Temperature-Related Mortality in Countries with Cold Climates: a Mapping Review

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1. Introduction

Climate change impacts polar and subpolar regions disproportionately, with warming rates exceeding the global average several times (Ji et al., 2014; Rantanen et al., 2022). This trend will persist, intensifying permafrost thaw, wildfires, and pathogen habitat shifts that threaten human health in addition to direct temperature-related effects (Reis et al., 2022; Grigorieva, 2024). Despite expected reductions in cold-related mortality, rising heatwave frequency poses increasing health risks, complicating future temperature-related mortality projections (Gasparrini et al., 2017).

Despite particular interest due to widespread adaptation to extreme cold along with heightened vulnerability to rare heat stress, cold-climate regions remain understudied. Furthermore, no universal definition exists for them (Kochemasova et al., 2019), therefore we focused on countries with substantial Arctic and Subarctic territories to balance geographic specificity with evidence availability.

Cold-climate regions experience long, severe winters and brief summers with occasional hot periods, resulting in distinct exposure profiles. Limited heatwave preparedness and considerable spatial heterogeneity complicate evaluation of temperature-related mortality patterns, while sparse populations and scarce large urban centers constrain data availability and statistical power (Shaposhnikov & Revich, 2016).

To address these gaps, this study systematically maps evidence for temperature-mortality relationship in cold-climate countries. We selected a mapping review to identify the evidence base and research gaps, thereby informing future comprehensive investigations. Specifically, we aimed to:

- Identify empirical evidence on associations between non-optimal temperatures and mortality;
- Examine evidence concerning mortality impacts of extreme temperature events (heatwaves and cold waves);
- Assess commonly used methodological approaches and their applicability in cold-climate contexts;
- Explore geographic factors influencing all-cause and cause-specific temperature-related mortality in cold-climate countries;
- Investigate how demographic and socioeconomic heterogeneity modifies temperature-related mortality risks.

2. Data and Methods

We systematically searched Scopus, Web of Science, and PubMed using multi-stage screening to identify relevant studies on extreme weather events and temperature-mortality relationships. Included countries encompassed most Subarctic and Arctic regions by Köppen-Geiger classification: Finland, Iceland, Norway, Sweden, Canada, Russia, parts of the US (Alaska), and Denmark (Greenland).

Following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, we restricted inclusion to peer-reviewed articles published in 1990-2023 examining general populations in designated areas. Eligible studies assessed direct short-term impacts of non-optimal temperatures on natural, non-communicable mortality (excluding external and infectious causes).

Original quantitative estimates of temperature–mortality relationships were considered with any relevant metric used, including relative risks (RR), attributable fractions (AF), percentage mortality increases, or years of life lost (YLL), etc. Air pollution studies were included only if temperature effects were reported separately. For projection studies, baseline estimates for observed periods were assessed when available.

Search queries were based on the following expression: ("temperature*" OR "climat*" OR "heat*" OR “hot*" OR "thermal stress" OR “cold*") AND ("mortal*" OR "death*" OR "life expectancy" OR “years of life lost” OR “yll” OR "attributable fraction" OR "relative risk" OR “mmt”) AND ("Alaska" OR "Greenland" OR "Norway" OR "Finland" OR "Sweden" OR "Canada" OR "Russia" OR "Iceland” OR "Subarctic" OR "Arctic" OR "Polar" OR "Subpolar") AND (NOT animal*) AND (NOT plant*).

Additional sources were identified through backward citation tracking (using Citationchaser tool), studies that used shared databases with eligible papers included previously (if reported relevant findings), and expert recommendations.

After removing duplicated studies, titles and abstracts were screened with ASReview, followed by independent full-text reviews by two researchers, with a third resolving disagreements. Data were extracted to capture study details, spatial/temporal scope, research design, causes of death, and categorized studies as examining extreme events or general temperature-mortality relationships.

For extreme event studies, we recorded event definitions, counts, and excess mortality estimation approaches. For temperature-mortality studies, we extracted model specifications, temporal trends, and lag structures. Additional fields included exposure metrics, confounder adjustment (e.g., air pollution), mortality outcomes, uncertainty estimates, and subgroup-specific results (age, sex, socioeconomic status, geography) when available.

3. Preliminary findings

We retrieved 6,676 articles from Scopus (n=3,352), Web of Science (n=2,280), and PubMed (n=1,044). Following deduplication and screening, 114 underwent full-text review, resulting in 65 eligible studies. Backward citation tracking (n=16), shared databases (n=13), and expert recommendations (n=5) contributed 34 additional studies, totaling 99 included in our mapping review.

