Cold Weather and Cardiac Arrest in 4 Seasons: Helsinki, Finland, 1997–2018

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See also Levy and Hernández, p. 48.

Objectives. To test the a priori hypothesis that out-of-hospital cardiac arrest (OHCA) is associated with cold weather during all seasons, not only during the winter.

Methods. We applied a case–crossover design to all cases of nontraumatic OHCA in Helsinki, Finland, over 22 years: 1997 to 2018. We statistically defined cold weather for each case and season, and applied conditional logistic regression with 2 complementary models a priori according to the season of death.

Results. There was an association between cold weather and OHCA during all seasons, not only during the winter. Each additional cold day increased the odds of OHCA by 7% (95% confidence interval [CI] = 4%, 10%), with similar strength of association during the autumn (6%; 95% CI = 0%, 12%), winter (6%; 95% CI = 1%, 12%), spring (8%; 95% CI = 2%, 14%), and summer (7%; 95% CI = 0%, 15%).

Conclusions. Cold weather, defined according to season, increased the odds of OHCA during all seasons in similar quantity.

Public Health Implications. Early warning systems and cold weather plans focus implicitly on the winter season. This may lead to incomplete measures in reducing excess mortality related to cold weather. (*Am J Public Health*. 2022;112(1):107–115. https://doi.org/10.2105/AJPH.2021.306549)

Substantial epidemiological evidence shows that mortality and morbidity from various causes is associated with cold weather.[1,2] According to one study in 383 locations around the world, 7.3% of total mortality was attributed to temperatures below the local optimum.[1] According to another study, the majority of the world's population lives in areas that could benefit from cold weather plans.[3] Organizations such as Public Health England and the National Institute for Health and Care Excellence have for years produced guidelines aimed at reducing weather-related excess winter mortality.[4] Patients with cardiovascular diseases are considered particularly vulnerable,[4–7] and consistent epidemiological evidence shows that cold weather increases the risk of acute myocardial infarction,[8] out-of-hospital cardiac arrest (OHCA),[9–14] and sudden cardiac death.[15,16]

The current early warning systems and cold weather plans focus implicitly on the winter season,[4,17] but what if unseasonably cold weather induces adverse health effects during the warm season too? Recent epidemiological evidence indicates that most of the temperature-related mortality burden is attributed to moderately low temperatures.[1] This can be explained by the high proportion of moderately cold days in a year. Some studies report similar findings for OHCA.[18] These studies do not elaborate on the seasonal context in which the temperatures occur. Another way of looking at the same phenomenon is to define cold weather in the context of the seasonal frequency distribution of daily temperatures, which produces indicators of unusually cold weather for the time and place.[15,16] The concept of the summer cold spell may seem counterintuitive, but meaningful physiological reactions take place at moderately low temperatures.[19] Consistent experimental evidence shows cardiovascular aggravation during short-term exposure to air that is just a few degrees below thermoneutrality (23°C to 26°C air for a resting, naked human).[19–24] Evidence from studies investigating acclimatization indicate that cardiovascular responses to moderate cold exposures may be even stronger during the warm season, when the preceding acclimatization to heat is disrupted.[25–30] Thermal exposures in humans are largely determined by clothing, microclimate, and behavioral adaptation, which, together with external factors such as indoor heating, are not tuned toward cold weather in the warm season.[25,31]

We hypothesized that there is an association between cold weather and OHCA during all seasons, not only during the winter. Demonstrating this could have implications beyond OHCA prevention by bringing attention to the fact that if early warning systems and cold weather plans are confined to the winter season, the problem is addressed only partially.

METHODS

We conducted a population-based epidemiological study, applying a case–crossover design on a prospective OHCA registry, to assess the relation between season-specific cold weather and OHCA in Helsinki, Finland, over 22 years: 1997 to 2018. We applied STROBE guidelines[32] in reporting the results.

