DEATH OF BACKCOUNTRY WINTER-SPORTS PRACTITIONERS IN AVALANCHES – A SYSTEMATIC REVIEW AND META-ANALYSIS OF PROPORTION OF DEATH CAUSES

Rong Guang[**,1], Lauri Ahonen[**, 1], Gerit Pfuhl[2,3], Benjamin Ultan Cowley[1,4,*]

[1] Faculty of Educational Sciences, University of Helsinki, Helsinki, Finland
[2] Department of Psychology, NTNU, Trondheim, Norway
[3] Center for Avalanche Research and Education, UiT the Arctic University of Norway, Tromsø, Norway
[4] Cognitive Science, Faculty of Arts, University of Helsinki, Finland

ABSTRACT: Avalanches are a significant natural hazard that can lead to fatal outcomes for winter-sports enthusiasts. Our study provides a comprehensive analysis of causes of death in avalanche accidents. By systematically synthesizing data from studies across different regions and languages we clarify the proportions of, and factors influencing, these causes of death. Our findings confirm that asphyxia is the most common cause of death in avalanches, followed by trauma and hypothermia. We also identify several factors that influence the proportions, such as the time period, data representativeness, forensic diagnostic procedures, and sample size. The results highlight the need for improved forensic diagnostic procedures and standardized reporting to enhance the reliability of future studies. By enhancing our understanding of causes of avalanche deaths, this study aims to inform better rescue strategies, safety protocols and preventive measures to protect winter-sports practitioners. The meta-analysis follows the PRISMA reporting guidelines and criteria; for an abstract in PRISMA style, please go to https://osf.io/8kj7u

Keywords: Avalanche, Cause of death, Asphyxia, Trauma, Hypothermia, Forensics

1. INTRODUCTION

Getting caught by an avalanche is a high-consequence event. Mortality is 1 to 4 (out of 5 victims), depending on the completeness of the burial and on the timeliness of rescue (Falk et al., 1994). Several different mechanisms of death may be considered, including mechanical trauma, hypothermia, and asphyxia (Stalsberg et al., 1989). In forensic autopsy an estimation of the cause of death is an essential item of evaluation. For avalanche victims, pathologists often consider burial duration, presence of injuries, core temperature, serum potassium levels, and/or airway patency to perform forensic differential diagnoses (Locher and Walpoth, 1996; Finnie, 2016; Brugger et al., 2009).

Although the literature reveals a stable proportion of these three pathologies (trauma, asphyxia, hypothermia) in the general population, the distinctive nature of avalanches as an accident scenario can greatly deviate from this pattern (Flobecker et al., 1993; Finnie, 2016; Rothschild, 2004). Different causes of avalanche deaths can be prevented with different procedures (Lane and McIntosh, 2023; Vargyas, 2016) and can lead towards different resuscitation pathways/resources such as cardiopulmonary bypass resuscitation for hypothermia (Locher and Walpoth, 1996; Pasquier et al., 2023). Clarifying the patterns of proportions of causes of avalanche death (PCAD) is important in reducing mortality. Hypothermia is consistently reported as a rare cause of death, whereas the proportions for the two other mechanisms are inconsistently reported. Previous review studies on the mechanisms for avalanche death have had several limitations in scope. Most reviews on this topic focused on discrepancies in the existing evidence, and, to our knowledge, none examined the pooled proportions, or compared the differential effects on the outcome of such factors as geographical region. However, indirect evidence on ***mechanisms*** of avalanche survival indicates that it is likely to find a consistent global ***distribution*** of PCAD. Based on the estimation of avalanche-survival probability curves first described by De Quervain sixty years ago (De Quervain, 1963), the survival probabilities of avalanche victims have four distinct phases in the survival curve.

This study attempts to aggregate the current evidence by structured search, and robustly estimate the distributions by meta-analysis. We furthermore account for methodological confounders and topographical and regional factors by follow-up subgroup analysis, which provide insights into how PCAD estimates vary. *This report is a synopsis of a longer work (under review at time of writing), and further details are linked throughout the text.*

2. METHODS

The meta-analysis follows the reporting guidelines and criteria set in Preferred Reporting Items for

*Corresponding author address:
B. Cowley, University of Helsinki
PL9, 00014, Helsinki, Finland;
tel: +358 50 3199 335;
email: ben.cowley@helsinki.fi
**RG and LA contributed equally to this article.

