Unwrapping the Surprisingly High Risk of Dying from Cardiovascular Disease at Christmas: The HUNT Prospective Population-based Cohort Study in Norway

Trine Moholdt
Norwegian University of Science and Technology

Clifford Afoakwah
Griffith University

Paul Scuffham
Griffith University

Christine McDonald
University of Melbourne

Louise Burrell
University of Melbourne

Simon Stewart (✉ simon.stewart@laureate.edu.au)
Torrens University Australia

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Abstract

Background

Although it is known that winter inclusive of the Christmas holiday period is associated with an increased risk of dying compared to other times of the year, very few studies have specifically examined this phenomenon within a population cohort subject to baseline profiling and prospective follow-up. In such a cohort, we sought to determine the specific characteristics of mortality occurring during the Christmas holidays.

Methods

Baseline profiling and outcome data were derived from a prospective population-based cohort with longitudinal follow-up in Central Norway - the Nord-Trøndelag Health Study. From 1984-1986, 88% of the target population comprising 39,273 men and 40,353 women aged 48±18 and 50±18 years, respectively, were profiled. We examined the long-term pattern of all-cause mortality and specific causes of death according to season, month and individual days of the year to determine the number of excess (cause-specific) deaths occurring at key timepoints (including the Christmas holidays).

Results

During 33.5 (IQR 17.1-34.4) years follow-up, 19,879 (50.7%) men and 19,316 (49.3%) women died at age-adjusted rate of 5.3 and 4.6 deaths per 1000/annum, respectively. Each winter, there were 44 (95% CI 43-45) more all-cause deaths compared to summer, with 21 (95% CI 20-22) more deaths attributable to cardiovascular disease. Compared to any other time of the year, December 25th-27th was the deadliest; being associated with an excess of 1.3 (95% CI 1.1-1.5) all-cause and 1.0 (95% CI 0.7-1.3) cardiovascular-related deaths per day each year. Compared to the pre-Christmas/Winter period (1st-21st December), the incidence rate ratio of all-cause mortality increased to 1.22 (95% CI 1.16-1.27) and 1.17 (95% CI 1.11-1.22) in men and women, respectively, in the next 21 days (Christmas/New Year holiday period). All observed differences were highly significant (P<0.001). A less pronounced pattern of seasonally-linked deaths attributable to respiratory illnesses (but not cancer) was also observed.

Conclusion

Christmas in Central Norway is characterised by a distinctive change and increase in cardiovascular-related mortality over and above that observed between winter (more deaths) and summer (fewer deaths). This distinctive pattern contrasted with cancer-related deaths. Further research to address vulnerability to the darker consequences of winter and, more specifically Christmas, is required.

Background

Although age-standardised mortality is typically reported as the number of deaths per 1,000 people at risk per annum, deaths are rarely evenly distributed throughout the year. Typically, more cardiovascular-related
deaths occur in winter compared to summer. [1] Paradoxically, seasonal variations in cardiovascular-related mortality are not simply explained by exposure to environmental provocations such as cold temperatures, reduced daylight hours, infections, or increased pollution. [2-5] Rather, they appear to reflect a more complex interplay between the environment and an individual's physical and psychological condition, their behaviours and the culture/society in which they live. [4, 6] In Scandinavia, for example, an individual-to-societal adaptation to extremely cold temperatures undoubtedly mitigates the cyclic exposure and physiological responses to seasonally driven provocations to cardiovascular health. [7]

Previous studies have sought to link clusters of increased mortality to large earthquakes [8] and the FIFA World Cup. [9] Beyond these exceptional events, there is an event that has strong potential to be detrimental to an individual's cardiovascular health on an annual basis. [10, 11] At Christmas, people around the world engage in potentially stressful social interactions and provocative behaviours they would not normally expose themselves to. In those already at risk of seasonal patterns of mortality (i.e. where Christmas coincides with winter), these factors may act as additional, short-term triggers for a broad range of cardiovascular-related events. [12] A number of studies based on administrative data have previously demonstrated increased rates of mortality, [12, 13] hospitalisation [11] and acute myocardial infarction (AMI) in Sweden during the Christmas holidays. [10] Beyond these studies, however, this phenomenon remains poorly characterised. [1]

We hypothesised that over and beyond long-term seasonal trends within a population periodically exposed to cold winters, we would find an additional risk of dying over the Christmas holidays. We also hypothesised that cardiovascular disease (CVD) would be the major contributor to this phenomenon and that we would find sex-specific differences in this regard.

