FATAL OCCUPATIONAL INJURIES OF AVALANCHE WORKERS IN THE UNITED STATES AND CANADA - 1950 TO 2026

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ABSTRACT: People working in avalanche safety are exposed to significant hazards at work. Despite the potential for harm, fatal workplace accidents involving avalanche workers are uncommon. While the total number of fatal accidents is relatively small, the fatal occupational injury rate is relatively high compared to other occupations. We present an updated dataset of avalanche worker deaths, examine trends discussed in Greene et al. (2014), and compare the rate of fatal occupational injuries of avalanche workers with industry sectors tracked by government agencies in the United States and Canada. Our estimates of annual fatal occupational injuries per 100,000 workers place the avalanche industry near the top of the list of high-risk occupations, but the size of the industry and the number of accidents make firm conclusions difficult. We present these data to promote industry discussions on acceptable risk in the workplace, professional training programs, and risk management strategies for managers and staff in avalanche safety operations.

KEYWORDS: worker safety, risk management, fatal occupational injuries, avalanche accidents

1. INTRODUCTION

Programs that operate in snow-covered, mountainous terrain must evaluate and often mitigate the hazard posed by avalanches. These operations can range from private businesses to government agencies or academic programs. They may be embedded in a transportation program, part of an industrial effort, or involved in outdoor recreation—providing safe experiences for people riding slopes or traveling through a winter mountain environment. The people who work in these avalanche safety programs create operational procedures and safety plans to manage the risk of avalanches to their customers, physical assets, coworkers, and employees. The people who evaluate and mitigate the avalanche hazard are an occupational group with similar training and skill sets; they are spread across a number of different industries. We are interested in the dangers these people face while they are at work.

Many people consider avalanche work a dangerous job, but just how dangerous is it? Although avalanche workers are killed on the job, the small number of workers, dispersed operating areas, and historically few accidents make it difficult to contextualize the risks of this profession. Recent trends in worker deaths in the United States and Canada are significantly different, with four deaths in four accidents in Canada since 2014 and 22 deaths in 20 accidents in the U.S. Is avalanche work getting more dangerous or safer? Is it dramatically different in the U.S. and Canada? It is difficult to answer any of these questions without examining industry trends and comparing avalanche work to different occupations in both countries.

Evaluating worker safety is an important part of any industry, and the results can affect both business and operational decisions. In both Canada and the United States, provincial, state, and federal government groups collect data on occupational injuries and examine trends. Common approaches of previous efforts are to look at regional differences and changes over time (Benavides et al. 2005; Loomis et al. 2003; Rossignol and Pineault 1993) or social, racial, or economic impacts on fatal occupational accident rates (Loomis et al. 2009; Loomis et al. 2004; Loomis and Richardson 1998; Richardson and Loomis 1997). In this effort, we build on previous work (Greene et al. 2014; Wilbur 1991) by looking at fatal occupational accidents of avalanche workers in the United States and Canada compared to other industries in these countries. We hope this will benefit discussions on the relative and acceptable risk to avalanche workers and promote efforts to better understand and track the progress of workplace accidents for the people in this small and specialized occupation.

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2. METHODS

The U.S. Bureau of Labor Statistics (US-BLS) and the Labour Program of Employment and Social Development Canada (ESDC) collect data on and report trends in fatal occupational injuries. Avalanche workers are a fairly small occupational group and part of several larger industries (U.S. Bureau of Labor and Statistics 2026b) as defined by the North American Industry Classification System (NAICS), used by both of these groups (U.S. Bureau of Labor and Statistics 2026c). As such, we could not use an existing dataset. Instead, we assembled our own dataset, following the methods used by these federal government groups as closely as possible.

We collected data from national databases of avalanche accidents (CAIC; Avalanche Canada). For the U.S., we reviewed records from the U.S. National Park Service and collections of outdoor-recreation accidents. We collected information from industry groups like the American Avalanche Association (Morris 2010) and the American Mountain Guides Association. We used common and AI search tools to scour media reports and records on the Internet. We spoke to our colleagues about events they recalled or were involved in. For Canada, we pulled data from Avalanche Canada's Fatal Avalanche Incidents Database, which pulls data in part from historic work from the National Research Council and the Canadian Avalanche Association. Provincial coroner services and WorkSafeBC are also sources for this data.