Systematic Reviews and Meta-Analyses (PRISMA 2020). All the statistical analyses were conducted using the R platform for statistical computing (R Core Team, 2014). The protocol was drafted before the literature search and registered at INPLASY (https://inplasy.com/inplasy-2024-3-0011/).

2.1 Search strategy to identify studies

We sought for literature which reported the number of avalanche fatalities along with forensic diagnoses of cause of avalanche death (or necessary information for computing these numbers), over at least two avalanche accidents. We had three outcomes including proportions of avalanche death by trauma (1), asphyxia (2) and hypothermia (3). For this purpose, we conducted a comprehensive literature search of the following electronic databases: MEDLINE (1950 to March 2024), Academic Search Complete (1948 to March 2024), SPORTDiscus (1982 to March 2024), Embase (1980 to March 2024), ERIC (Education Resources Information Center; 1965 to March 2024), Scopus (1970 to March 2024), the Cochrane database (1993 to March 2024), and SafetyLit (1870 to March 2024). We also screened all proceedings (1976 to 2023) from the International Snow Science Workshop (https://www.issw.net/).

We designed the search strategy to be inclusive, with precision to be improved by manual screening. To identify all relevant English and non-English articles, no language constraints were used – thus only non-English articles with English title and abstract were returned by this search. The search results were then refined by Boolean logic combinations of the terms. For search strategy for each database, see https://osf.io/bfvrt.

2.2 Eligibility criteria and study selection

The meta-analysis included descriptive and analytical studies involving the distribution of death causes (pathologies) due to fatal avalanche accidents.

The Inclusion Criteria were: descriptive and analytical studies that report PCAD.

The Exclusion Criteria were: (a) Studies based on a selected group of victims biasing the PCAD or making them impossible to obtain (e.g., studies focusing on traumatic death with other causes excluded; however, studies focusing on specific types of winter sports were kept, according to evidence that there is no difference in PCAD among major winter sports (Johnson et al., 2001)); (b) Studies with causes of avalanche death classified so that trauma, asphyxia, and hypothermia were not used nor could be inferred (e.g., a study with classification in no more detail than “avalanche death” or “brain death”); (c) Studies with no relevant statistics obtainable (e.g. a study summarising procedures to prevent avalanche trauma but without a report of statistics of death causes); (d) All relevant statistics were cited elsewhere (if the other source was not already in the study pool, then we searched for and included it); (e) Studies with a single accident or with sample size ≤3 (there are three common pathologies for avalanche deaths; PCAD can be tremendously biased in such cases); (f) Source and duration of data were already fully covered by an included study.

For English articles, two of us (R.G. and L.A.) screened the titles, and abstracts when available, of potentially relevant studies. The same reviewers independently assessed the full text based on the inclusion and exclusion criteria. Disagreements were resolved by consensus and arbitrated by consultation with a third reviewer (B.C.). We screened non-English articles (in German, French, Russian, Spanish, Japanese, and Norwegian) by consulting researchers who are native speakers or skilled readers of those languages.

After initial inclusion of studies from the database search, we checked the reference lists of all included studies for eligibility. Further, we consulted experts from Norway, Switzerland, and Germany for other eligible registries, reports or studies, focusing on non-English sources.

2.3 Risk of bias

We regard PCAD as a special case of prevalence study where the prevalence for each cause among fatalities was investigated. As such, two of us (R.G. and L.A.) independently assessed the risk of bias of the studies using an established tool for prevalence studies (Hoy et al., 2012). Disagreements were resolved by consensus and arbitrated by consultation with a third reviewer (B.C.). For more details on the tool and its use cases, see https://osf.io/su6cj.

