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Research note: How old are the people who die in avalanches? A look into the ages of avalanche victims in the United States (1950–2018)

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ABSTRACT

Since the winter of 1950–1951, 1084 individuals perished in snow avalanches in the United States. In this study, we analyze the ages of those killed (n = 900) by applying non-parametric methods to annual median ages and for age groups and primary activity groups. Change point detection results indicate a significant change in 1990 in the median age of avalanche fatalities. Significant positive trends exist for both the 1950 to 2018 and 1990 to 2018 median age of victims. The median age of victims from 1950 to 1989 is 27 and is 33 from 1990 to 2018. Since 1990, the 30–39 and 40–49 age groups are the only age categories to exhibit a positive trend in the number of fatalities. There is no significant difference in median ages between snowmobilers and other categories. These results can be used to enhance avalanche education and forecasting efforts in the United States.

Management implications: Using the best available dataset of avalanche fatalities in the United States, we found that the age of avalanche victims increased from 1950 to 2018. Though avalanche educators should still reach out to students of all ages, our results suggest that programs that target recreationalists over 30 years of age could have a better chance of reducing the number of people killed in avalanches. In addition, avalanche warning services should use a wide range of methods to disseminate avalanche safety information, and include products that target older and, potentially more experienced, users.

1. Introduction

Avalanches have killed 1084 people in the United States since 1950. In the last 10 avalanche years (avalanche year defined as September 1 to August 31 (Logan & Atkins, 1996)), an average of 27 people per year died in avalanche accidents in the United States (CAIC, 2018). Winter backcountry visits increased over time (Cordell et al., 1999; Rivers & Menlove, 2006), yet the number of avalanche fatalities has not mimicked this trend. Birkeland, Greene, and Logan (2017) report that the number of avalanche fatalities from 1995 to 2016 was steady with 25–30 avalanche fatalities per year. They also account for increases in winter backcountry use by using avalanche center website visits as a proxy. If the fatality rate increased proportionally, there would be more than 200 fatalities annually.

Several studies report the age of avalanche victims in the United States (Jekich et al., 2016; Page, Atkins, Shockley, & Yaron, 1999), and two studies examine ages in light of user groups (Atkins & Williams, 2000; Boyd, Haegeli, Abu-Laban, Shuster, & Butt, 2009). Winkler and Techel (2014) also report an increasing age of avalanche victims in avalanche accident data from Switzerland. Other research examined trends and some demographic patterns (i.e. temporal trends and primary activity) of avalanche fatalities (Höller, 2017; Pfeifer, Höller, & Zeileis, 2018; Techel et al., 2016). However, previous work has not provided a detailed examination of the ages and primary activity of avalanche victims in the United States.

A better understanding of the age of people who died in avalanches could improve targeted public messaging and education. Therefore, the objective of this study is to examine the ages of avalanche accident victims in the United States, including any differences in the ages of activity undertaken and trend of fatalities within various age groups.

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2. Data and methods

2.1. United States national avalanche accident database

We used a United States avalanche fatality dataset maintained by the Colorado Avalanche Information Center (CAIC) (CAIC, 2018). Construction of the dataset began in 1960 with the U.S. Department of Agriculture Forest Service (USFS) Avalanche Program's efforts to retrospectively compile fatality data prior to 1960 (Page et al., 1999). The USFS continued to collect the data, the Westwide Avalanche Network digitized the data in 1972, and the CAIC continues to manage the dataset. These data are widely available to the public and document 1084 avalanche fatalities. To allow comparison with other studies investigating avalanche fatalities in the U.S. (Birkeland et al., 2017; Jekich et al., 2016; Page et al., 1999) we used 1950 as a starting point in time. This period also contains the most robust and complete records (CAIC, 2018).