We defined an avalanche worker as:

- a person who makes avalanche safety decisions for other people or travels in avalanche terrain to
- collect data to support such decisions as part of their occupation.

We followed the methods used by the US-BLS Census of Fatal Occupational Injuries (CFOI) and included fatal injuries that:

1. Were the result of a traumatic injury
2. Stemmed from an incident that took place in the United States or Canada
3. Occurred while the person was at work

We erred on the side of inclusion, keeping accidents where a worker made avalanche safety decisions for coworkers. We included volunteers, such as volunteer climbing rangers at Denali National Park and search and rescue volunteers working in an established program. In several cases we included interns and junior workers in research and avalanche safety groups. If the person's role in an organization or work status was unclear, we tended to include their accident in the dataset. We grouped the events by year, using the avalanche year (AY) (Jamieson et al. 2010), where 2026 begins on October 1, 2025, and ends September 30, 2026. This effort produced a dataset of avalanche workers killed in both avalanche and non-avalanche incidents in avalanche years 1950 to 2026 (Figure 1), with AY 2026 data through August 31, 2026.

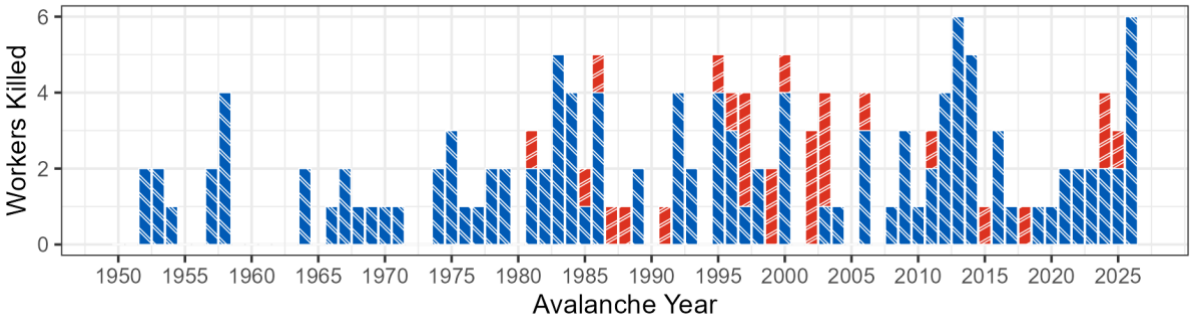

Figure 1: Avalanche workers killed in Canada (red) and the United States (blue) by Avalanche Year, from 1950 to 2026.

The US-BLS and ESDC use an hours-based approach to calculate the rate of fatal occupational injuries (US-BLS; ESDC), but their actual calculations differ. We followed methods used by each group for our comparisons with national data.

For the U.S., we calculated the rate of fatal occupational injuries per 100,000 full-time equivalent (FTE) workers (R)

$$R = \left(\frac{N}{EH}\right) \times 200{,}000{,}000 \qquad (1)$$

where N is the number of fatal work injuries in a specific group, EH is the total hours worked by all

employees in that group during a calendar year, and 200,000,000 is the base number of hours for 100,000 FTE (40 hours per week for 50 weeks per year).

For Canada, we calculated the Fatal Injury Incidence Rate (FIIR), which is the total number of fatal occupational injuries per 100,000 employees,

$$FIIR = \left(\frac{Total\ Fatal\ Injuries}{Total\ Employees}\right) \times 100{,}000 \qquad (2)$$

where the Total Employees is expressed as FTE. The total number of employees is the total number of hours worked by our occupational group in a single year divided by 2080, the number of hours 1 FTE works in a single year.