Geographic location of the selected studies

In this mapping review, Sweden (n = 35) and Canada (30) emerged as the most represented countries, followed by Russia (28), Finland (21), Norway (8), and Alaska (5), while no studies were identified for Greenland or Iceland. The most frequently investigated locations were Stockholm (24), Montreal (19), and Toronto (19). By Köppen-Geiger classification, most cities were located in Dfb zones (warm-summer humid continental, n=43), with limited representation of Dfc (subarctic, n=9) and study sites in polar climates (ET/EF) (Figure 1).

Climatic exposure in the selected studies

A total of 67 studies examining exposure-response relationships. Of these, 24 studies focused on heat, 6 on cold, and 37 on full spectrum. Among the latter, 15 reported greater risks associated with cold, 8 with heat, and 14 minimal/mixed differences. Most studies (n=54) employed time-series analyses (predominantly quasi-Poisson regressions), while 13 utilized case-crossover (conditional logistic regression) designs. Most studies (n=42) employed distributed lag models to model exposure-response relationship, others used splines without lags or polynomial/piecewise approximations. Lag periods were usually shorter for heat (up to 2 weeks) than cold (2-4 weeks) exposures.

When focusing on extreme temperature events, 40 studies were identified, including one examining only cold spells, 22 focusing on heatwaves, and 17 addressing both. Among these, 5 reported higher mortality risks from heatwaves, 8 from cold spells, and 4 yielded inconclusive results. Direct comparisons were limited by the heterogeneity in event definitions of heat waves and cold spells. Most studies defined heatwaves or cold spells as consecutive days exceeding temperature percentiles, commonly the 97th/3rd percentile (n=15), 98th/2nd percentile (n=7), or 95th/5th percentile (n=3), while 6 used absolute thresholds, and 6 defined extreme events arbitrarily. Evidence suggested that higher thresholds were associated with greater mortality risks (Guo et al., 2017), while the impact of duration effects remained uncertain (Oudin Åström et al., 2020). Methodologically, 7 studies employed case-crossover designs, and 33 utilized time-series approaches.

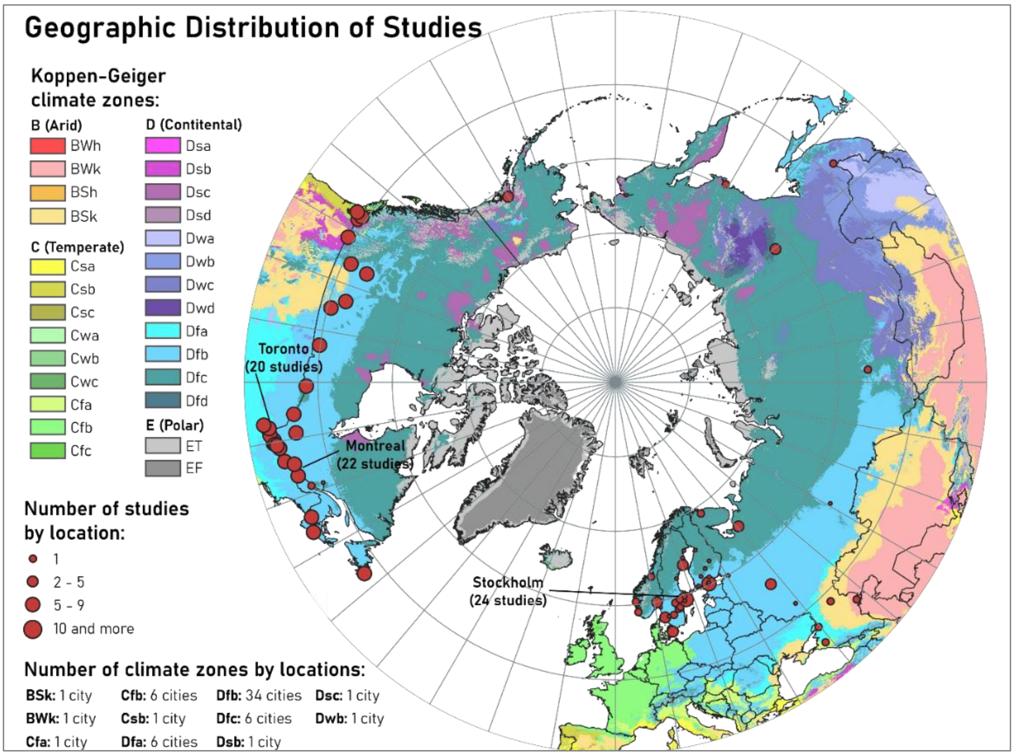

Figure 1. Total number of studies by geographic locations from studies included in the review
*Note: Where a single study covers multiple events or locations, these have been separated out into individual entries on the map (where possible).