Study Population

All consecutive cases of OHCA from the Helsinki Cardiac Arrest Registry who were aged 18 years or older and whose primary cause of cardiac arrest was medical according to the 2015 update of the Utstein Resuscitation Registry Templates for OHCA[33] were included in this study. We limited the study population to adults under the assumption of heterogeneity of OHCA etiology in the neonates, children, and adolescents. The Helsinki Cardiac Arrest Registry has been compiled following a prospective study protocol, and it includes all cases of witnessed and nonwitnessed sudden OHCAs, regardless of whether resuscitation was attempted, in the city of Helsinki, Finland, from 1997 onward.[34,35] Each entry to the registry is made by a specialist physician or emergency medical services field supervisor. Quality control is managed by a specialist physician on a daily basis. In Finland, practically all cases of both witnessed and nonwitnessed cardiac arrests are reported to the emergency dispatch 112, and, therefore, selection bias is minimal. This provides a good opportunity to cover the entire breadth of OHCA cases in the general population.

For the purposes of this study, we revalidated the medical versus nonmedical causes of OHCA by cross-examining data in various data fields, including the event descriptions and findings of coronary angiography and autopsy, where available. The division between medical and nonmedical causes of OHCA can be considered robust. Cases were excluded if the most likely primary cause of OHCA was trauma, drug overdose, drowning, electrocution, asphyxia, or not recorded.[33] We also excluded cases that had missing data on the location of the cardiac arrest (n = 8).

Exposure Assessment

We obtained a set of 10-kilometer-by-10-kilometer grids of daily minimum, mean, and maximum temperatures in Finland from 1961 to 2018 from the Finnish Meteorological Institute. The grids had been produced from daily weather station data by using a Kriging interpolation method, including altitude and the percentage of lake or sea as auxiliary variables.[36] We organized the weather data into a geographic information system (GIS) database, and we used GIS-based functions to extract continuous time-series of daily temperatures at each of the 8 rescue stations in Helsinki over the study years. We defined for each case a 7-day hazard period, including the day of OHCA and 6 preceding days.[15,16] We defined for each case 21 reference periods consisting of the same calendar days of the other study years. Each case of OHCA took place in the service area of a specific rescue station, and we extracted the daily temperature values for the dates of the hazard period and 21 reference periods from the continuous time-series of the pertinent rescue station. Using these daily temperature values, we calculated frequency distributions of daily temperatures for each case. Cold day was defined as a day with daily mean temperature below the fifth percentile of the individual frequency distribution. This method identifies days that are unusually cold in a given time and place.[15,16] We selected cold weather events of predefined durations a priori as predictors in the statistical models: (1) 1 or more, 2 or more, 3 or more, or 4 or more consecutive cold days during the hazard period, with each minimum duration serving as a dichotomic predictor in a separate model, and (2) the absolute number of cold days during the hazard period as a continuous variable, with values from 0 to 7, without the requirement for consecutive order.

Statistical Analyses

The statistical inference was based on a comparison of the occurrence of predefined cold weather during the hazard and reference periods. We estimated odds ratios (ORs) as the measure of effect, including 95% confidence intervals (95% CIs), by conditional logistic regression with PROC PHREG in SAS version 9.4 (SAS Institute, Cary, NC), applying the discrete logistic model and forming a stratum for each case identification number. We formed an indicator variable consisting of 5- to 6-year intervals over the study period to adjust for long time trends in the occurrence of cold spells. Season, month, day of the week, and holidays were controlled by design. The design also adjusts for time-invariable factors such as individual characteristics of the cases or changes in them over time.[16] The decision of not including air pollutants in the models was made a priori, because air pollutants are treated as intermediate variables in the pathway from cold weather to OHCA.[37] If part of the effects of cold weather was mediated by increased air pollution levels, adjustment for air pollution would lead to an underestimation of the overall effects of cold weather.

We conducted stratified analyses according to the season of OHCA. We used calendar time to define the 4 seasons (autumn: September to November; winter: December to February; spring: March to May; summer: June to August). We also conducted stratified analyses according to an increasing number of consecutive cold days during the hazard period (≥ 1, ≥ 2, ≥ 3, ≥ 4). We performed subgroup analyses by age (18–64, ≥ 65 years) and sex.