Ages were only recorded for 835 of those fatalities in the dataset from the CAIC and were only current to the year 2012, with a few years where ages of avalanche victims were unavailable. We used three additional sources to supplement this dataset: The Snowy Torrents – Avalanche Accidents in the United States 1996–2004 (Williams & Logan, 2017), *avalanche. org* (American Avalanche Association A3, 2018), and popular media articles and avalanche accident reports archived on the internet. The Snowy Torrents is a publication series of the American Avalanche Association that details avalanche accidents in the United States. By using Snowy Torrents, we were able to either correct the reported age or add ages to existing fatalities for 37 records. The A3 also maintains *avalanche. org* in partnership with the USFS National Avalanche Center. They host avalanche accident data from 1998 to the present. By using *avalanche. org* and other media sources, we were able to compile 28 additional records for 2007, 2008, 2009, 2010, and 2013 to 2018 for a total of 900 records of avalanche fatalities with associated victims' ages. We also used these sources to compile the primary activity of each fatality. We note that we are assuming that the popular media articles and avalanche accident reports provide accurate age and activity data. We cross-checked these sources with additional media sources, when available. Thus, the uncertainty of these data cannot be quantified.

2.2. Statistical analysis

We calculated descriptive statistics (mean, median, minimum, maximum, and standard deviation) of avalanche victims' age to describe the data. We then calculated the median age for each year, resulting in a time series that covered 65 years in total. Three years (1955, 1961, and 1965) contained no data for ages associated with avalanche fatalities. Throughout the analysis we consider test results with p-values < 0.05 to be significant. However, in light of recent literature and discussion on statistical significance, we relax this strict threshold when values are near the 0.05 value (Amrhein, Greenland, & McShane, 2019; Krueger & Heck, 2019).

We examined the time series of the full dataset of fatality counts (1084 fatalities), the counts of the age dataset (900 fatalities), and the annual median age dataset (65 years) for any significant ($p < 0.05$) change points using a non-parametric Pettitt test (Pettitt, 1979). This tests for a shift in the central tendency of a time series. Birkeland et al. (2017) suggest a shift in avalanche fatalities around 1990. Using this test allowed us to statistically determine a point in time where the number of fatalities or the age of fatalities significantly change. We then used this year to separate the time series for subsequent trend analysis.

Most of the data for the time period did not meet all of the assumptions necessary for linear regression analysis. Therefore, we applied the non-parametric Mann-Kendall test for monotonic trend (Mann, 1945) to all datasets for comparability. The Mann-Kendall test, in this case, assesses if the age of avalanche victims consistently increases or decreases through time, whether it is linear or not. However, serial correlation in a time series can affect the results of this test. We used both visual inspection of autocorrelation function plots and the Durbin-Watson test (Durbin & Watson, 1950; 1951) to detect serial correlation. If serial correlation existed, we used a modified Mann-Kendall trend test for autocorrelated data (Hamed & Rao, 1998). Both the modified Mann-Kendall and Mann-Kendall test provide the same statistics, including Sen's slope, a measure of how the median age changes with time, and Kendall's Tau (τ), a measure of the strength of correlation between two data series.

We also used Cook's Distance tests to detect influential points over $4/n$ (Cook, 1977). We identified any outliers, removed them from the trend analysis, and compared the results to the results with outliers included. If the results were similar, we kept the outliers in the analysis to preserve the full dataset.

To explore the observed trends in more detail, we segregated the data into separate age groups (1–19, 20–29, 30–39, 40–49, 50–59, 60–69) and repeated the trend analysis for each group. This distinction is important as specific age groups, not just the oldest age groups, demonstrate an increase in avalanche fatalities. Using the modified Mann-Kendall test, we examined each age category for the time periods 1950 to 2018 and 1990 to 2018 for monotonic trends. We chose 1990 because the aforementioned Pettitt test for median age (1950–2018) resulted in a significant change point in this year. We also analyzed different age groupings using the same techniques (0–14, 15–24, 25–34, 35–44, 45–54, 55–64, 65–74) to determine if age segregation had an effect on the trend in each group.