Mortality outcomes and temperature-related mortality

A total of 45 studies reported all-cause mortality, 44 examined natural or non-accidental mortality (ICD-10: A00–R99). The most frequently analyzed categories were circulatory (I00–I99, n=23) and respiratory diseases (J00–J99, n=31), followed by neoplasms (C00-C99, n=6), mental/behavioral disorders (F00-F99, n=4), and nervous system diseases (G00-G99, n=4). Within circulatory, ischemic heart disease (IHD, I20–I25) was examined in 25 studies and cerebrovascular diseases (I60–I69) in 24, while respiratory analyses included COPD (J40–J47, n=4).

Cause-specific comparisons showed that during heat exposure, 10 studies reported higher respiratory than cardiovascular risks, whereas 5 found the reverse. Under cold exposure, 8 studies observed higher cardiovascular and 1 higher respiratory risk. Among cardiovascular causes, heat was more strongly associated with cerebrovascular mortality (n=7), while cold was more strongly associated with ischaemic heart disease (n=3).

Sociodemographic vulnerability to temperature-related mortality risks

Among 54 studies providing separate analyses for different age groups, 22 examined individuals aged 65+ and 15 those aged 75+, with nearly all confirming significantly higher mortality risks among older adults. Sex-specific analyses (n=23) generally showed no significant differences: 5 reported higher risks for women and 8 for men. Studies on place of death (n=4) consistently found higher in-hospital mortality compared to risks of death at home during heatwaves. Investigations of pre-existing conditions (n=5) showed elevated mortality among individuals with chronic diseases, particularly mental disorders.

4. Discussion

Our review identified substantial evidence on temperature-mortality relationships in regions with cold climates, with most studies reporting predominant cold-related mortality risks. However, pronounced geographic heterogeneity was observed, with risk estimates varying widely across climatic zones, and distinctive patterns documented by cause of death and demographic subgroup.

Comparative assessment remains limited by methodological inconsistencies, including variability in model specifications, including lag structures, and covariate selection for exposure-response analyses, as well as inconsistent definitions of extreme events. Despite elevated cold-related mortality risks, literature disproportionately emphasized on heat, likely reflecting acute heatwave mortality spikes versus the more prolonged, less noticeable effects of cold exposure. This creates a knowledge gap for regions projected to maintain substantial cold-related mortality.

Geographic bias was noted: most research originates from milder regions, leaving polar climates (ET/EF) entirely unrepresented and evidence from cities in circumpolar region remain sparse. Location-specific data revealed notable heterogeneity, with cities in cold arid areas (BWk/BSk climates) showing higher heatwave risks, while subarctic cities with minimal heat exposure experienced low heat-related risks. This underscores the need for more detailed consideration of additional geographic details, such as the differences between oceanic and extremely continental climates (Revich & Shaposhnikov, 2022).

Cause-specific analyses confirmed varying temperature effects: both cardiovascular and respiratory diseases showed increased heatwave risks, consistent with prior evidence (Alahmad et al., 2023). Conversely, cardiovascular risks exceeded respiratory under cold exposure, contradicting global patterns (Ryti et al., 2016; Fan et al., 2023). Whether this reflects severe subzero temperature effects on cardiovascular systems or simple statistical variation remains unclear. Among cardiovascular causes, IHD mortality risks were higher during cold exposure while stroke risks increased during heatwaves. Temperature triggers multiple pathways, each resulting in varied outcomes with no single pattern, thus both investigated cardiovascular causes of death experience elevated risks with varying proportions under different temperature exposures. Many studies lacked statistical power for comprehensive assessment of other causes (renal, nervous system diseases), representing a notable gap.

Sociodemographic analyses confirmed greater susceptibility of older adults to both heat and cold exposures, while sex-specific patterns remained inconclusive except limited evidence of occupational risks among working-age males. Socioeconomic effects were examined infrequently, though several studies linked deprivation with increased risks (Oudin Åström et al., 2020). Critically, no studies quantitatively evaluated protective effects of adaptive measures (household heating, insulation) despite early research suggesting substantial mitigation (Donaldson et al., 1998).

5. Conclusions

This systematic mapping review synthesized temperature-mortality evidence from countries with cold climates, identifying substantial research together with numerous gaps. While geographic scope was determined at the country-level rather than by uniform climatic criteria, geographic bias toward temperate zones emerged, leaving polar areas understudied. Other gaps included methodological inconsistency that constrained comparability between studies; disproportionate research emphasis on heat versus cold-related mortality risks; and absence of quantitative assessments of adaptive measures to cold. Nevertheless, our findings enhance understanding of temperature-mortality relationships in cold climates and establish foundations for future quantitative assessments and evidence-based adaptation strategies.

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