FROM SALMONELLA TO SNOW: APPLYING LESSONS FROM PUBLIC HEALTH, FOOD SAFETY AND OUTBREAK INVESTIGATIONS IN AVALANCHE SAFETY RESEARCH

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ABSTRACT: Avalanche Safety and outbreak investigations & food safety are topics rarely considered alongside each other. However, at their core, both are focused on keeping the public safe(r) through assessing, analyzing, understanding, mitigating/controlling and communicating risk. Furthermore, whether it be avalanche or outbreak, these processes are happening in a highly complex world where practical, political, scientific, jurisdictional, economic, time pressure and communication factors shape the translation of research and knowledge into action to save lives.

This study is intended to examine the commonalities between food safety/outbreak investigations & avalanche safety from the perspective of an epidemiologist & researcher with experience in the avalanche safety realm, and examine some areas where approaches from public health could benefit the examination of avalanche safety research and translation from evidence into actions.

The realms of avalanche safety and outbreak investigations/food safety have a great deal in common. Whether it's snow or bacteria & viruses, nature presents a safety threat that ranges from individual harm to wider economic effects. An avalanche that blocks a major highway harms the economy much as an outbreak that closes restaurants and hospitalizes people. Neither pathogens nor avalanches are risks we can eliminate, only mitigate. We depend on gathering knowledge through experience, analysis and research to reduce the risks, and thus the wider burden of avalanches or pathogens on society. It is how we translate that knowledge into action & how effectively we communicate that determines how effectively we can mitigate that risk.

In public health (and medicine), this knowledge translation has been the subject of much research, and from that the concepts of evidence-based practice, evidence-informed practice, systematic reviews, data visualization and methods for communicating to various stakeholder groups have developed and continue to evolve. Systematic reviews in avalanche research have been published, but there is room to explore how other concepts and communications methods might be applied in the context of avalanche safety research.

KEYWORDS: Public Health; Evidence Based Practice, Food Safety, Evidence-Informed Practice

1. INTRODUCTION

At first glance, a huge unstable, sliding mass of snow and a microscopic foodborne pathogen may seem to have little in common. However, incidents the food safety (clusters/outbreaks/epidemics/pandemics) and snow safety realms (avalanches) have more in common than not, and are both the subject of a diverse range of research. The end goal of this research is to reduce the risks of these foodborne or avalanche incidents, and thus the direct and indirect costs.

However, in both realms, data from research is generally of little use if it cannot be translated into meaningful, economically and logistically feasible actions to reduce risk. Epidemiology and surveillance, it is sometimes said, are about "information for action" (Lussier et al 2012). Quality of data also matters – "garbage in, garbage out". Simply put, data needs to come from quality research, and translation into action depends on an understanding of how to correctly interpret and use data in risk mitigation. Whether pathogens or snow, this translation takes place in a dynamic world where politics, economics, logistics, human factors and the increasing role of social media all play a role.

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Almost certainly there is a significantly higher resource allocation to food safety research than avalanche research in Canada, given the near universal risk of direct impact from foodborne pathogens and subsequently higher profile of food safety incidents. It is possible to avoid snow, but not food. Large outbreaks tend to stay in the headlines longer than large avalanches, though there are many factors involved in the media attention span, including the involvement of deaths and vulnerable populations. Risk mitigation for foodborne pathogens has a much more public face – food safety messages on food labels, food recall notices, public outbreak notices, PSAs and facility closures (Government of Canada, 2026). Only a fraction of Canadians have likely interacted with an avalanche bulletin or been protected by on-site avalanche mitigation factors, but nearly every Canadian has seen a food label, recall, public safety announcement or news story regarding a food safety incident.

As such, there has been a longer history in food safety – and public health - of research and practice into assessing research and translating research into action. The concepts of research quality/assessment, evidence-based health practice and evidence-informed health practice and knowledge translation/exchange (KT/KE) are well established in food safety (FAO, 2017) – in grant applications, a KT/KE plan is generally a requirement. While these concepts are not unknown in snow safety – the creation of and improvements in the public avalanche bulletins, ATES and avalanche courses are excellent examples – there seem to be gaps and potential for improvement. The public health/food safety world, in particular, may provide some learnings that can help improve how assess (and improve) and translate information in the snow safety world.

2. FOOD SAFETY VS. SNOW SAFETY

In food safety, inspectors, investigators, epidemiologists, laboratories, researchers, policy makers, and (sometimes) politicians work together to battle a significant risk to the public. In Canada, it has been estimated that as many as 1 in 8 persons contract a foodborne illness each year; the cost of those illnesses – more than 4 million cases 238 deaths per year (Government of Canada, 2016) – is upwards of $3 billion CAD (Latuskie et al, 2019). The total cost of a single listeriosis outbreak in 2008 was estimated at almost $242 million CAD (Thomas et al, 2015).

