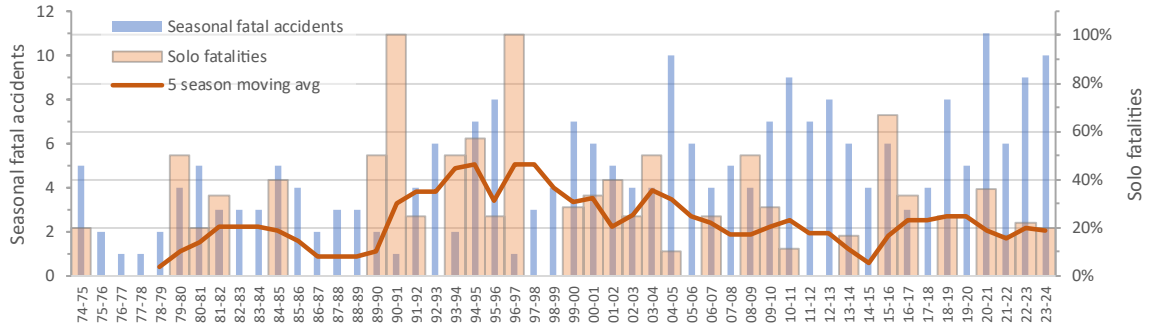

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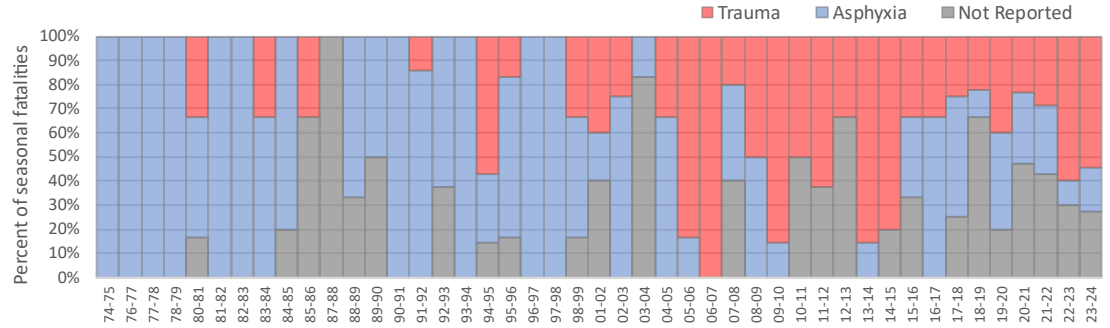

(d)

Figure 1. Trends over time in fatal recreational backcountry skier and snowboard accidents: (a) Proportion of risk management behaviors among accident parties; (b) Proportion of fatal accident parties with avalanche transceivers; (c) Frequency of solo travel; (d) Reported cause of death.

Prior to the 2000s shortages of transceivers, probes and shovels in rescue parties were the most frequently reported equipment issues. More recently however, additional issues have included transceivers switched off, forgotten or not worn. Probe breakage and malfunction also remain infrequent but persistent equipment failures.

Airbags first appeared in our data set in 2013 and were evident during the winters of 2020-21 and 2023-24. In the most recent avalanche season (2023-24) 50% of fatalities in our data set wore airbags. Airbag damage, malfunction and failure to deploy were infrequent failure themes.

Discussion – The adoption of transceivers among backcountry skier and snowboarder avalanche victims was a slow process taking three decades to reach the current level. As noted by other studies (e.g., Nichols et al., 2018), fully equipped parties have become more common. However, almost 20% of recent fatal avalanche victims were not wearing transceivers, a result that aligns with prior findings (Unger, 2023).

Applications – While most contemporary accident parties carried avalanche rescue equipment, shortages sometimes occurred during companion rescue. Other failures included victim transceivers switched off, forgotten or simply not worn. Supplemental messaging to address these problems could include: "Conduct transceiver and gear checks at the trailhead," "Have spares available in your car," and "Check and dry your probe after every use."

4.3 "Travel with a partner" - All

Results – We defined solo travelers to include avalanche victims who were separated from their party. Solo travelers as a percentage of all fatal accidents are depicted in **Figure 1c**.