Methods

Study context

Norway (population ~5.5 million people) has a long tradition of undertaking insightful, longitudinal population cohort studies; including the Tromsø Study in Northern Norway, [7, 14] and the focus of this report, the HUNT Study. [15] Although the warm currents of the Gulf Stream moderate its weather, given its northerly latitude, Norway still experiences extreme weather conditions. Central Norway's Köppen Climate Classification subtype is Continental Subarctic Climate. [16] The coldest month is January (mean temperature -3°C) and the warmest month is July (~13°C) with a mean annual temperature of ~ 4.8°C overall. Although Norway enjoys relatively clean air, the winter solstice and darkest days of the year coincide with Christmas.

Study design

We examined the long-term pattern of mortality within the prospective, longitudinal, population-based Nord-Trøndelag Health (HUNT) Study cohort living in Central Norway. [15, 17] The present study was
approved by the Regional Committee for Ethics in Medical Research (REK-midt, no. 2018/1509).

Data collection

The original wave of population screening (HUNT1) was undertaken during 1984-1986, with 88% of eligible inhabitants aged ≥ 20 years in Nord-Trøndelag County recruited. Here, we include the 79,626 men and women who attended a clinical examination and filled out detailed questionnaires about their health and lifestyle.[15] Specifically, data on socio-economic status, perceived levels of health and life satisfaction, lifestyle behaviours, and self-reported cardiovascular health CVD were derived from validated questionnaires.[15, 17] We used a previously developed index of physical activity to categorise levels of leisure-time physical activity.[18]

Study outcomes

The unique personal identification number of all Norwegian citizens allows linkage of each participant’s record in the HUNT Study to information from the national Cause of Death Registry on primary cause of death. These are classified according to the International Classification of Disease (ICD) – with precise data available until 1st January 2018. Based on the listed causes of death and the pre-specified hypotheses, the main codes of interest were - CVD (i.e., ICD-9: 390-459 and ICD-10: I00-I99t inclusive of the specific codes for coronary artery disease (CAD), AMI, cerebral infarction, and sudden cardiac death), as well as cancer/malignancy and respiratory disease/illness.

Data Analyses

This study conforms to the STROBE guidelines for the reporting of observational studies.[19] Deaths were initially grouped according to their occurrence in winter (December, January and February), spring (March, April and May), summer (June, July and August) or autumn (September, October and November). Data were then grouped into progressively smaller periods (months and 3-day rolling totals) to identify specific periods of increased mortality. Three, 21-day periods were then purposefully selected for more granular analyses and comparison – 1) the period in which, on a statistical basis, the least number of all-cause deaths occurred (17th May-6th June); 2) the 1st-21st December (the winter /pre-Christmas reference period for all comparisons) and; 3) the subsequent 21-days inclusive of the Christmas holiday period (22nd December-11th January) in which mortality rates were elevated above the winter average. We modelled excess mortality by adjusting for sex, age at death, day and month fixed effects as well as year trend. This approach helps to isolate unobservable characteristics that vary across time from the observed seasonal patterns in mortality. The number of lower/excess deaths per period was then estimated using ordinary least squares (OLS). Mortality was later estimated using a Poisson approach to estimate the increased/decreased risk of mortality (incidence rate ratio [IRR] with 95% CI’s) due to exposure to the Christmas holiday period. Using the profiling data presented in Table 1, we generated adjusted hazard
ratios (HR) for all-cause mortality during the median study period of 33.5 (IQR 17.1 to 34.4) years follow-
up using Cox-Proportional Hazards models (entry models using only those cases with full profiling data).
All analyses were performed using SPSS v26.0 and STATA v13. Statistical significance was accepted at a
2-sided alpha of $P < .05$.