We performed several sensitivity analyses to assess the robustness of results. First, we repeated the main analyses with minimum and maximum temperatures. Second, we extended the study period of the weather data and, consequently, the length of the individual frequency distributions of daily temperatures from 22 years to 38 years and 57 years. Third, we excluded the time trend adjustment from the models. Fourth, we divided the data into four 5- to 6-year periods, in which the reference periods for each case were limited to the same years of the respective period (i.e., a case in year 2015 would have reference periods from the years 2014, 2016, 2017, and 2018). Fifth, we repeated the main analyses for all adult cases, irrespective of the etiology of OHCA. Sixth, we excluded subsequent OHCAs in individuals with multiple OHCAs during the study period, and repeated the main analyses with the first OHCAs. Seventh, we excluded from the analyses the individuals with more than 1 OHCA during the study period.

We conducted all analyses with SAS version 9.4.

RESULTS

A total of 5685 adult cases of nontraumatic OHCA occurred in the city of Helsinki during the 22-year study period. After we excluded the 8 cases with missing location information, 5677 cases were included in the study. A flow diagram of the screening and selection process of eligible cases is provided in Figure A (available as a supplement to the online version of this article at http://www.ajph.org). Geospatial distribution of the cases in the 8 rescue station service areas is presented in Figure B (available as a supplement to the online version of this article at http://www.ajph.org).

Table 1 shows characteristics of the study population, with no marked differences in the incidence of OHCA by season or year. The 5th-percentile thresholds for seasonal cold days ranged from 11.6°C in summer to −15.9°C in winter. Table 2 shows descriptive statistics of daily temperatures in Helsinki during the study period of 1997 to 2018. These data were based on the time-series at the centrally located Käpylä rescue station. There were no major differences in temperature statistics between the other rescue stations.

Conditional logistic regression showed positive associations between cold weather and OHCA. Compared with weeks without cold days, the odds of OHCA increased 15% (95% CI = 7%, 24%) if there was at least 1 cold day during the hazard period. Each additional cold day during the hazard period increased the odds by 7% (95% CI = 4%, 10%), with similar strength of association during autumn (OR = 1.06; 95% CI = 1.00, 1.12), winter (OR = 1.06; 95% CI = 1.01, 1.12), spring (OR = 1.08; 95% CI = 1.02, 1.14), and summer (OR = 1.07; 95% CI = 1.00, 1.15). Table 3 shows the ORs and 95% CIs for the associations between 1 or more, 2 or more, 3 or more, and 4 or more consecutive cold days during the hazard period and the odds of OHCA in each season and all seasons combined.

Table 4 shows the results for the subgroup analyses by age and sex. The overall effect estimates were positive for all subgroups, with no notable effect modification by age or sex when all seasons were analyzed together. Subgroup analyses stratified by season suggested seasonal differences in vulnerability, however, but there was heterogeneity in the estimates.

The extensive sensitivity analyses showed that the results of the study were robust under changes in modeling choices and underlying assumptions (full disclosure in Tables A, B, and

TABLE 1— **Characteristics of the Study Population of Out-of-Hospital Cardiac Arrest Cases: Helsinki, Finland, 1997–2018**

Characteristic	Autumn, No. (%)	Winter, No. (%)	Spring, No. (%)	Summer, No. (%)	All Seasons, No. (%)
All	1359 (100.0)	1575 (100.0)	1478 (100.0)	1265 (100.0)	5677 (100.0)
Sex					
Male	893 (65.7)	1018 (64.6)	983 (66.5)	811 (64.1)	3705 (65.3)
Female	466 (34.3)	557 (35.4)	495 (33.5)	454 (35.9)	1972 (34.7)
Age, y					
18–64	535 (39.4)	558 (35.4)	612 (41.4)	532 (42.1)	2237 (39.4)
≥ 65	824 (60.6)	1017 (64.6)	866 (58.6)	733 (57.9)	3440 (60.6)
Presumed etiology					
Cardiac	935 (68.8)	1074 (68.2)	992 (67.1)	838 (66.2)	3839 (67.6)
Noncardiac	424 (31.2)	501 (31.8)	486 (32.9)	427 (33.8)	1838 (32.4)
Primary rhythm					
VF or VT	499 (36.7)	495 (31.4)	481 (32.5)	377 (29.8)	1852 (32.6)
ASY or PEA	852 (62.7)	1075 (68.3)	991 (67.1)	883 (69.8)	3801 (67.0)
Not recorded	8 (0.6)	5 (0.3)	6 (0.4)	5 (0.4)	24 (0.4)
Decade					
1997–2007	690 (50.8)	827 (52.5)	740 (50.1)	655 (51.8)	2912 (51.3)
2008–2018	669 (49.2)	748 (47.5)	738 (49.9)	610 (48.2)	2765 (48.7)