2.4 Data extraction

Two of us (R.G. and L.A.) extracted the parameters from the studies, including data source, sample size, forensic diagnosis method, time period of the source data, study design, location/region of the accidents, number of victims who died due to each cause, number of each gender, age (mean or median), proportion of complete burial, mean/median burial time, and mean/median burial depth. A fatality was assigned with more than one cause of death if the authors have reported so. If two or more studies have source and duration of data partially (not fully) covered by each other, we tried to extract the non-overlapped subsets of statistics from the studies. When such subsets were not available, we recorded them as separate entries but marked the overlap condition (for sensitivity analysis).

2.5 Data synthesis

A generalized linear mixed model (GLMM) was used to estimate the pooled proportions for each cause of avalanche death, separately. A random-effects model was employed to generate pooled estimates of effect. The pooled proportion was expressed as proportion estimate with accompanying 95% confidence intervals (CIs). Overall pooled proportion estimates and the contribution of individual cohort for each cause of avalanche death were visualized as forest plots(Verhagen and Ferreira, 2014). For technical and theoretical details of data synthesis, go to https://osf.io/r6eyx, section 1.

2.6 Sensitivity analysis

To assess the robustness and stability of the syntheses, leave-one-out sensitivity analyses were performed for each cause. Other sensitivity analyses were conducted to deal with: *a.* studies with overlapping data (defined in *Data Extraction* section), *b.* studies with varying risk-of-bias, and *c.* studies potentially influenced by commercial interests. We did this by: *a.* keeping one single study with largest sample size for each overlapped group of studies, *b.* removing studies with high risk-of-bias rating, and *c.* removing studies potentially influenced by commercial connections, respectively.

2.7 Assessment of heterogeneity

Heterogeneity in meta-analysis refers to the variation in study outcomes between studies (Higgins et al., 2008). A pooled estimate with high heterogeneity indicates the estimate should be interpreted with caution. In the present study, we followed the method proposed by Borenstein (2023) and evaluated heterogeneity by combining Prediction interval (PI)(Prediction interval provides a range within which we can expect the effect size of a new study to fall with a certain level of confidence) and I^2(I^2 quantify the percentage of variation in the pooled proportion that was due to observed variation between studies rather than sampling error). For technical and theoretical details of the assessment, go to https://osf.io/r6eyx, section 2.

2.8 Subgroup analysis

Subgroup analysis was performed if there was unexplained high heterogeneity for the initial pooled proportion estimates, and if sufficient data was available. The primary focus was on data *time period*, *regions*, *sample sizes*, *data representativeness*, and *forensic diagnostic procedures*.

Technical and theoretical foundations for the categorizing of each subgroup is documented in https://osf.io/r6eyx, section 3.

2.9 Other methodological practices

The percentage we reported is percentage point. For example, we reported an increase of 4% when the proportion moved up from 40% to 44%. We documented the procedures in treating missing values and the tools we used for managing the study in https://osf.io/r6eyx, section 4 and 5.

3. RESULTS

3.1 Study selection

The flow of study selection is charted in Fig 1. Initial searches returned 1,451 records plus three registries. After duplicate removal, title and abstract review, full-text review, citation searching and expert consultation, we obtained 22 eligible studies, including two registers (Bruce Jamieson and Gauthier, 2010; Irwin et al., 2002), 19 published studies (d'Alnoncourt, 2017; Bilek and Würtl, 2011; Boyd et al., 2009; Christensen and Lacsina, 1999; Eliakis, 1974; Gross et al., 2021; Grossman et al., 1989; Hohlrieder et al., 2007; Johnson et al., 2001; Lugger and Unterdorfer, 1972; Martínez et al., 2022; McIntosh et al., 2007, 2019; Moroder et al., 2015; Oshiro and Murakami, 2022; Sheets et al., 2018; Stalsberg et al., 1989; Tough and Butt, 1993) and one unpublished study (Degawa, 2023). Twenty-seven studies were in English only and five were in German (Locher and Walpoth, 1996; Lugger and Unterdorfer, 1972; Markwalder, 1970; Geisenberger et al., 2015; Bilek and Würtl, 2011), three in French (d'Alnoncourt, 2017; Eliakis, 1974; Lapras, 1980), one in Norwegian (Geisenberger et al., 2015), and one having both English and Polish versions (Kobek et al., 2016). One of the included studies (Grossman et al., 1989) reported PCAD for three separate cohorts (USA, Canada and Europe), they were treated as three individual entries for the meta-analysis, resulting in 24 cohorts with an overall sample size of 1,550. A table of study characteristics are documented in https://osf.io/d7bq9.