**Results**

**Cohort characteristics**

The study cohort comprised 40,353 women (50.1%) and 39,273 men aged 50±18 and 48±18 years,
respectively. Two-thirds were married and just over half had <10 years of formal education. Most
participants reported generally positive health and life-satisfaction levels. Alternatively, many had
relatively high levels of risk for CVD and other chronic diseases, including elevated baseline levels of
blood pressure (BP) and smoking combined with relatively high levels of sedentary behaviours and
overweight status (**Table 1**).
### Table 1
Baseline characteristics according to survival status

|                          | Total (n=79,626) | Alive (n=40,431) | Dead (n=39,195) |
|--------------------------|------------------|------------------|-----------------|
| **Demographic Profile**  |                  |                  |                 |
| Women, %                 | 40,353 (50.7)    | 21,037 (52.1)    | 19,316 (47.9)   |
| Mean age at baseline (years) | 49.1±18.0         | 35.7±9.6         | 62.9±13.6       |
| Mean age at census (years) | 74.9±11.6         | 70.1±11.4        | 79.9±9.6        |
| Married, % (n=76,775)    | 52,709 (66.6)    | 26,532 (69.5)    | 26,177 (67.8)   |
| ≤9 years education, % (n=61,240) | 32,928 (53.9) | 9,082 (29.9) | 23,886 (77.4) |
| **Employment status, % (n=76,870)** | | | |
| Full-time employment     | 32,333 (42.1)    | 21,585 (56.2)    | 10,748 (28.0)   |
| Non-employed             | 23,156 (30.1)    | 3,623 (9.4)      | 19,533 (50.8)   |
| **Health Status**        |                  |                  |                 |
| Life Satisfaction, % (n=75,815) |                  |                  |                 |
| Dissatisfied (Quite to Extremely) | 2,005 (2.6) | 630 (1.7) | 1,375 (3.6) |
| Satisfied (Quite to Extremely) | 62,342 (82.2) | 32,967 (86.6) | 29,375 (77.9) |
| General Health Status, % (n=76,863) |                  |                  |                 |
| Bad                      | 2,023 (2.6)      | 202 (0.5)        | 1,821 (4.7)     |
| Poor                     | 18,752 (24.4)    | 4,615 (12.0)     | 14,317 (36.7)   |
| Good                     | 44,215 (57.5)    | 24,411 (63.6)    | 19,804 (51.5)   |
| Very Good                | 11,873 (15.4)    | 9,165 (23.9)     | 2,708 (7.0)     |
| Physical Activity Status, % (n=57,212) |                  |                  |                 |
| Inactive                 | 27,145 (47.4)    | 13,157 (45.1)    | 13,988 (49.9)   |
| Low                      | 18,730 (32.7%)   | 9,728 (33.3)     | 9,002 (32.1)    |
| Moderate                 | 8,283 (14.5)     | 4,951 (17.0)     | 3,332 (11.9)    |
| High                     | 3,054 (5.3)      | 1,362 (4.7)      | 1,692 (6.0)     |
| Alcohol intake, % (n=61,520) |                  |                  |                 |
| >5-10 drinks in 14 days  | 3,608 (5.9)      | 1,685 (5.5)      | 1,923 (5.1)     |
| Abstains                 | 7,536 (12.2)     | 1,899 (6.2)      | 5,637 (18.3)    |
All-cause mortality