Snow safety involves a team of avalanche practitioners, search & rescue team members, researchers, technicians, guides, policy makers and both governmental & non-governmental organizations. Avalanche incidents results in fewer deaths – an average of 10 per year – (Safaie et al, 2024) – but the cost of a highway closure alone can be more than $3 million CAD per hour (Government of Canada, 2025). There is little published research on the comprehensive economic burden of avalanche incidents, which includes the costs of search & rescue, medical & psychological treatment, lost days of work for victims, caregivers & incident responders due to physical & psychology injury and caregiving, damage to infrastructure & natural settings, interruptions to production processes, investigation costs and costs of resulting legal cases and mitigation requirements.

Avalanche (snow safety) hazard is defined by the likelihood of avalanches (sensitivity to triggers and spatial distribution) and the destructive avalanche size (Statham et al 2018). For food safety a biological hazard is a pathogen in a food that can cause adverse health effects in humans (Lammerding et al, 2000). This hazard can be introduced anywhere from farm to fork. Risk in avalanche parlance involves the interaction of hazard and exposure & vulnerability to hazard. In food safety, we exposure is considered in terms of the likelihood of exposure to the hazard and the amount of the pathogen a person is exposed to (Lammerding et al, 2000); risk is characterized by the interplay of exposure with dose-response/severity and/or type of adverse effects. Risk is considered along with the uncertainty in the estimate and the variability of influencing factors, as with risk in avalanches.

For instance, a person is more likely to be exposed to a pathogen that is widely distributed in terms of a food item or production environment; the ongoing outbreak of cyclosporiasis in the United States is a good example (CDC, 2026). However, a less widely distributed pathogen may result in a much more consequential outbreak because the infectious dose is much lower and the severity of illness much higher. The risk also may be higher in vulnerable populations such as the very young and elderly. The outbreak of Shiga Toxin Producing E. coli (STEC) O157 in Alberta in 2023 is an excellent example of higher risk (Snedeker, 2026) – the likelihood of exposure was high in the outbreak because the most likely contaminated food item was ground beef. Not only is ground beef a high-risk item for STEC, as STEC is naturally found in bovine digestive tracts, but ground beef is almost always sourced from tens of cattle; grinding spreads contamination from all surfaces throughout the beef. This beef was being used in a kitchen that served multiple daycare locations; daycares are a high-risk setting as they involve

an age-groups with poor hygiene and one of the highest risks of severe complications. The combination of STEC, ground beef and a daycare is the food safety equivalent of the perfect powder dump on a huge surface hoar layer, on a 38 degree open slope easily seen and accessed from a parking lot with unlimited parking spaces within easy driving distance of Calgary. On a bluebird day.

In snow safety, models and risk assessment strategies tend to be unique to countries or regions, with guidelines and standards in Canada, for instance, laid out in publications such as TASARM and OGRS, published by the Canadian Avalanche Association (CAA, 2024). For food safety, internationally the Codex Alimentarius Commission lays out risk assessment frameworks, though each national and sub-national jurisdiction may have their own frameworks as well (CAC, 1999).

In the end, the risk in snow and food is one that cannot be eliminated – the goal is mitigation via best practices within the limitations established by logistics, financial constraints, legislation, policy and politics. The question is what risk(s) we are willing to take, and the circumstances in which risk mitigation strategies should be societal and/or individual. In snow safety, the question of acceptable risk is addressed in a variety of extents by legislation/waivers, regulations like those enacted by Parks Canada for guardianship groups in avalanche terrain, scope of practice for guides, GIAT and ski resort guidelines for opening of at-risk terrain. In food safety, risk tolerance is written into documents such as guidelines for inspection of abattoirs and locations where food is sold and/or prepared, the regulations on the acceptable amount of pathogen contamination in food items, and cooking temperature requirements in restaurants for ground beef.

In food and snow safety the research into hazard, risk, risk analysis and risk mitigation has resulted in an ever-expanding knowledge base. This knowledge is quantitative, qualitative or a mix of the two, and the result of formal research, case studies or more informal, observational research or data gathering. To mitigate the risk of foodborne pathogens, this body of work must be assessed and translated into effective changes. These changes may be formal and professionally focused in terms of changing risk assessment protocols, legislation, guidelines and strategies, or more widely focused on changing behaviours in the general public.