Note. ASY = asystole; OHCA = out-of-hospital cardiac arrest; PEA = pulseless electrical activity; VF = ventricular fibrillation; VT = ventricular tachycardia.

C, available as supplements to the online version of this article at http://www.ajph.org).

DISCUSSION

This case–crossover study showed positive associations between unseasonably cold weather and OHCA during all seasons, not just during winter. The findings are consistent with our hypothesis and robust under the several sensitivity analyses. Each additional cold day preceding the OHCA increased the odds of OHCA by approximately 7%, with similar strength of association during the autumn, winter, spring, and summer. Similar exposure–response patterns were produced by both analytical approaches. All investigated subgroups displayed increased odds of OHCA associated with unseasonably cold weather. Season-specific subgroup analyses suggested seasonal differences in vulnerability to the weather events, but there was heterogeneity in the estimates.

TABLE 2— **Descriptive Statistics of Daily Temperatures, in Degrees Celsius, at the Centrally Located Käpylä Rescue Station: Helsinki, Finland, 1997–2018**

Statistic	Autumn, °C	Winter, °C	Spring, °C	Summer, °C	All Seasons, °C
Mean (SD)	6.6 (5.7)	−3.5 (6.1)	4.7 (6.5)	16.8 (3.3)	6.2 (9.1)
Range	42.8	41.3	51.0	32.8	62.8
Lowest minimum	−18.3	−30.6	−21.7	0.6	−30.6
Highest maximum	24.5	10.7	29.3	32.2	32.2
5th percentile threshold	−3.3	−15.9	−6.4	11.6	−9.2
Quartile					
Q1	2.7	−6.7	0.6	14.6	0.0
Q2	6.8	−2.1	4.4	16.6	5.9
Q3	11.1	0.9	9.5	18.9	13.9

TABLE 3— Associations Between Number of Cold Days During the Hazard Period and the Odds of Out-of-Hospital Cardiac Arrest by Season: Helsinki, Finland, 1997–2018

Days	Autumn, OR (95% CI)	Winter, OR (95% CI)	Spring, OR (95% CI)	Summer, OR (95% CI)	All Seasons, OR (95% CI)
≥ 1[a]	1.12 (0.96, 1.30)	1.16 (1.01, 1.33)	1.20 (1.05, 1.39)	1.12 (0.97, 1.30)	1.15 (1.07, 1.24)
≥ 2	1.15 (0.95, 1.38)	1.13 (0.93, 1.37)	1.14 (0.95, 1.37)	1.21 (0.98, 1.49)	1.16 (1.05, 1.27)
≥ 3	1.15 (0.86, 1.52)	1.31 (1.01, 1.71)	1.12 (0.85, 1.47)	1.53 (1.11, 2.09)	1.25 (1.09, 1.44)
≥ 4	1.67 (1.08, 2.59)	1.42 (1.02, 1.98)	1.39 (0.85, 2.25)	1.43 (0.61, 3.39)	1.47 (1.18, 1.84)
Per day[b]	1.06 (1.00, 1.12)	1.06 (1.01, 1.12)	1.08 (1.02, 1.14)	1.07 (1.00, 1.15)	1.07 (1.04, 1.10)

Note. CI = confidence interval; OR = odds ratio.