Some studies (Christensen and Lacsina, 1999; Tough and Butt, 1993) focused on PCAD for victims doing specific types of sports, such as skiing. Since current evidence does not reveal different percentage of PCAD with these activities, we included them, but gave special attention to their influence on pooled estimates and heterogeneity during leave-one-out sensitivity analysis. In contrast, since existing evidence has established the association between burial duration (or extrication time) and depth with increasing risk of death by asphyxia

(Procter et al., 2016), studies selecting fatalities under the influence of these factors were excluded. Examples of excluded studies were documented in https://osf.io/kn8zf

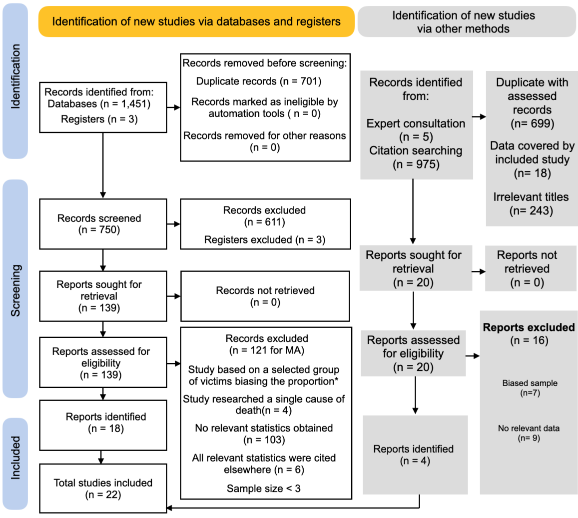


Figure 1: Flowchart of the study selection process.

3.2 Meta-analysis

The proportions in 24 cohorts (22 studies) were pooled. Results are shown in Fig 2 (a–c). Pooled proportion estimates are 21% (CI 16–25%) for trauma, 80% (CI 74–85%) for asphyxia, and 2% (CI 1–4%) for hypothermia. For trauma, the observed proportions vary widely (PI 11–36%), and 41% of that variance reflects variance in true proportions ($I^2 = 43\%$), indicating substantial heterogeneity. For asphyxia, the observed proportions vary widely (PI 54–93%), and 55% of that variance reflects variance in true proportions ($I^2 = 57\%$), also indicating substantial heterogeneity. For hypothermia, while the observed proportions vary moderately (PI 0–9%), 0% of that variance reflects variance in true proportions ($I^2 = 0\%$), indicating low heterogeneity.

3.2.1 Risk of bias

Most of the included studies have moderate risk of bias. The rating is illustrated in Fig 2 (d).

Notably, the items most often rated as 'high risk of bias' were: *case definition (F)* due to lack of forensic diagnostic criteria, followed by *mode of data collection (H)*, and *Numerators and denominators (J)*. For details on the justification for the rating of each item, see https://osf.io/su6cj.

3.2.2 Overlap

Five cohorts risk overlaps. Two used USA data from 1992 to 1999 (Johnson et al., 2001) and 1989 to 2006 (McIntosh et al., 2007), respectively. Here, overlap is not certain because they had different sources of data, and we hence included both in the original synthesis and removed the one (Johnson et al., 2001) fully covered by another in sensitivity analysis for overlaps. Three cohorts used Canadian data in 1980 to 1991 (Tough and Butt, 1993), 1979 to 1985 (Grossman et al., 1989), and 1984 to 2005 (Boyd et al., 2009). The overlap is again not certain (data sources are different). We included all in the original synthesis, and removed those with higher risk of bias (Grossman et al., 1989; Tough and Butt, 1993) for sensitivity analysis.