Finally, we compared ages for various activity categories. For this study, and defined by the CAIC database, backcountry tourers and sidecountry riders are defined as skiers and snowboarders traveling in an area that is not part of an active avalanche hazard mitigation program. Sidecountry riders access this area from an operating ski area. We compared snowmobilers (including motorized snowbikes) to backcountry tourers/sidecountry riders as well as snowmobilers to all other activities for any significant differences using a Mann-Whitney U test (Mann & Whitney, 1947). Our comparison of ages in these activities extends from 1990 to 2018 as there are only 11 snowmobile fatalities from 1950 to 1990 in the dataset with associated ages. We used the Mann-Kendall test to detect any trends in the number of fatalities with ages recorded as well as the median ages of snowmobilers and backcountry tourers/sidecountry riders from 1990 to 2018. We also examined the two age groups comprising the majority of fatalities for any trends or patterns in primary activity throughout the time series.

3. Results

The median age of avalanche victims from 1950 to 2018 was 31 with a range from 6 to 68 years old (Figs. 1 and 2).

3.1. Change point detection

A significant change point in the median annual age of avalanche victims time series (65 years) existed at the year 1990 ($p < 0.01$) (Fig. 1). For the full CAIC dataset of the annual number of fatalities (1084 fatalities) the change point was 1991 ($p < 0.01$), and the change point for the full count dataset of fatalities with ages recorded (900 fatalities) was also 1991 ($p < 0.01$) (Fig. 3). Given the objectives of this study in examining trends and patterns associated with age, we chose the 1990 change point. The median age dataset best reflected major patterns and changes in the age of avalanche victims, and these patterns were similar when using mean age.

Two potential influential points (1990 and 1991) existed in the median age dataset, and when removed, caused the change point to move to 1992. However, we chose to keep these points in the dataset as their removal did not influence subsequent trend analysis results. No other significant change points existed in the 1990 to 2018 period.

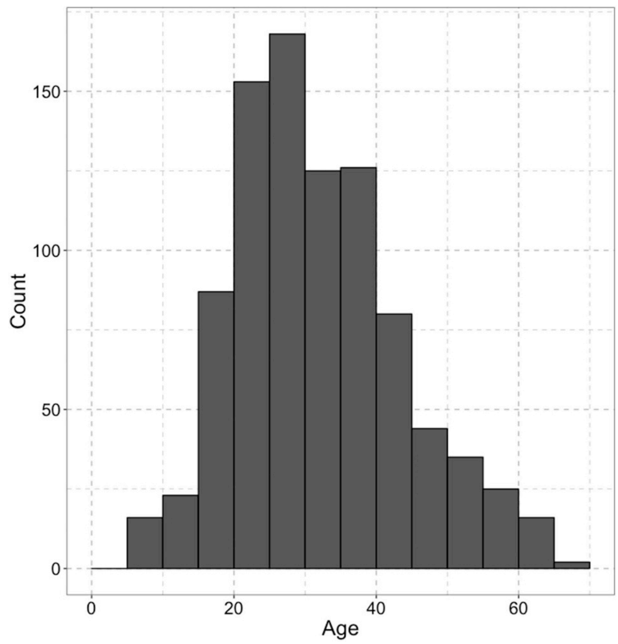

Fig. 1. Histogram of ages of avalanche victims from 1950 to 2018 (n = 900).

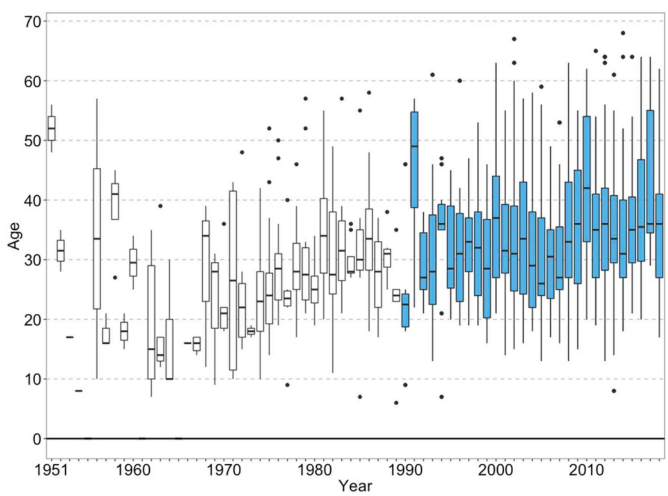

Fig. 2. Box plots of ages of avalanche victims per avalanche year. The white boxplots depict the years 1950–1989, and the blue boxplots represent 1990 to 2018 (see Sec. 3.1). The three years with no available data (1955, 1961, and 1965) are included on the x-axis.