[a] Estimates for the ≥ 1-, ≥ 2-, ≥ 3-, and ≥ 4-day durations were derived by using the respective number of consecutive seasonally defined cold days as a dichotomic predictor, and each model was run separately.

[b] Estimates for odds per each additional cold day were derived by using the absolute number of seasonally defined cold days (0–7) as a continuous predictor in the model.

Validity of Results

The study had several limitations. A limitation of the study was the general difficulty of determining the primary cause of OHCA from prehospital records.[33] We used the Helsinki Cardiac Arrest Registry, which is prospective by nature[34,35] and includes detailed individual information on all consecutive cases of OHCA in the area in Utstein-compliant format.[33] Each entry to the registry is made right after the OHCA, minimizing recall bias. We manually cross-validated data by using event descriptions and the findings of medico-legal autopsy and coronary angiography, minimizing selection bias. The diagnostic criteria are homogenic throughout the registry. Another limitation of the study was that it was not possible to be certain that all cases had spent time at the service areas where they experienced the OHCA. Widespread exposure misclassification is not likely and would not contribute toward coherence of the effect estimates seen here. Another limitation of the study was the relatively small number of OHCA cases in Helsinki across the 22-year period, which introduced statistical heterogeneity in the estimates. We conducted the main analyses in 2 complementary ways, and these results together displayed a coherent pattern of increasing odds of OHCA during cold weather in all seasons.

A strength of the study was the design, which examined the temperatures in the seasonal context in which they occurred. This provided a complementary perspective to the phenomenon of adverse health effects attributable to moderately low temperatures.[1] Another strength was the season-specific definition of cold weather. As opposed to the standard definition of cold spell,[2] which implicitly captures cold spells during the coldest months of the year, our method

TABLE 4— Associations Between an Increasing Number of Cold Days During the Hazard Period and the Odds of Out-of-Hospital Cardiac Arrest in Different Sex and Age Groups by Season: Helsinki, Finland, 1997–2018

Subgroup	Autumn, OR (95% CI)	Winter, OR (95% CI)	Spring, OR (95% CI)	Summer, OR (95% CI)	All Seasons,[a] OR (95% CI)
Age 18–64 y	1.08 (0.99, 1.18)	1.02 (0.93, 1.11)	1.05 (0.96, 1.15)	1.13 (1.01, 1.26)	1.06 (1.02, 1.12)
Age ≥ 65 y	1.05 (0.97, 1.13)	1.09 (1.02, 1.16)	1.10 (1.03, 1.18)	1.03 (0.94, 1.13)	1.07 (1.03, 1.11)
Male	1.05 (0.98, 1.12)	1.06 (0.99, 1.13)	1.02 (0.95, 1.09)	1.14 (1.04, 1.24)	1.06 (1.02, 1.10)
Female	1.09 (0.99, 1.19)	1.08 (0.98, 1.18)	1.20 (1.09, 1.31)	0.96 (0.85, 1.09)	1.09 (1.04, 1.15)

Note. CI = confidence interval; OR = odds ratio. All estimates were derived by using the absolute number of seasonally cold days (0–7) as a continuous predictor in the model.

[a] Estimate for all seasons was derived by including all cases in the analyzed subgroup, irrespective of the season of occurrence, into the analysis.

produced season-specific estimates for all seasons, not just winter.[15,16] We compared the probability of cold weather between 2 period types, which controlled for individual attributes and changes in them over time. We used modeling choices to adjust for long time trends, and other temporal, time-varying and time-invariant confounders were controlled by design. The 7-day hazard period accommodates potential time lags between cold weather and OHCA.[9,12,15,16] The rescue stations were linked with high-resolution weather data that took into account geographical differences among locations, which can be important in a coastal city like Helsinki. The weather data were validated, and instrumentation bias was minimal. Finally, we conducted several sensitivity analyses to assess robustness of the results.