For both countries, we used the hours-based rates to calculate the Index of Relative Risk (IRR)

$$IRR = \frac{R_i}{R_T} \qquad (3)$$

where R_i is the rate for an individual group of workers and R_T is the rate for all workers during the same time period (U.S. Department of Labor 1994). We calculated the *IRR* for avalanche workers in 2024, which is the most recent published data from the US-BLS and ESDC. We also calculated a ten-year average for 2015 to 2024, a period where there is comparable data from the two federal agencies.

We estimated the number of avalanche workers in the U.S. and Canada in recent years, using different methods for each country. For Canada, we conducted interviews with experienced avalanche workers in Alberta and British Columbia. We created a list of ski areas in western Canada and estimated the number of avalanche workers. We estimated the number of full-time and part-time workers and used that to calculate the number of hours worked in a year. We followed a similar method for other industry sectors (Table 1). For the U.S., we estimated the number of workers in avalanche centers and transportation programs by surveying government and non-profit avalanche centers and using previous industry surveys (PTEX 2024; Ferber 2010). We used membership information from the American Mountain Guides Association, Cat Ski US, and HeliskiUS to estimate the number of guides. We used the number of instructors and annual number of courses from the American Avalanche Association and the American Institute for Avalanche Research and Education to make estimates for avalanche educators. For ski area workers, we compiled a list of U.S. ski areas and sorted them by the size of their avalanche program into three categories: small, medium, and large. We estimated the number of avalanche workers in each program category using employment numbers from the industry and records from the Colorado Department of Labor and Employment, which oversees the use of explosives for avalanche work in Colorado. We assumed that the distribution of avalanche program size at ski areas in Colorado is similar to the distribution of ski areas in the western U.S. We calculated the annual number of hours based on the number of full-time and part-time workers in each industry sector (Table 2). The estimates in Tables 1 and 2 are for the size of the avalanche safety workforce during avalanche year 2026. We used this estimate for all of the calculations in this study, going back to 2015.

Table 1: Estimated number of avalanche workers and annual hours worked in Canada for 2026.

Industry	***Number of Workers***	***Number of Hours/Year***
Mechanized Guiding	290	282,000
Self-propelled Guiding	150	180000
Industrial	50	72000
Ski Areas	350	280000
Public safety and forecasting	120	88560
Education and Research	80	16000
Total	1040	918,560

The US-BLS and ESDC both publish annual summaries of fatal occupational injuries by occupation and industry sector. They have both changed their calculation methods in the last 10 years, and the most recent published data is for 2024. We compared our calculations with the federal data from 2024 for each country. We also calculated summary statistics for multiyear periods attempting to group values calculated by the same method.

Table 2: Estimated number of avalanche workers and annual hours worked in the United States for 2026.

Industry	***Number of Workers***	***Number of Hours/Year***
Mountain Guiding	326	216,000
Transportation	137	107,280
Utility/Industry	45	53,040
Ski Areas	3,327	5,111,100

Industry	*Number of Workers*	*Number of Hours/Year*
Mechanized Guiding	433	294,800
Public safety and forecasting	186	228,480
Total	4,454	6,010,700

3. RESULTS

Our effort produced a dataset of fatal occupational injuries of avalanche workers with 148 deaths in 116 accidents (Figure 1). In avalanche years 1950 through 2026, 96 avalanche workers were killed in avalanches, and 52 died in other types of workplace accidents. In this time period, 1937 people were killed in avalanches in the U.S. and Canada (Figure 2). Avalanche workers made up 5% of the total avalanche deaths in the combined dataset.

In Canada, 27 avalanche workers were killed in 20 accidents between AY 1950 and 2026. Avalanches were the deadliest type of accident for avalanche workers in Canada, killing 20 workers in 18 separate avalanches. This is about 77% of the total number of avalanche workers killed in Canada. Seven were killed in other types of accidents (Table 3). The industry sector with the most fatal occupational accidents was mechanized guiding, followed by self-propelled guiding (Table 4). The majority of the fatal accidents occurred in British Columbia. There are only two accidents in our records where more than one avalanche worker was killed in the same event.