3.2.3 Sensitivity analysis

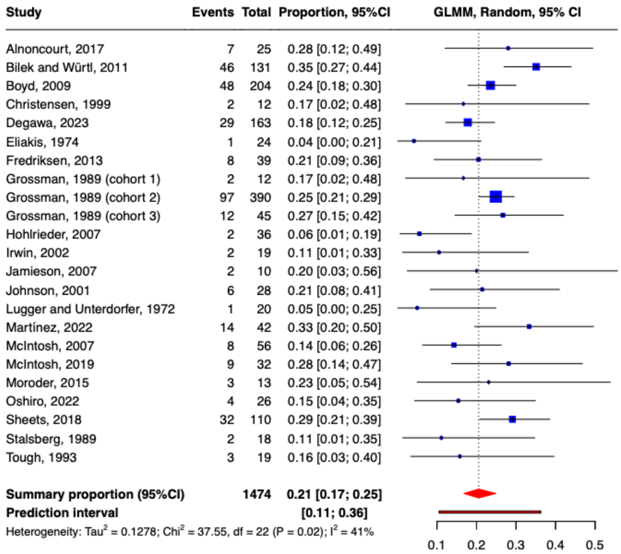
The results of the *leave-one-out*, *risk-of-bias*, and *overlap* sensitivity analyses indicated that the pooled effect estimate are stable. Removal of any single study (on https://osf.io/z68gw (see *a.*)), high risk of bias studies (https://osf.io/z68gw (*b.*)), or overlapping group of studies (https://osf.io/z68gw (*c.*)) altered the overall effect sizes by 0% to 2% in trauma, 0% to 3% in asphyxia estimates, and 0% in hypothermia estimate. None of these changes were considered substantial. Similarly, the changes in heterogeneity indicators across these analyses were tiny. We planned to give special attention to Christensen and Lacsina (1999) and Tough and Butt (1993) (see Sec 3.1). By removing either of them, pooled proportion estimates and 95%CI remained unchanged.

We performed a sensitivity analysis by removing studies having potential commercial connections (not registered beforehand, see https://osf.io/gnez3). Trivial changes in pooled proportions was detected for either trauma (22%, CI 18–26%, increased by 1% from 21%), asphyxia (78%, CI 72–84%, decreased by 2% from 80%), or hypothermia (2%, CI 1–4%, unchanged). Heterogeneity remained at the same level with overall estimates. See https://osf.io/z68gw (*d.*).

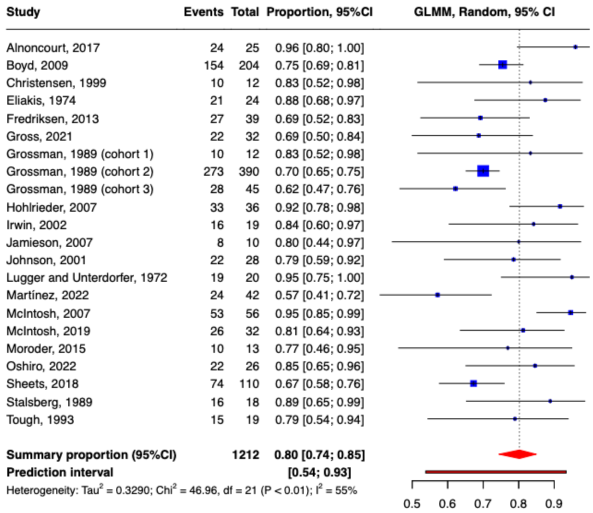
3.2.4 Subgroup analyses

To explore the substantial heterogeneity in the proportions of trauma and asphyxia, we performed subgroup analyses. For full results, see table documented in https://osf.io/rk4g5.