Finally, there were no significant change points detected in the 1990 to 2018 time series for any specific age group.

3.2. Trend analysis

The number of avalanche fatalities with age recorded trended positive from 1950 to 2018 using a non-parametric Mann-Kendall test ($p < 0.01$, $\tau = 0.68$, Sen's slope = 0.44). A positive trend also existed in the number of avalanche fatalities with age recorded from 1991 to 2018 ($n = 636$) ($p = 0.01$, $\tau = 0.33$, Sen's slope = 0.40). However, the complete national dataset of all avalanche fatalities exhibited no trend from 1991 to 2018 ($p = 0.51$, $\tau = 0.09$, Sen's slope = 0.13).

The full time series (1950–2018) of median age of avalanche fatalities failed to meet all of the assumptions necessary for linear regression analysis and the series was autocorrelated. Implementing a modified Mann-Kendall test for trend resulted in a significant positive trend in median age ($p < 0.01$, $\tau = 0.42$, Sen's slope = 0.26) (Fig. 4).

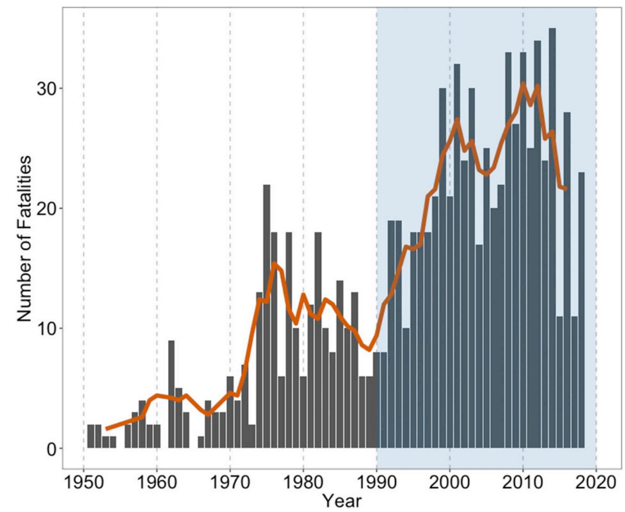

Fig. 3. Time series of the number of fatalities with age recorded from 1950 to 2018. The red line represents a 5-year moving average, and the blue shading represents 1990 to 2018. Year indicates avalanche year, i.e. if an avalanche occurred in December of 1950, it was recorded as 1951.

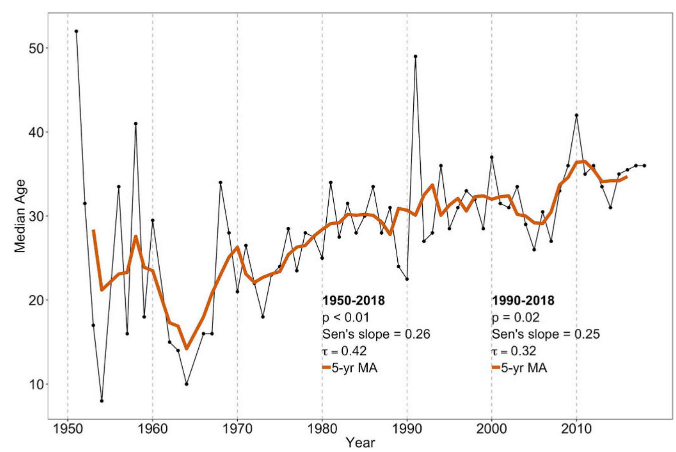

Fig. 4. Time series of median age from 1950 to 2018. The red line represents a 5-year moving average.