Discussion – The advice to not travel alone in avalanche terrain is a venerable avalanche safety message. Across recent decades however, solo avalanche accidents consistently comprise about 1 in 5 fatal accidents. In many accidents where the exact location of the solo burial was unknown, considerable search and rescue resources were expended and some victims were not recovered until spring.

Applications – A blanket exhortation not to travel alone will apparently be ignored by a consistent portion of backcountry users. Supplemental messaging aimed at the safety of the solo tourer might include: "If you decide to travel alone choose safer terrain." Additional messaging would highlight the responsibilities of the solo backcountry traveler: "Let someone know your plan, wear a transceiver and use a satellite tracking device."

4.4 "Have a plan" - All

Results – We found planning details of accident parties to be sparse in accident records. Thematic analysis indicated some groups agreed on a broad plan at the start of the tour and some groups revised their plan while traveling. Failure themes included not discussing tactical route choices with the group and members not verbalizing concerns.

4.5 "Understand the forecast" - RM

Results – Due to limitations in our source data we were not able to fully evaluate how well avalanche victims understood the avalanche forecast. However, our thematic analysis showed a steady increase in accident parties being aware of the current forecast and discussing the avalanche danger rating within their party.

We also examined the location of each accident relative to slopes with the highest (tier 1) danger rating at the time of the accident. We found the proportion of accidents on these slopes involving RM parties increased over time (**Figure 2a**).

Discussion – Avalanche forecasts often specify danger ratings by aspect and elevation or highlight specific types of slopes (e.g., north facing and wind loaded) as especially dangerous. Accident location and forecast data indicates that the majority of RM parties did not use their skills to avoid the most dangerous slopes identified in the avalanche forecast. Similar to findings by Mannberg et al. (2018) and Greene and Logan (2022), this evidence suggests that knowledgeable accident parties used their avalanche skills to access avalanche-prone slopes during periods of instability. Worth noting is that this trend appears to be increasing.

Applications – Modern avalanche courses stress the importance of the avalanche forecast in planning backcountry tours. Additional emphasis could be placed on the conditions under which people are lured onto slopes they had hoped to avoid. Pre-mortem scenarios and countermeasures may prove helpful in preparing students for field decisions in dynamic group settings.

4.6 "Recognize avalanche terrain" - RM

Results – For each fatal avalanche we coded two presence/absence terrain variables: 1) obvious path easily recognizable (steep open start zone, trim lines, stunted trees), and 2) one or more terrain traps. Similar to past studies (McCammon,