The body of evidence in food safety is significantly larger than that of snow safety, given the larger amount of study and financial & government commitment to food safety research. This scale of research on food safety, under the wider umbrella of public health and medicine, has allowed for a more in-depth focus on methodologies for assessing and translating research of all kinds into action, whether than be policy, regulation or communication to the public. This process has existed, albeit less formally in snow safety science, as seen in the assessment of research to create the conceptual model of avalanche hazard and apply it to actual assessments, the development of public avalanche bulletins through assessment of research and interaction with public users through means such as surveys and focus groups.

Yet, in snow safety these efforts are still limited by factors such as the size of the avalanche research field in terms of research groups and finances, the reach to public groups and policy and decision makers, non-governmental and governmental. As with food safety, snow safety research depends on properly assessed, high-quality research and knowledge to make effective and appropriate decisions to ensure that knowledge translation to both professional and public realms is most effective and efficient. And so that limited funds, time and effort can be given to research and knowledge collection that is properly conducted and most useful for decision making.

In both realms, while wider concepts, models and guidelines are important, the key to risk reduction/mitigation strategies that are effective and efficient is context. Every setting is different, and developing the best mitigation strategy(s) requires an understanding of the unique factors inherent in different settings, locations, demographic groups, risk tolerances, educational backgrounds, regulatory structures, political and non-political influences. In snow safety, while risk assessment follows fairly set pathways, the ways it is translated to manage risk in a ski resort, heli-skiing, a national park and for communicating to recreating groups, for instance, varies widely.

Similarly in food safety, context is key – there are lot more regulations, but also a lot more nuance. Those who inspect and enforce regulations & investigate outbreaks face a variety of settings and are limited by legislation, the time they have for inspections & investigations, both preventive and reactive, and capacity in general. Just as ski patrollers and park safety specialists cannot monitor every square meter of avalanche terrain every minute, and pay attention to ever possible sign or clue of instability, nor can health inspectors monitor every square meter of every restaurant & market every day of the year.

These systems rely on humans, with human weaknesses and biases, as well as human decision making that involves assessing numerous, factors, guidelines, knowledge bases and understanding from experience. An avalanche technician with years of experience in a specific area can look at current reports and assessments and models, and combine that information with knowledge drawn from experience about how the snow, weather and human factors in that region combine to affect avalanche risk. Epidemiologists and public health inspectors/investigators/nurses rely on both research & surveillance/outbreak data and models in addition to knowledge from prior experiences with pathogens, risk factors and facilities. As with snow, with pathogens, past experience does not guarantee and identical current experience.

Yet, just as a heli-ski guide in morning assessment can decide on red (yellow) and green runs based both on objective and subjective facts, an epidemiologist can use objective facts and prior experience with outbreaks and pathogens to assess risk, relevant data and provide recommendations to decision makers. In practice, I've heard the subjective factor referred to as a "Scooby sense". Subjective knowledge has distinct limitations, but that "Scooby sense", when developed through good training, good mentorship and a good knowledge base, is very useful.

Do rangers/wardens/safety teams shut down an area likely to have very high avalanche risk, but then end up pushing more people into other areas, increasing the risk of avalanche triggers there? Does a public health inspector shut down a daycare with cases of a highly transmissible pathogen, forcing parents who cannot miss work to find either unsafe alternate care arrangements for sick, pathogen-shedding toddlers or sneaking their toddlers into other daycares. To (mis) use a saying about models, there are no right answers, only answers that are less wrong.

3. FROM PUBLIC HEALTH TO SNOW SAFETY – USEFUL CONCEPTS

There are a number of key concepts from knowledge translation and application in public health and food safety – and more widely in medicine and food science – that can be more widely explored in snow safety science.

The first is that of assessing the quality of research and evidence. In medicine and public health, we have moved towards structures to both assess the quality of research and rank the types of evidence in terms of rigor of methodology and the minimization of bias.

Ranking of research quality - hierarchies of evidence – are often illustrated in terms of evidence pyramids (Murad et al, 2016). While there is certainly disagreement and variations in the exact structure, rankings generally go from anecdotes/opinions/ideas up to systematic reviews and meta-analyses. Not all levels/study types in the typical evidence pyramid are applicable to every field.