The 1990 to 2018 median age time series also failed to meet the assumptions of linear regression, but the data were not autocorrelated. A Mann-Kendall test revealed a significant positive trend in median age from 1990 to 2018 ($p = 0.02$, $\tau = 0.32$, Sen's slope = 0.25) (Fig. 4). It is worth noting that when we removed potential influential points in the median age dataset for both time periods, significant positive trends remained. We also examined different change points in the time series for comparison: 1991 to 2018, 1992 to 2018, and 1993 to 2018, and a positive trend still existed with respect to median age.

3.3. Age groups

All age groups, except the Under 20 category, exhibited a positive trend from 1950 to 2018 in the number of avalanche fatalities (Fig. 5). From 1990 to 2018, only the 30–39 group exhibited a significant positive trend in a strict statistical sense in the number of avalanche fatalities ($p = 0.02$, $\tau = 0.32$, Sen's slope = 0.17; Fig. 5). However, there is a positive trend in the 40–49 age group as well when relaxing the strict cutoff of $p < 0.05$ ($p = 0.07$). We also examined different age groupings (i.e. 0–14, 15–24, 25–34, 35–44, 45–54, 55–64, 65–74), and the 35–44 was close to the significance threshold ($p = 0.09$) while the 45–54 exhibited a significant trend ($p = 0.02$).