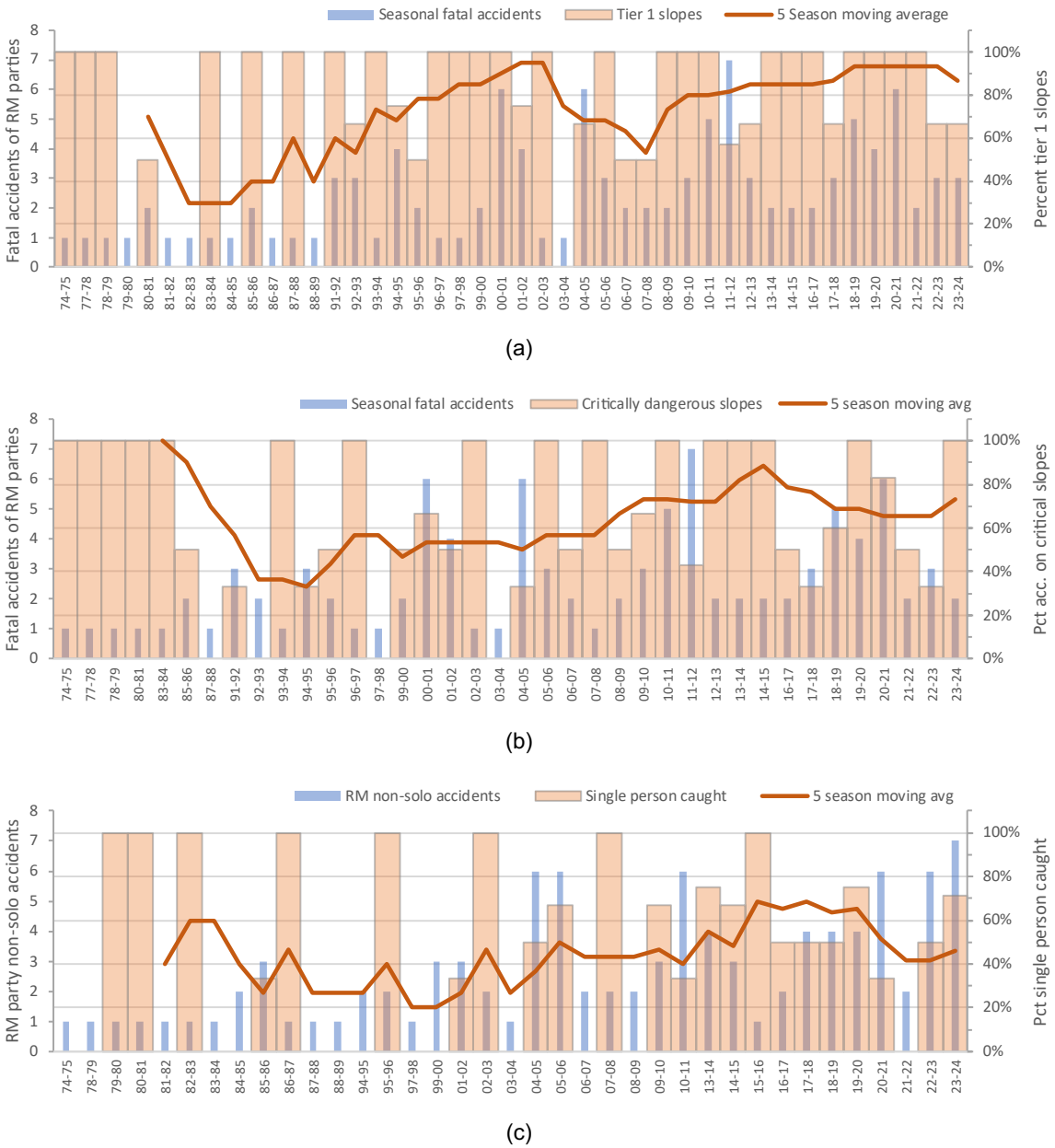

Figure 2. Trends over time in backcountry skier and snowboard accident parties that were exhibiting risk mitigation (RM) behaviors: (a) Fatal accidents on slopes identified as most dangerous (tier 1) in the avalanche forecast; (b) Slopes in (a) that were obvious avalanche paths above one or more terrain traps; (c) Fatality proportion in non-solo RM parties where only one person was caught ("one at a time").

2000), we found a stable trend of about 80% of accidents involving RM parties happened on obvious avalanche paths.

The presence of terrain traps in fatal avalanches gradually rose from about 50% in the 1990s and has stabilized at about 80% over the last decade. **Table 1** shows the frequencies of terrain traps in fatal accidents that occurred to RM parties.

We also examined these two terrain variables in combination with the results of the previous section. As shown in **Figure 2b** there is a rising proportion of accidents involving RM parties who entered tier 1 slopes that were obvious avalanche paths above clearly visible terrain traps ("critically dangerous slopes").

Our thematic analysis indicated some parties initially discussed avoiding steep slopes and often made efforts to choose safe routes both on the ascent and descent. We found a gradual increase in this risk mitigation strategy over five decades

Type	*Count*	*Frequency*
Trees	67	60%
Gully	44	40%
Cliff/rocks	33	30%
Transition	7	6%
Creek	4	4%
Other	0	0%

Table 1. Terrain traps in fatal avalanche accidents involving RM accident parties. More than one terrain trap was present in 40% of these accidents.

suggesting a growing awareness and increasing application of proactive measures.