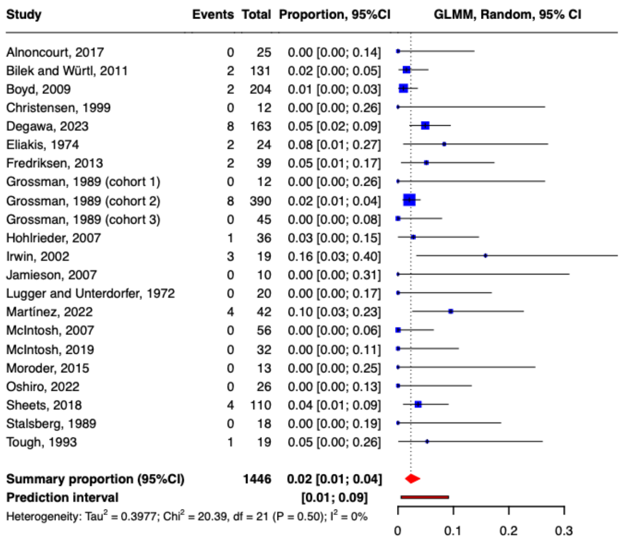
Time span. For trauma, the observed proportions in 1970–2000 and after-2000 subgroups vary to some extent (PI 19–28%, 16–46%, respectively). 0% of that variance reflect variances in true proportions ($I^2 = 0\%$ for both), indicating low heterogeneity. However, the observed proportions in across-2000 subgroup vary widely (PI 9–41%), and large portion of that variance reflects variances in true proportions ($I^2 = 59\%$), suggesting substantial heterogeneity. This high heterogeneity in across-2000 subgroup alone further validates the presence



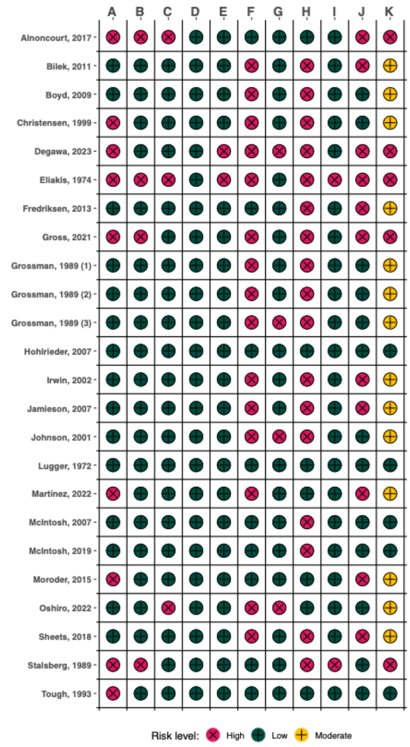
(a) Trauma



(b) Asphyxia



(c) Hypothermia



(d) Risk of bias

Figure 2: Overall cause-of-death proportions and individual-study risk of bias. A higher definition version can be found here https://osf.io/68xc5 *The size of blue squares visualizing point estimate of each study is adjusted by sample size. "Total" is sample size; "Events" is the number of corresponding causes. For columns names in (d): A.Representative target population; B.Sampling frame; C.Random selection; D.Non-response bias; E.Direct data collection from subjects; F.Case definition; G.Reliable and valid measurement; H. Mode of data collection; I. Length of the shortest prevalence period; J. Numerators and denominators; K.Summary*

of a temporal pattern. Compared to overall proportion estimate (21%), subgroup estimates increase to 23% for 1970–2000 subgroup and to 29% for after-2000 subgroup, and the between-subgroup difference approach statistical significance (p = 0.07), with low statistical power(13%).

For asphyxia, the observed proportions in 1970–2000 and after-2000 subgroups vary moderately (PI 67–76%, 58–94%, respectively), and small to moderate portion of that variance is attributable to variances in true proportions ($I^2 = 21\%$ and 15%, respectively), indicating low to moderate heterogeneity. Meanwhile, across-2000 subgroup has large dispersion in observed proportions (PI 25–98%), and a big portion of it can be attributable to variances in true proportions ($I^2 = 79\%$), pointing to substantial heterogeneity. This again validates the presence of a pattern due to time span. Compared to overall proportion estimate (80%), subgroup proportion estimates decrease to 78% for 1970–2000 subgroup and increase to 82% for after-2000 subgroup, and between-subgroup difference was significant(p = 0.05), but the statistical power is low (39%).