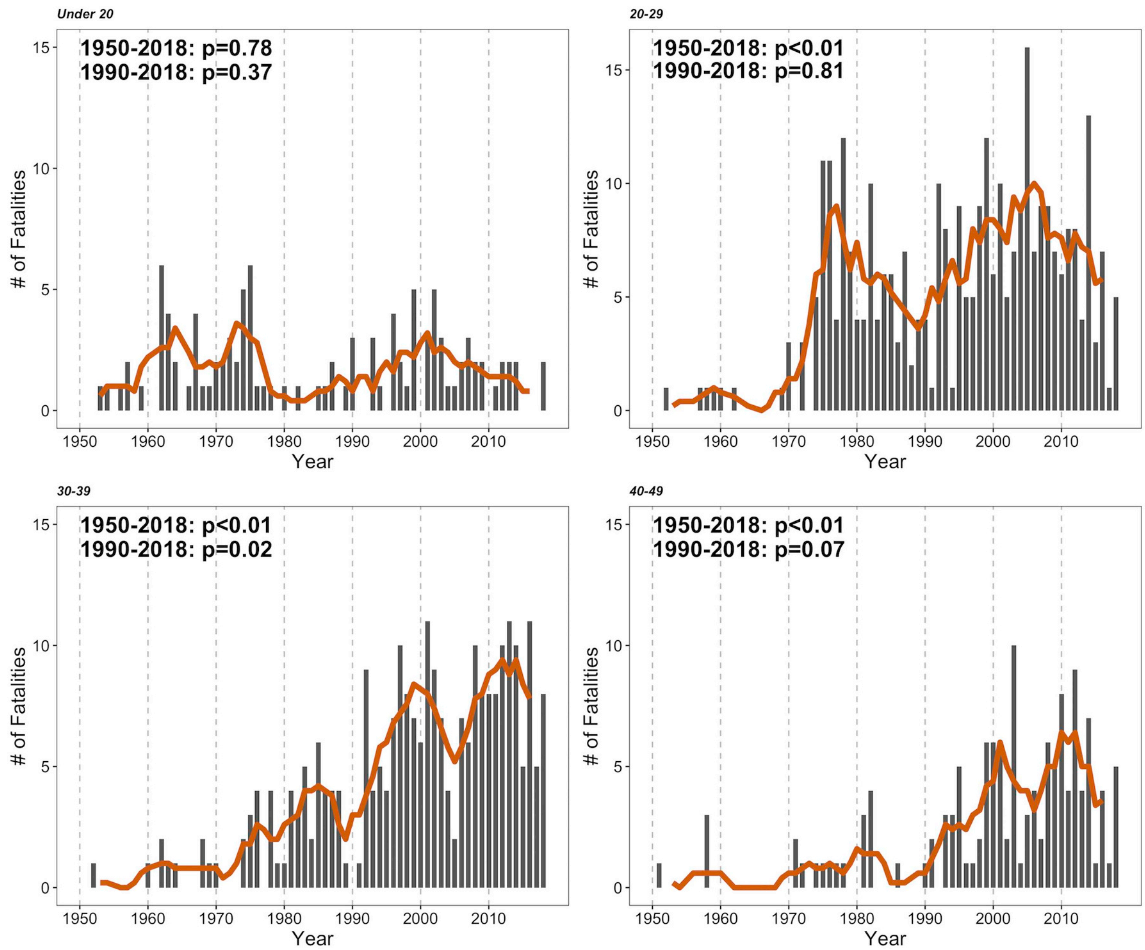

Fig. 5. The number of fatalities for each age group from 1950 to 2018 (upper left: Under 20, upper right: 20–29, lower left: 30–39, and lower right: 40–49). Age groups 50–59 and 60–69 were omitted due to small sample sizes. The red line represents a 5-year moving average. The p-value represents the significance of the trend (significant at $p < 0.05$) for the specific time period.

3.4. Age and activity

Of the individuals in their 30s who died in avalanches from 1990 to 2018, 85 (57%) were backcountry tourers or sidecountry riders and 64 (43%) were snowmobilers. Similarly, of the individuals in their 20s, 92 (61%) were backcountry tourers or sidecountry riders, and 60 (39%) were snowmobilers. In the overall dataset with age and activity both recorded, 258 (55%) were backcountry tourers or sidecountry riders and 213 (45%) were snowmobilers.

There was no significant difference between the median age of snowmobilers, 35 years, from 1990 to 2018 and the median age of backcountry tourers/sidecountry riders, 31 years, the two groups that comprise the bulk of fatalities in the dataset ($p = 0.15$, Manny Whitney U test, Fig. 6a). There was also no significant difference between the median age of snowmobilers and the median age of all other activities, 32 years, from the same period ($p = 0.21$, Mann Whitney U test, Fig. 6b).

The number of fatalities of both snowmobilers and backcountry tourers/sidecountry riders with ages recorded trended positive from 1990 to 2018 ($p = 0.03$ and $p = 0.04$, respectively, Fig. 6c), but the trend of all fatalities from the full national dataset with activity recorded was not significant for either group ($p = 0.09$ and $p = 0.11$, respectively). The median age of snowmobilers exhibited no significant trend from 1990 to 2018 ($p = 0.57$), while a positive trend existed for backcountry tourers/sidecountry riders ($p = 0.04$) and all other activities ($p = 0.01$).

4. Discussion

Results from the period 1990 to 2018 are most germane to current avalanche practitioners. As per Birkeland et al. (2017), and in light of the reported significant change points, it is important to note that the 1990 to 2018 time series reflects a shift in the dataset of both age and number of avalanche fatalities and more accurately describes current trends.

As Birkeland et al. (2017) point out, it is important to segregate the time series to account for a marked shift in snowmobile and backcountry touring gear technology, and for the effects of increased avalanche education and forecasting efforts. This likely explains the absence of a significant trend in either direction in total avalanche fatalities in the United States since 1995. Our results are consistent with Birkeland et al. (2017), indicating the absence of a significant trend using non-parametric tests: we detect no significant upward or downward trend in the total number of avalanche fatalities since 1991.

4.1. Age of avalanche victims

The median age of avalanche victims from 1990 to 2018 in our dataset, 33, is the same as that found by (Boyd et al., 2009) for avalanche fatalities in Canada from 1984 to 2005. In our full time series dataset, the median age of backcountry skiers, 32, and snowmobilers, 35, is also similar to those reported by (Boyd et al., 2009), 32 and 36, respectively. In Switzerland, Winkler and Techel (2014) report that the