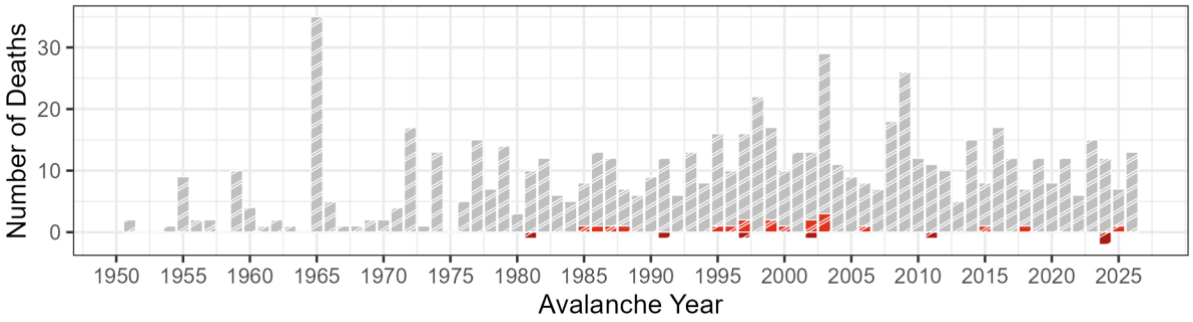

Figure 2: Avalanche deaths and avalanche worker deaths in Canada by avalanche year, 1950–2026. Gray bars show all avalanche deaths. Red bars above zero show avalanche workers killed in avalanches; red bars below zero show avalanche workers killed in other types of workplace accidents.

Table 3: Accident type and number of avalanche workers killed in Canada, 1950 to 2026.

Accident Type	*Number Killed*
Avalanche	20
Aircraft	3
Explosive	1
Fall	2
Vehicle	1

Table 4: Industry sector and number of avalanche workers killed in Canada, 1950 to 2026.

Worker Type	*Number Killed*
Mechanized Ski Guide	12
Self-propelled Guide	4
Ski Patroller	2
Transportation	2
Educator	2
Snowmobile Guide	1
Other	4
Mechanized Ski Guide	12

The annual rate of fatal occupational injuries of avalanche workers in Canada ranged from 0 to 435 deaths/100,000 FTE in avalanche years 2017 through 2026 (Figure 4). During these 10 years, the rate was zero in seven of the 10 years, with an average value of 80 deaths/100,000 FTE. In 2024, the FIIR for avalanche workers in Canada was 435 deaths/100K FTE. This is the highest FIIR value in the 10-year period we looked at by nearly a factor of two, giving avalanche workers the highest fatal injury rate among the industry sectors included in this comparison. That rate was much higher than the

industry sectors with the two highest rates of fatal occupational injuries, Feed, Flour, and Seed and Grain Handling and Grain Elevators (Figure 4). The IRR for avalanche workers in 2024 was 75. For the 10-year period of 2015 to 2024, the average IRR for avalanche workers was 17, an estimated fatal injury rate for avalanche workers 17 times the rate for the overall Canadian workforce.

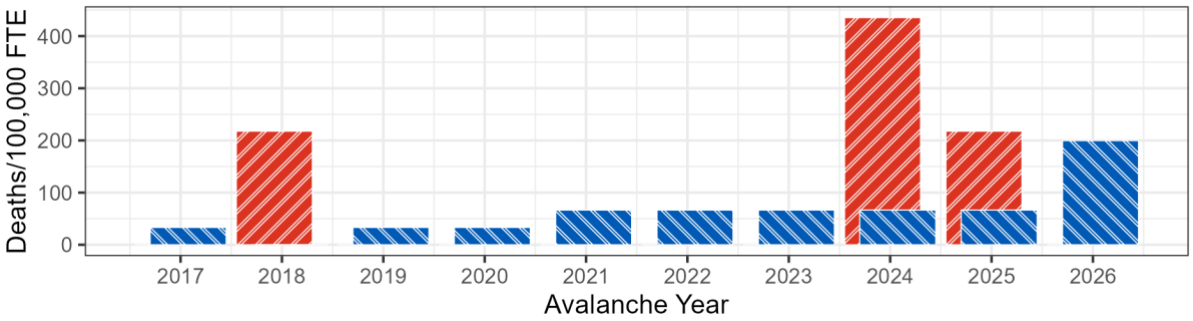

Figure 3: Annual fatal occupational injury rates for avalanche workers in Canada (red) and the United States (blue), avalanche years 2017–2026.