Discussion – The rising trend of RM parties discussing and managing avalanche risk is encouraging. However, there is also an increasing trend of RM parties finding themselves on the very slopes they had planned to avoid and entering these slopes even though they were obvious avalanche paths above terrain traps. This trend is increasing with time, suggesting a growing gap between these parties' perception of their skills and their actual ability to manage avalanche risk.

Applications – A growing body of research indicates that avalanche education produces increased confidence in skills (Mannberg et al., 2018; Greene and Logan, 2022; McNeil et al., 2023). Skills overconfidence is a pervasive problem in safety education in general (McCammon, 2004; Mueller at el., 2012), at times producing more risk taking and subsequent accidents.

Research suggests two approaches for reducing overconfidence: 1) Real-time pre-mortems that quantify objective hazards (Kahneman, 2011: 264-5) such as red flags, ALP TRUTh or other objective measures, and 2) distinguishing between decisions and actions that must be executed without error (Russo and Schoemaker, 1992).

The majority of these accidents involved trauma due to trees, cliffs and rock bands. An important supplement to avalanche messaging about terrain would be increased awareness of the nature of avalanche-induced trauma (McCammon et al., 2008; Atkins, 2012; Radwin, 2016).

4.7 "Recognize red flags" - RM

Results - This advice typically lists between five and seven signs of avalanche danger (e.g., NAC, 2024). Limitations in our source data prevented a full analysis of which signs accident parties observed prior to the accident. To improve future accident research, these signs could be added to official reporting forms (AAA, 2022: 101).

4.8 "Expose one person at a time" – RM

Results – RM parties successfully engaged in this practice at frequencies shown in **Figure 2c.** The practice shows moderate growth since the mid-1990s despite being a pervasive avalanche safety message. In the decade prior to 2020, the practice was correctly executed by RM parties only in 50-60% of fatal accidents. In recent years the practice was correctly executed less often.

Discussion - Lapses in this practice proved fatal for 43 individuals in our data set. Common failure modes included misjudgment of safe locations, communication challenges and an apparent desire to stay close to the group in dangerous terrain.

Applications – Public messaging and avalanche courses commonly stress the concept of "go one at a time." But it appears many accident parties made mistakes when executing this practice. Increased awareness of how this practice fails would be a worthy supplement to avalanche courses. Scenario-based discussions and countermeasures that prevent having multiple people on a slope would be worthy additions in avalanche courses.

4.9 "Perform a companion rescue" - RM

Results – Our thematic analysis revealed two common failures in companion rescue: 1) transceiver search errors such as unfamiliarity with their operation, transceivers left in or reverting to send mode during search, signal confusion during multiple burials and damaged or malfunctioning transceivers; and 2) rescue execution errors such as difficulty reaching the victim, probe malfunction and breakage, miscount of victims and triage errors. Both failure themes appear to be decreasing in fatal accident reports over the past decade. Transceiver search errors appear 50% less frequently and rescue execution errors 40% less frequently than in past decades.

We also examined the proportion of victims who died of trauma versus asphyxiation (**Figure 1d)**. The rise of trauma in fatal accidents roughly coincides with the rising presence of transceivers in fatal accidents (**Figure 1b**) and the increase in accidents involving terrain traps (**Figure 2b**).

Discussion – Our analysis indicates more parties are now carrying rescue equipment and companion rescue errors are decreasing. These results suggest companion rescue is becoming more effective over time and avalanche victims who in the past would have died are now being recovered alive.

Applications - Excavating a buried avalanche victim is not the sole success metric for companion rescue. Fatal trauma rates are increasing among avalanche victims indicating that parties need to be prepared to deal with critical injuries in a wilderness setting. Avalanche instructors can help their students by defining the types of injuries that result from avalanche involvements (McCammon et al. 2008; Radwin, 2016) and the relevant first responder skills upon which to focus their first aid training.

5. CONCLUSIONS

We found no accidents where parties had engaged without error in the behaviors recommended in avalanche safety messages. This result supports the conclusion of Birkeland et al. (2017) that public messaging, avalanche education and rescue technology are saving lives.