Synthesis With Previous Knowledge

Our findings are consistent with previous evidence on the associations between cold weather and OHCA.[9–14,18] In addition, we explicitly showed that similar associations exist in all seasons. Our findings are not in contrast with the substantial evidence of winter peaks in cardiovascular disease mortality or morbidity,[6] nor are they in contrast with evidence on seasonal variation of OHCA incidence or survival.[38,39] Even if an outcome is more common during month A, its association with an independent environmental stressor can be stronger during month B. Our findings are in agreement with previous evidence on adverse health effects of moderately cold weather.[1,18] The methods are not directly comparable but provide mutually complementary information.

In our data, the highest maximum temperature of winter (10.7°C) was colder than the 5th percentile of summer temperatures (11.6°C). The population of Finland is well-prepared to face 10°C weather in winter, because the infrastructures of society, heating of indoor environments, heating of transportation vehicles, insulative winter clothing, and attitudes of the population are seasonally adapted. But experiencing 10°C summer weather in Finland may be disastrous: the indoor environments have been precooled rather than heated, the population is accustomed to dressing lightly in shorts and short-sleeved shirts, and the perception of risk may be inadequate across the society. Just as it would not make sense to issue a public health warning of 10°C winter weather in Finland, it might not make sense not to issue a public health warning of 10°C summer weather in the same setting. We did not assess whether some absolute temperature level during the summer season is more hazardous to health than the identical temperature level in the winter season, but this example opens up interesting new hypotheses and illustrates why considering the seasonal context of temperatures could be meaningful.

In our subgroup analyses, the elderly seemed most vulnerable to the effects of cold winter weather. This is consistent with previous evidence on winter cold spells.[2] Women seemed most vulnerable to the effects of cold spring weather, which may provide important mechanistic clues for future studies. For example, the majority of cases in which pulmonary embolism was suspected as the underlying cause of OHCA occurred during the spring (32%) and in women (4.4% of all women compared with 2.1% of all men). However, our data did not permit further speculation. Young men seemed most vulnerable to the effects of cold summer weather. We suspect that behavioral factors, such as prolonged outdoor activities, limited clothing, or increased alcohol consumption during the summer, may play a role. We recognize the possibility that some of these subgroup differences could be explained by chance. Their value is in the demonstration that classification of vulnerability to cold weather may not stay constant over annum.

Biological foundations for explaining cardiovascular aggravation during cold weather have been laid out over a century of experimental work.[5,19,40,41] Cutaneous vasoconstriction, driven by the autonomic nervous system, is the major and immediate thermoregulatory response to cold in humans. It leads to increases in systemic vascular resistance, cardiac preload, cardiac afterload, and myocardial workload.[5,19,41] Cutaneous vasoconstriction begins when skin temperature falls below 35°C, and becomes maximal at moderate ambient temperatures.[19,41] Relevant cardiovascular responses are consistently reported during ambient moderate cold exposures in experimental settings. In a study by Keatinge et al.,[24] 6-hour exposure to moving air at 24°C induced an increase in arterial pressure from 126/69 millimeters mercury to 138/87 millimeters mercury. The authors also reported increased blood viscosity, an increased thrombocyte count, and increased mean thrombocyte volume to produce a 15% increase in the fraction of plasma volume occupied by thrombocytes. Mäkinen et al. exposed patients to 10°C ambient temperature for 2 hours.[21] The patients were wearing shorts, socks, and athletic shoes.

The authors reported increases in systolic and diastolic blood pressure, increased plasma noradrenaline levels, and changes in autonomic nervous system function. Nagelkirk et al. exposed resting patients to 5°C or 8°C ambient temperature for 15 minutes,[20] followed by a maximal cycle ergometer test in the same temperature. Exposure to the cold air induced a prothrombotic state before and after the exercise. Mercer et al. exposed patients to 11°C ambient temperature for 1 hour[22] and concluded that the moderate cold exposure induced a mild inflammatory reaction and a tendency for an increased state of hypercoagulability. Neild et al. exposed patients to 18°C moving air for 2 hours.[23] With little change in core temperature, this exposure significantly increased plasma fibrinogen concentrations from 2.97 grams per liter to 3.39 grams per liter. Plasma concentrations of factor X and protein C did not increase significantly.