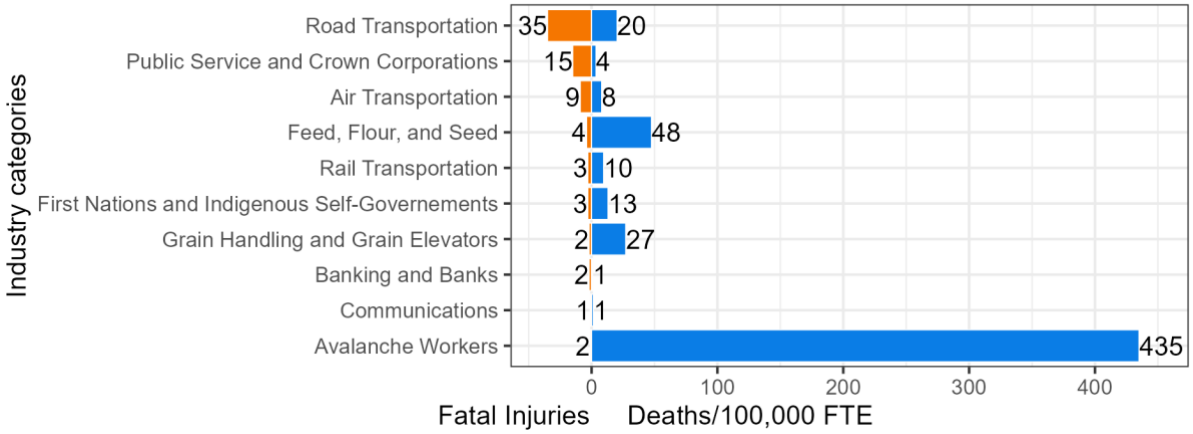

Figure 4: Fatal occupational injuries and fatal injury rates for avalanche workers and selected Canadian industry sectors in 2024.

In the U.S., there were a total of 121 workers killed in 99 accidents between AY 1950 and 2026 (Figure 5). Avalanches were the deadliest type of accident, killing 76 workers in 62 avalanches, about 63% of the total avalanche worker deaths. Forty-five were killed in 37 accidents that did not involve avalanches (Table 5). Accidents that involved a fall was the second deadliest type of accident, followed by accidents involving explosives. The deadliest industry sector was ski areas (ski patrolling), about 37% of the total worker deaths (Table 6). More avalanche workers died at work in California, followed closely by Colorado and Alaska. More than one person was killed in 15 of the accidents in our dataset, which is about 15% of the accidents.

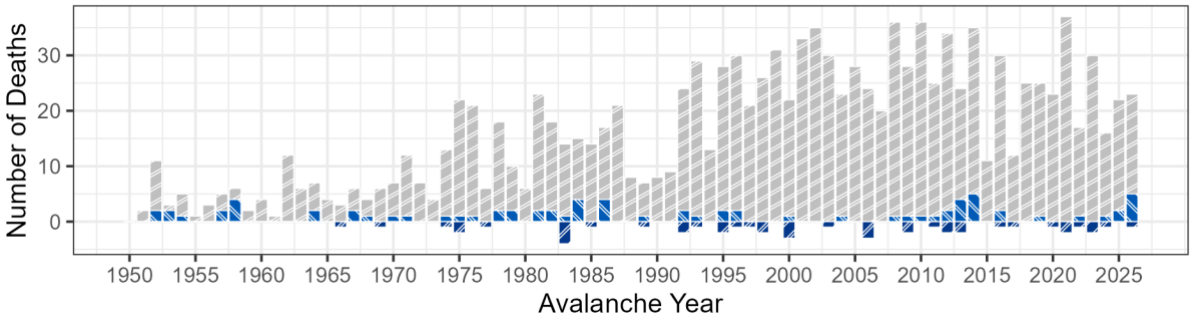

Figure 5: avalanche deaths and avalanche worker deaths in the United States by avalanche year, 1950–2026. Gray bars show all avalanche deaths. Blue bars above zero show avalanche workers killed in avalanches; blue bars below zero show avalanche workers killed in other types of workplace accidents.