But it appears our community could be doing more to reduce avalanche fatalities. Evidence-based supplements to standard avalanche safety messaging are listed in **Table 2**. More importantly, our results join a growing body of evidence indicating skills gained through avalanche training may be enabling parties to access avalanche-prone terrain during periods of instability (Mannberg et al., 2018; Greene and Logan, 2022; McNeil et al., 2023). Particularly concerning is that trained parties are venturing into critically dangerous terrain (type 1 slope + obvious path + terrain trap) and failing to correctly execute safety measures such as going one at a time. Overconfidence in avalanche skills cannot be ruled out as a causative factor in these accidents.

Perhaps the greatest risk to these parties was not the avalanche conditions or the terrain, but their confidence that their risk management skills could overcome the avalanche danger they were trying to avoid.

Although our study was limited to fatal accidents, we believe our results may have broader relevance. Tremper (2018: 15-16) argues that every fatal accident represents many more incidents that go unreported: avalanche victims recovered uninjured, close calls and parties that didn't know how close they came to being caught.

As avalanche educators we believe we have a responsibility to impart demonstrably life-saving risk management skills and knowledge. But we also believe we have a responsibility to help our students understand the limitations of these skills in practice and help them avoid becoming another avalanche fatality.

6. LIMITATIONS

Our reliance on skier and snowboarder accident data is subject to reporting biases, data variation and incomplete information. Also, our analysis focused on each message independently and did not address behavioral interactions. Our results

Message	*Selected findings*	*Suggested supplemental messages*
"Carry rescue gear"	About 20% of modern avalanche victims were not wearing transceivers.	• "Conduct gear and transceiver checks at the trailhead" • "Carry spares in your car"
"Travel with a partner"	Solo fatalities are stable at about 20% of accidents.	• "If you choose to travel alone choose safe terrain." • "Let someone know your plan and wear a transceiver."
"Understand the avalanche forecast"	Over 90% of RM parties were caught on tier 1 slopes.	• "Many avalanche victims were lured onto slopes they planned to avoid."
"Recognize avalanche terrain"	Over 60% of trained parties were caught on obvious tier 1 avalanche paths above terrain traps.	• See Sec. 4.6 • "Bad terrain choices lead to bad injuries."
"Expose one person at a time"	Trained parties failed to do this about 60% of the time.	• "Many trained victims failed to take this simple precaution."
"Perform a companion rescue"	Trauma now 50% of victims	• "Prepare for companion trauma."

Table 2. Improvements to avalanche messaging and education suggested by our results, specific to backcountry recreational skiers and snowboarders. Further details can be found in the text. Two additional messages "Have a plan" and "Recognize red flags" were not fully evaluated due to source data limitations.

should be viewed as preliminary rather than predictive or probabilistic.

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The authors also express their deepest sympathies to the survivors, families and friends of avalanche victims. May we continue to learn the lessons that these tragic deaths can teach us.

REFERENCES

American Avalanche Assoc. (AAA): Snow, Weather and Avalanches: Observation Guidelines for Avalanche Programs in the United States, 4th ed., 2022.

Atkins, D.: Skiers, trees and avalanches: A murderous triad, Proc. Int'l Snow Science Workshop, 736-739, 2012.

Birkeland, K., Greene, E. and Logan, S.: In response to avalanche fatalities in the United States by Jekich et al. Wilderness & Environ. Med., 28(4), 380–382, 2017.

Fraser, C.: The Avalanche Enigma, Rand McNally & Co., Chicago, IL, 301 pp., 1966.

Greene, E. and Logan, S.: Patterns in accidents: Education and experience levels of people involved in avalanches during the 2019-2020 and 2020-2021 Colorado avalanche seasons, Avalanche Review, 40(3), 36-39, 2022.

Greene, K., Hendrikx, J. and Johnson, J.: The impact of avalanche education on risk perception, confidence, and decision-making among backcountry skiers, Leisure Sciences, April, 1–21, 2022.

Jekich, B., Drake, B., Nacht, J., Nichols, A., Ginde, A. and Davis, C.: Avalanche fatalities in the United States: A change in demographics, Wilderness & Environ. Med., 27(1), 46-52, 2016.