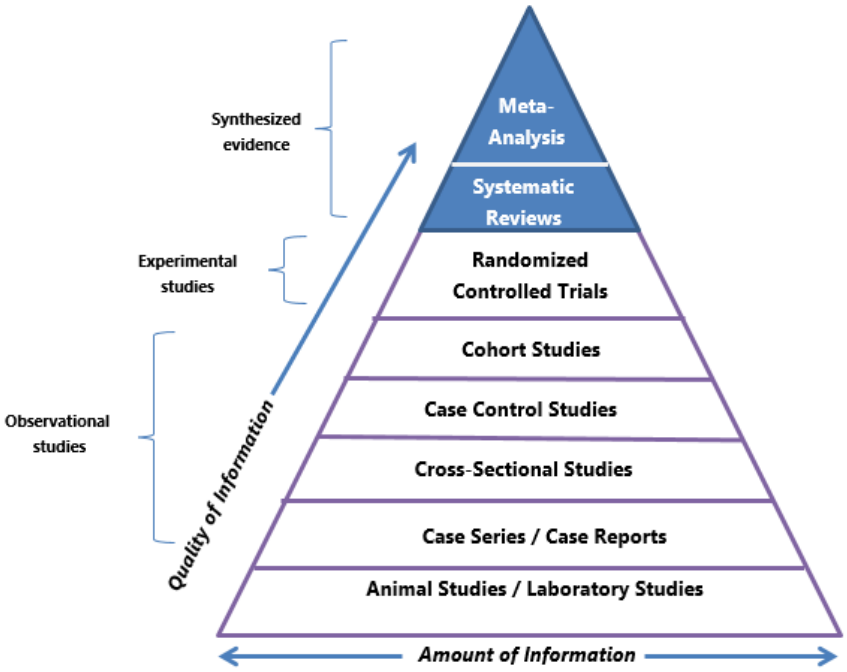

Figure 1. Hierarchy of Evidence (source: *Evidence-Based Practice: Study Design* from Duke University Medical Center Library & Archives. This work is licensed under a Creative Commons Attribution-ShareAlike 4.0 International License.)

In snow safety science, randomized controlled trials (RCTs) are not common. Evidence relies more on theoretical papers, observational studies, collections of observations and case studies. Given the far smaller populations to study in terms of avalanches, the diversity of research and the nature of avalanche research, this is not so much a flaw but a factor that has to be accounted for in assessment.

Even in outbreaks investigations, formal evidence for legal, regulatory and practical action, when applicable, is generally derived from case-control and cohort studies as well as laboratory testing and in-person inspections. For instance, if we have a cluster of cases of a particular pathogen, where most cases ate, for instance, at Vietnamese restaurants in a particular city and had dishes containing pork, there is already evidence for study, testing and some formal action.

With these limitations in mind, a generalized hierarchy of evidence pyramid is not likely applicable to snow science research. The scope of this paper is not to suggest a specific pyramid, as the author does not have the snow-safety expertise to do so, but to spark a conversation about quality in snow study research. What kind of research is done, and how do we quantify quality? Who has the expertise to assess the quality of snow safety research? Who should be sitting at the round table to discuss quality and assessment? There already examples of the latter in terms of the expert panels convened by the Wilderness Medical Society, after avalanche deaths and major incidents, as well as to create new avalanche safety tools.

A pyramid of evidence cannot work in isolation, as it does not adequately incorporate the quality of the evidence in a study. The World Health Organization summarizes this concept: “not all evidence is equally convincing. How convincing evidence is depends on what sorts of observations were made and how well they were made” (WHO, 2013).

In recent decades, there has been a push in many scientific fields to developing reporting guidelines for researchers that specify what must be included in a good quality research studies/research papers. Simply put, what must be in a methodology, study description, results and discussion for the reader to critically appraise the quality of the study and thus the usefulness of the evidence presented in informing further action. For many journals, these components are now condensed into guidelines that have been compiled in the equator network: ://www.equator-network.org/reporting-guidelines/

The diversity of relevant snow safety/avalanche research does not readily lead to a unified assessment/reporting tool, but there is potential exploring guidelines for assessing certain kinds of snow safety studies or evidence. These reporting tools not only guide research reporting, but allow effective assessment of existing evidence, help shape future studies and knowledge collection.

Additionally, reporting guidelines can help assess study quality for systematic reviews, another useful tool to assess quality and bring together research where individual studies may lack relative power to guide decisions. Both assessment guidelines and systematic reviews also are tools that can help bring research, evidence and knowledge out of the so-called grey-literature – data that is unpublished and often unavailable via public sources. Systematic reviews are studies that involve synthesis of evidence with explicitly systematic approaches to defining the research question, eligibility criteria, literature searches, collection of data and assessing bias and summarizing the data via meta-analyses. (Brignardello-Petersen et al 2025). Worldwide in medicine, systematic reviews are conducted under the auspices of the Cochrane Reviews. There are a few systematic reviews that have been published regarding snow safety related topics (examples include Sharma et al, 2025, Denissova et al, 2024, Boyd et al, 2011, Rong et al, 2025).