Table 5: Accident type and number of avalanche workers killed in the United States, 1950 to 2026.

Accident Type	*Number Killed*
Avalanche	76
Fall	14
Explosive	11
Aircraft	8
Collision	2
Gas Inhalation	3
Medical	2
Vehicle	2
Crushed	1
Immersion	2

Table 6: Industry sector and number of avalanche workers killed in the United States, 1950 to 2026

Worker Type	*Number Killed*
Public safety and forecasting	3
Transportation	22
Ranger	12
Rescuer	4
Ski Patroller	45
Mechanized Guide	14
Self-propelled Ski Guide	8
Climbing Guide	9
Industry/Utility	2
Educator	1
Consulting and Research	1

The annual rate of fatal occupational injuries of avalanche workers in the United States ranged from 0 to 200 deaths/100,000 FTE in AYs 2017 through 2026 (Figure 3). During these 10 years, there was only one year where the rate was zero. The highest rate was 200 and the average was 48 deaths/100,000 FTE. In 2024, the rate of fatal occupational injuries for avalanche workers was 67 deaths/100,000 FTE. This rate was higher than the fatal occupational injury rates for the U.S. industry sectors included in this comparison (Figure 6). The IRR for avalanche workers was 20 in 2024. For the 10 avalanche years from 2015 to 2024, the average IRR for U.S. avalanche workers was 13, suggesting that the estimated fatal injury rate was 13 times the rate for the overall U.S. workforce.

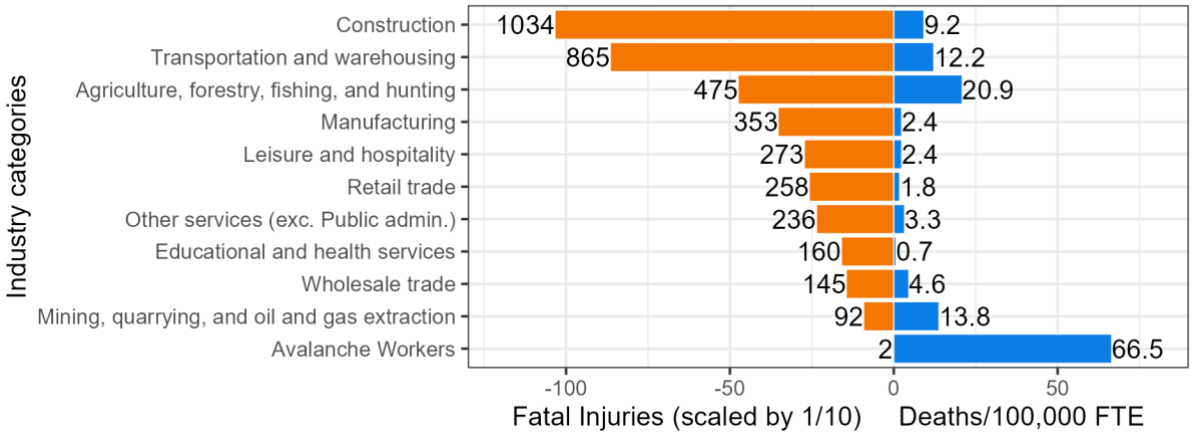

Figure 6: Fatal occupational injuries and fatal injury rates for avalanche workers and selected U.S. industry sectors in 2024. Fatal injury counts are scaled by one-tenth for display.

4. DISCUSSION

Our investigation suggests that avalanche work is dangerous work, compared to other occupations and industries in both the United States and Canada. This unfortunate result is consistent with previous efforts (Greene et al. 2014; Wilbur 1991). Although this result is not encouraging, when we consider the size of the industry and the data we compiled, interpreting our results and drawing firm conclusions is not straightforward.