Humans also undergo short-term, long-term, and seasonal thermophysiological adjustments, acclimatizing to heat during the summer and to cold during the winter.[25] The evidence suggests that humans are less prepared to face cold thermal challenges when the timing is in contrast with seasonal acclimatization.[25–27,29,30] The evidence also suggests that while habituation can take place during these weather events, aggravated physiological responses are likely before the physiological adjustments take place.[21,28] To make the topic more complex, seasonal variations in factors like blood pressure, serum lipid concentration, and diet can have relations with low temperature, cardiovascular health, or both, in the acute and chronic setting.[6] However, these factors are at best mediators or modifiers in the current study design, and as such out of the scope of further speculation.

To summarize, experimental evidence supports the hypothesis that moderate cold exposures during all seasons can be hazardous to health. More elaborate assessment of these phenomena in the epidemiological setting could provide new insights.

Public Health Implications

The Network of European Meteorological Services provides real-time warnings of cold spells throughout Europe. These events are defined in circannual terms and occur in the winter (http://www.meteoalarm.org). So do the cold weather events defined by the National Weather Service of the National Oceanic and Atmospheric Administration in the United States (https://www.weather.gov/safety/cold). The warnings issued by the Finnish Meteorological Institute are based on temperatures between −20°C and −45°C as indicators for health risk (https://en.ilmatieteenlaitos.fi/warnings-on-hot-and-cold-weather). The Toronto Cold Weather Program in Canada has been operational since 1996 and uses −15°C as trigger for public health action.[17] The Cold Weather Plan for England mentions winter 220 times, summer zero times, autumn zero times, and spring once (in an unrelated context).[4] These and many other programs explicitly or implicitly confine the cold-related public health action to the winter season.

If cold weather causes adverse health effects during all seasons, is it justified to limit public health action to the winter months? Should the general public not at least be informed? If the majority of health effects are attributed to moderately low temperatures,[1] would protection from moderately low temperatures not have the greatest potential of reducing excess mortality? If the relation between cold weather and health effects is truly loglinear and constant over the calendar year,[42] would similar reduction in exposure not lead to similar public health benefits in all seasons and, if the relationship varies by season instead, would it not be critical to take this into account in public health planning? Our study did not answer these questions per se, but we hope to have made a reasonable case for looking more closely into the seasonal context of temperatures in future assessments. The patterns observed in Helsinki cannot be assumed to be generally applicable elsewhere, but, together with the presented literature, they stimulate universal questions that could have major implications for the assessment of weather-related mortality and, consequently, for public health policy and practice. The fundamental question remains: how should cold weather be defined for the monitoring and managing of public health? AJPH

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CONTRIBUTORS

N. R. I. Ryti initiated and designed the study, executed the statistical programming and analyses applying the new methodological concept created by N. R. I. Ryti and J. J. K. Jaakkola, and drafted the article with intellectual input from all authors. J. Nurmi co-initiated the study with N. R. I. Ryti, retrieved ethical clearance for the study, assisted in designing the case eligibility criteria, provided clinical and scientific expertise in cardiac arrest, and provided intellectual input for the interpretation of results. A. Salo was responsible for the cardiac arrest registry including the measures of quality control, performed the final case selection, provided clinical expertise on the diagnostics and treatment of cardiac arrest patients in Helsinki, and provided intellectual input for the interpretation of results. M. Kuisma provided clinical and scientific expertise on emergency medical services and cardiac arrest, and provided intellectual input for the interpretation of results. H. Antikainen performed the geographic information system programming, extracted and validated the time-series of weather for the study, and provided intellectual input for the geospatial variation of weather in the study area and interpretation of the results. J. J. K. Jaakkola co-created the new methodological concept with N. R. I. Ryti, provided expertise in modeling the health effects of weather, and provided intellectual input for the interpretation of results.

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CONFLICTS OF INTEREST

The authors declare no potential or actual conflicts of interest.

HUMAN PARTICIPANT PROTECTION

The study protocol was approved by institutional review board at the Hospital District of Helsinki and Uusimaa, Finland (HUS/278/2018).

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