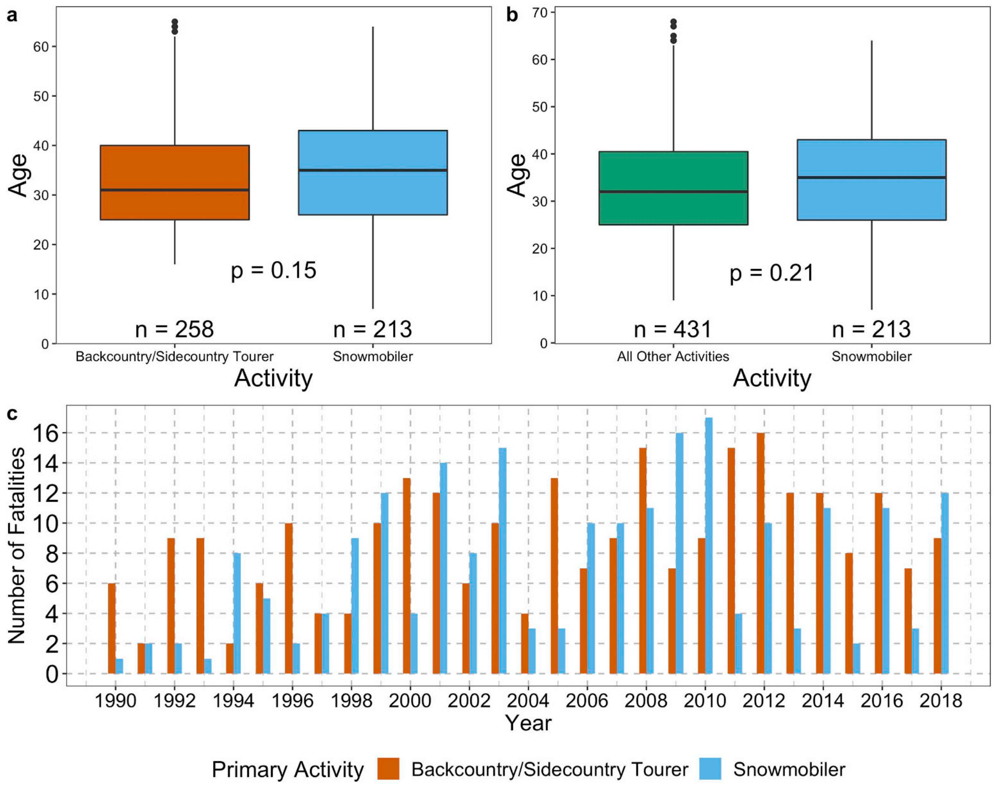

Fig. 6. **a**: Boxplots illustrating the distribution of ages between snowmobilers (blue box) and backcountry tourers/sidecountry riders (red box). **b**: Boxplots illustrating the distribution of ages between snowmobilers (blue box) and all other activities (green box, including backcountry tourers/sidecountry riders). **c**: Number of fatalities of the three main primary activity groups (backcountry tourer/sidecountry rider combined, red, and snowmobilers, blue) from avalanche years 1990–2018.

median age of avalanche victims from 2004 to 2013 is 39 years, slightly greater than that found in our dataset.

The positive trend in median age from 1990 to 2018 in our results indicates that avalanche victims are older in recent years than in the past. This is similar to other work reporting increases in ages of avalanche victims. Atkins and Williams (2000) report the average age of avalanche victims in the United States rose from 27 in the 1970s to 32 in 1999. Soulé et al. (2014) found an increasing age of avalanche victims in France from 35 in the 1980s to 40 in the 2000s. Winkler and Techel (2014) also found an increase from 33 in the 1994 to 2003 period to 39 years in the 2004 to 2013 period.

It is important to note that when we segregated the age groups differently than 20s, 30s, 40s, etc., the trends varied slightly. However, the significant (or nearly significant) trends of the age groups incorporating late 30s through 40s illustrates that positive trends still exist for older age groups. The significant trend for the 45–54 age group is also likely influenced by a smaller sample size with years of no fatalities in this age group, particularly earlier in the time series.