While p-value for Cochran Q was significant in overall estimate (p = 0.02 for trauma and <0.01 for asphyxia, see figure 2(a) and 2(b)), no difference is revealed for 1970–2000 and after-2000 subgroups, either for trauma (p =0.66 and 0.42) or asphyxia (p = 0.26 and 0.32), again suggesting the role of time periods in explaining heterogeneity. Consistent with this finding, for across-2000 subgroup, differences can be detected (p =0.22 and <0.01).

Regions. The findings show some regions have a meaningful degree of heterogeneity, while others not. And we cannot exclude that the heterogeneity is explained by data representativeness (see Sec 3.2.4). Find details in `https://osf.io/rp28s`.

Sample size. Reduced heterogeneity was observed in n≤30 subgroups for both trauma and asphyxia: their observed proportions vary in a narrow range (PI 11–22% and 79–90%, respectively) with nil amount of variance reflecting variance of true proportion ($I^2 = 0\%$ for both).

Hypothermia already shows low heterogeneity (high dispersion but none of the variance is from variances of true proportion) in overall proportion estimate. However, meta-analysis with extremely small pooled estimates (defined as <10%) often associates with low I^2 value regardless of the true heterogeneity (Migliavaca et al., 2022). Therefore, we continue to look for possible moderators of hypothermia to reduce its between-study variation. We observed in sample size >75 subgroup, though the proportion estimate remains unchanged from overall estimate, variations of observed proportions across studies reduced (PI for the subgroup estimate: 0.01–0.08, PI for overall estimate: 0–0.09) and dispersion no longer covers zero.

Data representativeness. Heterogeneity reduced in national representative subgroups for trauma (PI 16–28%, $I^2 = 0$) and asphyxia (PI 62–84%, $I^2 = 45\%$): the observed proportions vary moderately (PI 0.62–0.84) and 45% of it reflects variances in true proportions ($I^2 = 45\%$). In contrast, local representative subgroups' heterogeneity remained substantial for trauma (PI 8–37%, $I^2 = 34$) and asphyxia (PI 54–95%, $I^2 = 60\%$). This can be further evidenced by insignificant p of Cochran's Q within each national subgroup (0.46 for trauma; 0.14 for asphyxia) (approximately) significant p of Cochran's Q within each local subgroup (0.09 for trauma; <0.01 for asphyxia). Furthermore, p of Cochran's Q between local and national subgroups was significant (<0.01 for trauma; 0.02 for asphyxia).

Forensic diagnostic procedure. Heterogeneity reduced to low levels in full/strategic-autopsy subgroup for trauma (PI 4–25%, $I^2 = 2\%$) and asphyxia (PI 72–95%, $I^2 = 0\%$). In contrast, mixed-autopsy subgroup heterogeneity remained substantial for trauma (PI 15–40%, $I^2 = 45$) and asphyxia (PI 44–93%, $I^2 = 64\%$). This is supported by insignificant p of Cochran's Q within each full/strategic-autopsy subgroup (0.40 for trauma; 0.43 for asphyxia) and (approximately) significant p of Cochran's Q within each mixed-autopsy subgroup (0.07 for trauma; <0.01 for asphyxia). Furthermore, p of Cochran's Q between two subgroups was significant (0.02 for trauma; <0.01 for asphyxia).

Comparing to overall proportion estimates (21% (PI 11–36%) for trauma; 80% (54–93%) for asphyxia), the estimates from full/strategic autopsy subgroup shifted towards lower estimates noticeably (11% (PI 4–25%)) for trauma, and towards high estimates slightly for asphyxia (81% (PI 72–95%)).