During the study period, there were 39,195 deaths (49.2%) comprising 19,879 (50.7%) men and 19,316 women. Age-adjusted mortality was slightly higher in men compared to women (5.3 and 4.6 deaths per 1000/annum, respectively); rising from 1.6 to 224 deaths and from 1.1 to 183 deaths per 1000/annum in men and women initially aged <30 years and >80 years, respectively. An increased risk of all-cause mortality ($P < .001$ for all comparisons unless indicated) was correlated with advancing age (adjusted HR 1.11, 95% CI 1.11-1.12 per year), male sex (1.59, 1.55-1.64 versus women), lower education (1.15, 1.11-1.18 for ≤9 years education versus rest), greater unhappiness (1.30, 1.21-1.39 for any degree of life dissatisfaction versus rest), being divorced/separated (1.15, 1.06-1.20 versus unmarried), obesity (1.13, 1.09-1.18), being a current smoker (1.89, 1.79-1.91 versus rest), excessive alcohol intake (1.09, 1.02-1.16 for >10 drinks in 14-days versus abstinence; $P=.017$), an elevated heart rate (1.03, 1.02-1.03 per 5 beats/min), higher systolic (1.02, 1.02-1.03 per 5 mmHg) and diastolic BP (1.01, 1.00-1.02 per 5 mmHg), as well as a self-reported history of AMI (1.65, 1.55-1.76), angina pectoris (1.26, 1.20-1.33) and stroke/cerebral event (1.48, 1.36-1.60). Alternatively, being married (adjusted HR 0.80, 95% CI 0.77-0.83 versus unmarried), better self-reported general health (0.76, 0.74-0.79 for good/very good versus rest), mild alcohol intake (0.94, 0.91-0.97 1-4 drinks in 14-days versus abstinence) and greater levels of exercise (0.89, 0.86-0.92 for moderate to high adherence to recommended exercise versus rest) were associated with a reduced risk of all-cause mortality.

Specific causes of death

The three most common causes of death in men and women were CVD (8,355 [43.6%] and 7,969 deaths [43.0%, respectively); cancer (5,051 [26.4%] and 4,150 deaths [22.4%]) and; respiratory disease/illness (1,599 [8.3%] and 1,606 [8.7%] deaths). Collectively, these accounted for 78% and 74% of all deaths in
men and women, respectively. Other causes of death included endocrine disorders (1,343 [3.4%]), psychiatric disorders (1,118 [2.9%]) and external factors including motor vehicle accidents and violence (951 [2.5%]).

Seasonal patterns of mortality

A striking pattern of seasonal fluctuations in all-cause mortality was evident throughout the study period (Figure 1). Overall, 1,707 more deaths occurred in winter (10,790 [27.5%]) compared to summer (9,083 [23.2%]). The differential between cardiovascular- and respiratory-related mortality occurring in winter (4,446 [27.4%] and 1,037 [32.4%] deaths) versus summer (3,832 [23.5%] and 661 [20.6%] deaths) contributed to 59% (1,010 deaths) of the observed variance between winter and summer. Although a more even distribution of mortality was observed in spring (9,900 [25.3%] deaths) and autumn (9,442 [24.0%] deaths), a seasonal pattern was still evident. Overall, 44 (95% CI 43-45) more deaths occurred each winter when compared to summer, with CVD (21, 95% CI 20-22 more deaths per annum), respiratory disease (13, 95% CI 13-14) and other miscellaneous conditions (14, 95% CI 13-14) being the main contributors to this differential. Moreover, the winter-to-summer differential in mortality for cancer-related deaths was only 10 during the entire study period – see Figure 2.

Monthly patterns of mortality

All-cause mortality peaked in the winter months of December (3,675 deaths) and January (3,592 deaths). The lowest mortality occurred in June (2,920 deaths). The annual excess all-cause mortality occurring during each of the peak months of December and January versus the low of June accounted for 22 (95% CI 21-22) more deaths. Cardiovascular-related deaths were the main contributors to this phenomenon in both December (11, 95% CI 9-10 more deaths) and January (8, 95% CI 7-9 more deaths) – Supplementary Figure S1. Both respiratory disease and a range of other causes of death (6-8 more deaths/month) also contributed to this phenomenon – Supplementary Figure S2.