4.2. Activity and age

There were no significant differences in median age between snowmobilers and other activities in this dataset. This indicates that differences in activity, and associated age, cannot fully explain the positive trend in median age throughout the dataset of avalanche fatalities. The user groups of fatalities in our dataset are similar to other findings in both the United States and Canada (Atkins & Williams, 2000; (Boyd et al., 2009)). Atkins and Williams (2000) illustrate the increasing number of snowmobile-related avalanche fatalities in the 1990s. This, as previously mentioned, is likely linked to the increase in snowmobile technology allowing riders to venture further into and spend more time in avalanche terrain (Birkeland et al., 2017; Rivers & Menlove, 2006; Strong-Cvetich, 2014). From 1984 to 2005, (Boyd et al., 2009) report that snowmobilers represent 22% of Canadian avalanche fatalities, while backcountry tourers account for 30%. These are similar ratios of backcountry skiers to snowmobilers in our dataset as well. However, our results indicate that there is no clear evidence that an increase in snowmobile use since 1990 explains the increase in fatalities of individuals in the 30–39 or 40–49 categories.

The number of fatalities of both snowmobilers and backcountry tourers/sidecountry riders with ages recorded exhibited a positive trend, but the full CAIC dataset showed no significant trend for any activity. While the full dataset provides a more complete perspective on trends of activities of avalanche victims, both results provide further evidence that increasing ages of avalanche victims cannot be explained by an increase in snowmobile use. However, the significant positive trend of median age of backcountry tourers/sidecountry riders suggests that these activities are a driver of the increasing age.

4.3. Limitations and future research

Soulé et al. (2014) discuss the limitations of studies such as ours without knowing the parent population profiles (the ages of those traveling in avalanche terrain overall). Without knowing the parent population of these user groups, it is often challenging to interpret results. Parent population demographics for the age distribution of backcountry travelers are currently unavailable. However, the International Snowmobile Manufacturers Association reports that the average age of a snowmobiler is 43 years old (ISMA, 2018). This is greater than the median age of snowmobile avalanche victims in our dataset, but includes all types of snowmobilers, not just mountain snowmobiling. The Outdoor Foundation (2018) reports that participants aged 25–44 comprise 29% of all outdoor recreation participants, and those aged 45 and over comprise 36% of participants. These limited data provide some context for the age distribution of avalanche victims, but cannot truly serve as a parent population or proxies for comparison purposes.

It is likely that the increase in age of avalanche victims cannot be explained by any single factor, but rather a combination of factors as well as others beyond the scope of this discussion. Again, without parent population profiles, interpretation is challenging.

It is also worth exploring if the increase in avalanche fatalities is a function of the age group or the actual cohort. In other words, will the trend continue for those in the 40–49 and 50–59 age group in the future or persist within the 30–39 and 40–49 age group? Regardless, the results illustrate an important pattern in the age of avalanche fatalities, and revisiting this analysis within a few years will be worthwhile.

Our results indicate that the age of avalanche victims has increased over time since 1950, and can help inform us about how to tailor avalanche education to older, and perhaps more experienced, user groups, specifically backcountry tourers/sidecountry riders. Avalanche education providers might find it beneficial to provide courses that target older users to help update their avalanche skillset with new techniques or knowledge without spending too much time reviewing older material. Avalanche education providers would need to determine a specific curriculum for such populations based on local and regional interest and knowledge.

Future research should compare the age distribution of avalanche education participants to ages of avalanche victims. This would aid in understanding if a lack of, or lapse in, avalanche education (i.e. no avalanche education for many years), influences the trend of increasing age in avalanche victims.

5. Conclusions

A significant positive trend in the median age of avalanche fatalities occurs from 1950 to 2018 and from 1990 to 2018. When segregated by age groups, the 30–39 and 40–49 age groups demonstrate a positive trend in the number of avalanche fatalities from 1990 to 2018. While a combination of factors likely explains the increase in age of avalanche fatalities, we emphasize that the overall trend in the number of avalanche fatalities occurring every year currently remains flat.

Continued monitoring of the age of avalanche victims paired with the analysis we presented would allow us to determine whether these trends are tied to the age group or the cohort. Results could help inform avalanche forecasting and education efforts by identifying groups most vulnerable to avalanche accidents. This, in turn, helps the avalanche community target and apply appropriate messaging and educational techniques. For example, the widely used "Know Before You Go" program (www.kbyg.org) primarily targets youth. If current trends continue, an additional program primarily targeting an older age group may be warranted.

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