Kahneman, D.: Thinking Fast and Slow, Farrar, Strauss and Giroux, New York, 499 pp., 2011.

LaChappelle, E.: The ABC of Avalanche Safety, Mountaineers, Seattle, WA, 60 pp., 1978.

Landrø, M., Engeset, R. and Pfuhl, G.: The role of avalanche education in assessing and judging avalanche risk factors. Journal of Research in Arts and Sport Education, 6(2), 37-60, 2022.

Logan, N. and Atkins, D.: The Snowy Torrents: Avalanche Accidents in the United States 1980-86, Colorado Geol. Survey, 265 pp., 1996.

Logan, S. and Reardon, B.: The Snowy Torrents: Avalanche Accidents in the United States 1986-1996, Amer. Avalanche Assoc., 400 pp., 2022.

Lovejoy, D.: Avalanche Education in the United States: The Good, the Bad, and the Ugly, Proc. Int'l Snow Science Workshop, 814-819, 2012.

Mannberg, A., Henrikx, J. and Johnson, J.: Are they experts? Self-assessed backcountry skills among backcountry skiers in Norway and North America, Proc. Int'l Snow Science Workshop, 1355-1359, 2018.

McCammon, I.: The role of training in recreational avalanche accidents in the United States, Proc. Int'l Snow Science Workshop, 37-45, 2000.

McCammon, I.: Sex, drugs and the white death: Lessons for avalanche educators from health and safety campaigns, Proc. Int'l Snow Science Workshop, 492-501, 2004.

McCammon, I., Ditolla, M. and McIntosh, S.: Terrain and traumatic injury in U.S. avalanche accidents, Proc. Int'l Snow Science Workshop, 238-243, 2008.

McNeil, K., Morgan, J., Riggs Meder, L. and Walker, E.: Understanding backcountry travel behaviors after participation in recreational avalanche courses, Proc. Int'l Snow Science Workshop, 1112-1119, 2023.

Mueller, J., Stanley, L. and Manlove, K.: Multi-stage novice defensive driver training program: Does it create overconfidence?, Open J. of Safety Sci. and Techn., 2, 133-139, 2012

National Avalanche Center (NAC): Signs of instability/Red flags, https://avalanche.org/avalanche-encyclopedia/snowpack/snowpack-observations/signs-of-instability-red-flags/, last access: 2 Aug. 2024.

Ng, P., Smith, W., Wheeler, A. and MacIntosh, S.: Advanced avalanche safety equipment of backcountry users: Current trends and perceptions, Wilderness & Environ. Med., 26(3), 417-421, 2015.

Nichols, T., Hawley, A., Smith, W., Wheeler, A. and McIntosh, S.: Avalanche safety practices among backcountry skiers and snowboarders in Jackson Hole in 2016, Wilderness & Environmental Medicine, 29(4), 493–498, 2018.

Perla, R., and Martinelli, M.: Avalanche Handbook: Agr. Handb. 489, U.S. Dep. Agr., 238 pp., 1975.

Radwin, M.: Avalanche victim trauma: Evidence-based recommendations, Avalanche Review, 34.3, 38-39, 2016.

Russo, J. and Schoemaker, P.: Managing overconfidence, Sloan Management Review, Winter, 7-17, 1992.

Silverton, N., MacIntosh, S. and Kim, H.: Avalanche safety practices in Utah, Wilderness & Environ. Med., 18(4), 264-270, 2007.

Spencer, J. and Ashley, W.: Avalanche fatalities in the western United States: A comparison of three databases, Nat. Hazards 58, 31-44, 2011. 2010.

Unger, J.: Avalanche transceiver use among backcountry travelers in San Juan Mountains, Colorado, USA, Proc. Int'l Snow Science Workshop, 384-389, 2023.

Williams, K. and Logan, S.: The Snowy Torrents: Avalanche Accidents in the United States 1996-2004, Amer. Avalanche Assoc., 350 pp., 2017.

Williams, K., and Armstrong, B.: The Snowy Torrents: Avalanche Accidents in the United States 1972-79, Teton Bookshop, 221 pp., 1984.