The Christmas Holiday Effect

Regardless of the season, accumulative 3-day mortality mainly fluctuated between 90-110 deaths. However, a clear increase in mortality commencing the 22nd December was evident. The subsequent 3-day period over Christmas was the deadliest of the year (Figure 3) with 439 all-cause deaths. This was not a random phenomenon and was largely driven by an increase in cardiovascular-related and, to a lesser extent, cancer-related deaths (Figure 4). Each year, there were 1.3 (95% CI, 1.1-1.5) more all-cause and 1.0 (95% CI 0.7-1.3) cardiovascular-related deaths/day (accumulated total of 3.9 and 3.0 deaths) over this specific period compared to any other time of the year. This elevated mortality rate persisted until early January. During the 21 days from the 22nd December, there were 2,679 deaths (51.1% women)
compared to 2,351 deaths (49% women) during the preceding 21 days and 2,016 deaths (49.6% women) during the lowest 21 days of mortality May 17\textsuperscript{th} through June 6\textsuperscript{th}.

Compared to the already elevated levels of mortality observed during the first 21 days of December/winter, each year there were 0.8 (95% CI 0.6-1.0) more all-cause deaths/day during the Christmas/New Year period. The major contributors to this phenomenon were CVD and to lesser extent, cancer and other causes.– Supplementary Figure S3. When compared to the preceding 21 days, the Christmas period was also notable in respect to within and between differences among men and women in respect to fatal AMI (78 versus 16 more deaths, respectively), strokes (13 fewer versus 32 more deaths) and heart failure (1 more versus 12 more deaths). Similarly, in men and women, the number of cancer-(18 and 29 more deaths, respectively) and respiratory-related (19 and 33 more deaths, respectively) deaths also increased.

**Winter and Christmas vulnerability**

Overall, except for cancer-related mortality (both sexes) and respiratory disease in men, compared to the first 21 days of December/winter, the risk of dying in the late spring/early summer period of 17\textsuperscript{th} May to 6\textsuperscript{th} June was significantly lower - Supplementary Figure S4. Alternatively, except for an increased risk of dying from respiratory illnesses/disease among women, men had a higher risk of dying over the equivalent 21-day Christmas period; the major contributor to this increased mortality risk (from 6% to 22% higher overall) being CVD - Supplementary Figure S5.
Table 2
Correlates of All-Cause Mortality According to Baseline Profile