Where a formal systematic review may not feasible due to the variety of study type or breadth of topic, or an assessment of gaps in the topic literature, scoping reviews can be performed (Mak et al 2022). Scoping reviews focus on summarizing the literature rather than specifically assessing or appraising studies, though assessment can be a part. Such reviews may be more appropriate in snow study topics where there a paucity of formally published research and/or a wide variety of approaches to a question. In avalanche safety, scoping reviews already published include Romy et al, 2025, Hetland et al, 2024 and Eckert et al, 2024.

Within the scope of this paper, a suggestion can be made for continued conversation on reporting and assessment guidelines for specific types of snow safety studies and data gathering, and continued use of systematic reviews where relevant. Improved data quality and data collection is not only a step towards better evidence, but can improve the standing of snow/avalanche study research in attaining funding and attention. First, however, a valuable next step would be to start with a simple framework that can help those in the avalanche field assess research and knowledge gathering. Those directly and indirectly involved in the avalanche/snow safety profession range from experienced researchers to field technicians with extensive practical training but little to no research training to members of the general public at both ends of the spectrum. With this range in mind, what are the key points, concepts and factors that a reader should take into to account when reading a published or grey literature paper on a snow/avalanche safety subject? What should they consider if they are collecting data with research/evidence in mind?

The last pair of concepts that bridge research to real-world decisions are Evidence-Based Practice (EBP) and Evidence-Informed Practice (EIP). There is overlap and confusion in how these concepts are defined, but EBP is defined as “the conscientious, explicit and judicious use of current best evidence in making decisions about the care of individual patients. The practice of evidence-based medicine means integrating individual clinical expertise with the best available external clinical evidence from systematic research. By individual clinical expertise we mean the proficiency and judgment that individual clinicians acquire through clinical experience and clinical practice.” (Sackett et al, 1997).

This can be generalized beyond medicine to making decisions for action, based on 1) coming up with an appropriate, answerable (research question), 2) seeking evidence to answer the question, 3) assessing the quality, validity and applicability of the evidence, 4) taking the evaluated evidence from step 4 and combining it with professional expertise and context about the circumstances to answer the question/ & operationalize an intervention/change/improvement and 5) evaluating the effectiveness of the intervention (Straus et al, 2011).

Where EIP overlaps and expands upon EBP is that EIP often is open to a wider breadth of evidence, and in the medical context, it is patient centered (Woodbury et al, 2014). In the context of snow/avalanche safety, the wider view of EBP or EIP would seem to be good fit. EIP allows for a breadth of evidence, which is the reality of snow safety research. It also allows for centering the patient, or more broadly the person or population that will benefit from the change/intervention/improvement based on the evidence. In many levels of snow safety, context is important – e.g., what works to inform the general public versus a snow safety professional to applying improvements in practices to a ski resort versus a remote energy facility or groups of recreational backcountry users. EIP can even take into to ac-

count the complexities and knowledge for specific locations – Ski Resort A, or mountain range A. Taking the user focused approach towards making evidence-based change respects the experience & knowledge of the professionals and the specific context in which an intervention or change based on evidence will be operationalized, but without ignoring the value of the evidence since experience is not bullet (avalanche?) proof. Humans are fallible. In the food safety world, this cooperative approach is common – blending the experience of those with many years in the field with the evaluated evidence that can improve our understanding and help us to avoid making the same errors or mistakes. Science and knowledge are a continuum and constantly changing.

Again, the challenge is to integrate this approach into the many facets of avalanche/snow safety research. A first step or challenge could be to see how this approach has been used or can be applied to how changes have been made in snow safety in the past. Then to start thinking of how the EBP/EIP paradigm can continue and better be used together with effective assessment of the research to taking the evidence into action in the many contexts of real-world snow safety. What topics in snow/avalanche safety might be well adapted to increased use of this approach?

4. CONCLUSION

This study has illustrated how two very different fields of research – food safety and snow safety have many commonalities, based on a core of risk assessment and the need for risk mitigation in complex situations and contexts. The concepts used in food safety – and more widely in public health – including assessment of research quality, hierarchies of evidence, systematic reviews, scoping reviews and evidence-based practice/evidence-informed practice – can be adapted for (increasing) use in snow safety research. While no specific applications are suggested in this study, questions are raised to spark discussion among professionals as how this adaption and integration can work and who should be at the table in the process.

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