The number of deaths in our dataset varies dramatically from year to year. In Canada there

are no avalanche workers killed while at work during most years. During most of the years where there is a workplace death, only one person is killed. The most deaths in a single year is three, and there are only two years with three deaths in the 76 years of our data record. In the United States, there are 25 years without a worker death, around one-third of the years. One worker died in about 20% of the years, and two or fewer workers were killed in 80% of the years.

The size of the avalanche occupational group in both the U.S. and Canada makes comparisons with other industries quite difficult. Avalanche workers in the U.S. are about 11% of the next smallest industry group in the 2024 CFOI, and the difference grows quickly as we move to other industries. In Canada, the number of hours worked by avalanche workers is about 25% more than people in the Interprovincial Infrastructure (Bridges, Tunnels, etc.) category, but has a much larger rate of fatal occupational injuries. When we look at industry sectors with a similar fatality rate, avalanche workers put in about 5% of the hours worked by the other groups.

The US-BLS and ESDC issue annual reports on fatal occupational injuries. The publication of these reports lags a year or more, due to the significant amount of effort that goes into collecting and analysing these data. The reports compare occupational groups and industry sectors for a single year, and often discuss trends from the previous year. The 2024 report was the most current report available that included fatality rates. We created comparable values to provide a comparison between avalanche workers and other occupational groups that was as consistent as possible with the methods used by these federal agencies. The high year-to-year variability in the avalanche worker data limits the utility of comparing a single year. The 2024 comparison for Canada is a good illustration of this limitation, as two workers were killed that year, producing the highest fatality rate in the years we examined. We used 10-year averages in an attempt to provide a more useful comparison for people in the avalanche industry. Hopefully these comparisons are helpful, but comparing averages is not consistent with the established methods used by these two federal agencies.

5. CONCLUSION

Is working in avalanche safety a dangerous job? The data we collected and our analysis do not provide a conclusive answer. While certain metrics rank avalanche work among the most dangerous of industries, several factors make answering this question quite difficult. High annual variability, low overall sample sizes (for both workforce and fatalities), and a heavy reliance on estimations introduce substantial uncertainty in our conclusions. This predicament is not unique to avalanche workers. Toscano (1997) used elephant trainers as an example when describing small industries in his investigation into “dangerous jobs”. There are a very small number of elephant trainers working during an individual year. Most years there are no fatal injuries, but other years have one or two. Elephant training looks like either a very safe or very dangerous job depending on which year is examined. This analogy holds up well for our analysis of fatal occupational injuries in Canada. However, in the United States, there is only one year in the last 10 with zero deaths, and a disturbingly high number of deaths in 2026.

It is difficult to identify a problem without good data. It is even harder to fix a problem without the ability to track progress and evaluate the results of any change. Both Canada and the U.S. have national programs that track fatal and non-fatal injuries in occupations and industry sectors. People who work in avalanche safety are spread across several of these established groups. Although this is not a unique circumstance, it hampers investigation into the true statistical danger faced by avalanche workers and drawing lessons that could improve the safety of these individuals

6. ACKNOWLEDGEMENTS

We would like to acknowledge the following organizations and people who contributed to this work: Association of Canadian Mountains Guides, American Avalanche Association, American Mountain Guides Association, Avalanche Canada, British Columbia Coroner Service, Canadian Avalanche Association, Canadian National Research Council, Canadian Ski Guides Association, CatSki US, Colorado Department of Labor and Employment – Division of Oil and Public Safety, Colorado Department of Transportation, United States Bureau of Labor Statistics, Vail Resorts Patrol Center of Excellence, Dale Atkins, Colani Bezzola, Eric Deering, Dave Gauthier, Laura Gaylord, Pascal Haegli, Phil Hein, John Hetherington, Clair Israelson, Brian Lazar, Sarah MacGregor, Meghan McElrone, Halsted Morris, Jen Reddy, Scott Savage, Peter Schaerer, Don Sharaf, Steve Sewell, Chris Stethem, John Stimberis, Ian Tomm, Matt Wade, and Emma Walker.

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