|                      | Dec 1<sup>st</sup> – 21<sup>st</sup> (Winter) versus May 17<sup>th</sup> – June 6<sup>th</sup> (Summer) | Dec 22<sup>nd</sup> – Jan 11<sup>th</sup> (Christmas/New Year) versus Dec 1<sup>st</sup> – 21<sup>st</sup> (Winter/Pre-Christmas) |
|----------------------|-----------------------------------------------------------------|-----------------------------------------------------------------|
|                      | Men (n=1,543) P .001 Women (n=1,351) P .001                   | Men (n=1,636) P .001 Women (n=1,424) P .001                     |
| **Demographic profile, adjusted HR (95% CI)**                                  |                                                                 |                                                                 |
| Age at baseline (per year) 1.06 (1.05–1.07) | .001 | 1.05 (1.04–1.06) | .001 | 1.06 (1.05–1.07) | .001 | 1.05 (1.04–1.06) | .001 |
| ≤ 9 years education vs. rest - | - | - | 1.25 (1.03–1.52) | .026 |
| Married vs. rest - | - | - | 0.71 (0.59–0.86) | .001 | 0.70 (0.54–0.91) | .001 |
| **Well-being, adjusted HR (95% CI)**                                           |                                                                 |                                                                 |
| Good/V. good physical health vs. rest 0.75 (0.64–0.87) | .001 | 0.82 (0.70–0.95) | .008 | 0.79 (0.68–0.92) | .002 | 0.82 (0.70–0.95) | .009 |
| Life dissatisfaction vs. rest - | 1.52 (1.03–2.25) | .036 | - | - | - | - | - |
| **Past History, adjusted HR (95% CI)**                                          |                                                                 |                                                                 |
| Angina pectoris vs. rest 1.26 (0.98–1.63) | .074 | 1.57 (1.19–2.08) | .002 | 1.39 (1.06–1.80) | .016 | 1.99 (1.05–1.84) | .021 |
| Acute myocardial infarction vs. rest 1.52 (1.11–2.07) | .008 | - | - | 1.45 (1.06–1.99) | .021 | 2.41 (1.46–3.80) | .001 |
| Stroke vs. rest - | - | - | - | - | 2.01 (1.28–3.17) | .002 |
| **Lifestyle, adjusted HR (95% CI)**                                             |                                                                 |                                                                 |
| Current smoker vs. rest 1.28 (1.06–1.53) | .009 | 1.24 (1.04–1.49) | .018 | 1.39 (1.16–1.66) | .001 | 1.51 (1.26–1.82) | .001 |
| Vital Signs, adjusted HR (95% CI) |
|----------------------------------|
| Heart rate (per 5 beats/minute)  | 1.03 (1.01-1.06) | .011 | - | 1.03 (1.00-1.06) | .045 | - |
| Systolic BP (per 5 mm/Hg)        | 1.04 (1.02-1.07) | .001 | 1.04 (1.02-0.06) | .001 | 1.03 (1.01-0.05) | .002 | 1.03 (1.00-0.03) | .019 |
| Diastolic BP (per 5 mm/Hg)       | - | 1.07 (1.03-0.09) | .001 | - | - |

Beyond advancing age, a combination of baseline demographic, health perceptions and clinical factors were independently correlated with dying during – 1) late spring/early summer versus early winter, and then 2) early winter versus the Christmas holiday period. Whilst these factors were broadly similar for both sexes, including a 30% reduced risk during the Christmas holidays associated with being married at baseline, there were some notable differences. For example, consistent with an excess number of strokes among women, but not men, during the Christmas holidays, a pre-existing history of stroke conferred a 2-fold risk of dying during this period among women. Educational status among women also appeared to modulate the additional risk of dying during this period – see Table 2.

**Sensitivity analyses**

We conducted sensitivity analyses by estimating four different models to test if the phenomenon of Christmas-related excess mortality is a reliable and consistent observation. All four models supported the findings of a significant increase in mortality over the Christmas period – Supplementary Table S1.

**Discussion**

We investigated the seasonal pattern of mortality within the HUNT Study cohort living in Central Norway. This population cohort is regarded as representative for the Norwegian population as a whole, except for a lower proportion of non-whites and the absence of large cities. Our analyses revealed a striking long-term difference in mortality occurring in winter compared to summer. CVD accounted for half of this seasonality. Although not the coldest, December proved to be the deadliest month, with 22 more people dying each year compared to June. Overall, the 3-day period of 25th-27th December proved to be the deadliest time of the year with CVD as the major contributor. Critically, both the frequency and cause of death in men and women appeared to change over the Christmas period. Compared to the same pre-Christmas/wintry period, men were 22% and 17% more likely to die from all-causes and CVD (particularly AMI), respectively. In women, the equivalent risk increases were 17% and 15%, with the contribution of CVD (particularly stroke) even more prominent. Although previous studies have also identified a specific Christmas effect on mortality[10],[11-13, 20], we are unaware of any studies and findings equivalent to those reported here.

There is pre-existing evidence to support the hypothesis that Christmas can be harmful to some
individuals. A study of the overall pattern of mortality in the US during 1973-2001 revealed a “holiday effect” during Christmas, with ~5% excess deaths, after adjustment for the winter season.[12] Similarly, data from a nationwide coronary care unit registry in Sweden revealed a 15% increase in AMI cases during the Christmas holidays.[10] A higher risk of 30-day mortality or readmission among those hospitalised at Christmas in Ontario, Canada has also been found.[11] From a Southern Hemisphere perspective there is both supportive [13] and contrary evidence [21] of an equivalent phenomenon occurring in summer conditions.