4. DISSCUSSION

Our work presents a meta-analysis of evidence from 22 studies (24 cohorts) using an unbiased sampling framework. Our analyses suggest the following eight results. First, the highest proportion of avalanche deaths are due to asphyxia, 81% (CI 75–86%), followed by trauma, 20% (CI 16–25%), and then hypothermia, 2% (CI 1%–4%). Second, no individual study disproportionately affects estimated proportions, establishing the credibility of the results. Third, no evidence was found for a role of potential data overlaps or commercial connections on estimated proportions. Fourth, the observed proportions for death by trauma and asphyxia vary substantially across cohorts, pointing to the importance of exploring the reasons of these variations. Fifth, time period of accidents explained the between-study variations for trauma and asphyxia to a fair extent, and sample size explained the between-study variations for hypothermia to a fair extent. Sixth, for the period 1970 to 2000 the proportion of death by trauma is 23% (CI 20%–27%) and that by asphyxia is 72% (CI 68%–75%), whereas for the period after 2000 trauma is 29% (CI 21%–39%) and asphyxia 82% (CI 72%–88%); proportion of death by hypothermia is 2% (CI 1%–4%) for n>75 subgroup. Seventh, nationally representative data and full/strategic autopsy leading to the forensic diagnosis explained the between-study variations for trauma and asphyxia to a fair extent. Eighth, more than half of the included studies have high risk of bias, with a lack of reporting forensic diagnostic criteria being the most prevalent issue.

Our findings reveal that asphyxia is the predominant cause of avalanche deaths, occurring in 80% (CI 74-85%) of cases, which is significantly higher compared to its prevalence in general forensic autopsies (denominator is all-cause death rather than avalanche death) where asphyxial deaths account for only 4.9% (Gour et al., 2023) to 15.7% (Azmak, 2006). This substantial difference underscores the unique lethal risks posed by avalanche burial. Similarly, the proportion of trauma-related deaths in our study (21%, CI 17-25%) exceeds the 8% prevalence reported in general forensic contexts (WHO, 2022), highlighting the severe impact of physical injuries in avalanche incidents. The prevalence of hypothermia as a cause of death in avalanche cases (2%, CI 1-4%) remains relatively low, yet it is notably higher than in the general population, where it rarely exceeds 0.5% (Nikolić et al., 2010). These disparities emphasize the specific coldness hazards associated with avalanches.

Previous reviews have focused on either naïve pooling or narrative summary of proportions of causes of avalanche death.

Stalsberg et al. (1989) combined their finding on PCAD with four existing studies at the time (Lapras, 1980; Eliakis, 1974; Markwalder, 1970; Lugger and Unterdorfer, 1972) by naïve pooling (unweighted additions of cases from multiple studies), and concluded with 69.1% for asphyxia (including drowning), 2.9% for a combination of asphyxia and trauma, 13.2% for trauma, 3.7% for hypothermia, and 11% for cases with unknown causes. The results for trauma and asphyxia are less than the lower end of the 95% confidence intervals in our study. Notably, Stalsberg and colleagues' proportions can be heavily under-estimated, considering the 11% cases with unknown forensic diagnosis. Furthermore, due to the weakness of naïve pooling, small sample studies and methodologically-weaker outlier studies can be over-represented in the finding.

Pasquier et al. (2023) reported the minimum and maximum observed PCAD across the included studies on proportions of causes of avalanche death: 65-100% for asphyxia, 5–29% for trauma and 0–4% for hypothermia. In contrast, our finding determined a narrower 95% confidence interval for trauma and asphyxia. This reflects a less uncertain estimation that accounts for study variability, in addition to further confirming the reliability of our results. Our findings for hypothermia (CI 1-4%) align closely with their results and consolidate its lower prevalence as a cause of avalanche deaths.

For more detailed discussion of all results, see https://osf.io/56dyw

5. CONCLUSION

We re-affirm asphyxia as the predominant cause of avalanche deaths, followed by trauma, and then hypothermia. Time periods shifted the PCAD by trauma and asphyxia. A sample size > 75 is needed to estimate the proportion of hypothermia. Regional PCAD discrepancies can be reduced by using nationally representative samples. Without proper forensic diagnosis procedure, PCAD by trauma can be over-estimated. The results of meta-analysis build upon synthesizing and summarizing studies mostly with moderate to high risk of bias and should be interpreted with caution. Under-reporting of forensic diagnostic criteria is an important bottleneck to the reliability of evidence in the field.

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