In the (understandable) absence of prospective studies, it is challenging to delineate between the overall impact of winter and a Christmas-specific effect. As shown by the Tromsø Study [22], there is evidence of winter peaks in blood pressure, heart rate, body weight, total cholesterol and overall CVD risk. Seasonal variation in physical activity may also be an important consideration for cardiovascular-related mortality. [23] Aerobic exercise, especially with high intensity, can acutely lower systolic BP in the hours following exercise.25

As in many parts of the world, life in Central Norway during the Christmas holiday period is characterised by festive celebrations, travel away from home/central services, and reduced health services. Reduced access to follow-up health care was noted to contribute to 26 excess deaths (and 188 hospital readmissions) per 100,000 patients in Canada during the Christmas holidays.[11] However, this phenomenon does not fully explain the size of the phenomenon we observed within our cohort and the contributory reasons are likely to be multifactorial. Consuming a high-fat diet for only 3 days exacerbates insulin resistance and glycolipid metabolism disorders in obese men.[24] Even among healthy men, decreasing physical activity for 1-3 weeks decreases insulin sensitivity and attenuates postprandial lipid metabolism.[25] Vascular stiffness, due to impaired endothelial function of the conduit vessels, is an important factor in the development of hypertension and an independent risk factor for a fatal cardiovascular event.[26] After a high-fat meal, which is typically consumed during Christmas in Norway, endothelial function decreases substantially postprandially.[27] The potential negative impact of increased emotional stress associated with dealing with loneliness and family tensions [28] with the potential for seasonally triggered depression [29], also cannot be ignored. As suggested by our sex-specific findings, any or all of these “stressors” may affect men and women differently. For example, it has been demonstrated that diabetes, high-density lipoprotein levels and triglyceride levels have more impact on cardiovascular health of women compared to men.[30] The emerging literature around Tako-tsubo cardiomyopathy with a predominance of women affected [31] is notable when considering the small, but intriguing, increase in deaths due to heart failure in women, but not men, at Christmas.

Unfortunately, in the absence of specific interventions, expert clinical guidelines rarely mention or address seasonality. Beyond ensuring appropriate vaccination against influenza [32], there is a strong justification for more proactive screening and management of high-risk patients by general practitioners leading up to Christmas. The identification of educational levels in women and marriage status as modifying mortality risk in both sexes, reinforces the importance of considering health literacy and the emotional well-being of individuals leading up to provocative times of the year. Promotion of a healthy lifestyle should occur all year round [33], but should perhaps be highlighted and re-emphasised in the lead-up to Christmas: a
time of excessive indulgence of all kinds with potentially tragic consequences. The current COVID-19 pandemic both directly (via residual cardio-pulmonary impairment post-infection [34]) and indirectly (via its negative effects on emotional and psychological well-being, patterns of social interaction, seeking care for pre-existing chronic conditions and reduced exercise levels), has further potential to exacerbate Christmas mortality in 2020 and beyond.[35]

**Study limitations**

To robust test our primary hypothesis we examined patterns of long-term mortality within the HUNT cohort [15, 17] in Central Norway. Although this is a specific population and relies upon historical outcomes, findings from the HUNT cohort have consistently supported previous novel observations as well as discover new ones that have been likewise externally validated. To maintain the size of outcome data for analyses, we relied upon baseline profiling of the original cohort. As of yet, we have not examined linked hospitalisation data, to improve and inform our findings. However, even with such data, the HUNT Study was not specifically designed to examine this specific issue. For example, whilst we will be able to determine the cause and timing of any hospital admissions, we will not be able to ascertain the quality of care and extent of outpatient follow-up. However, the timing of death (unless a sudden cardiac death) is not indicative of exactly when a person becomes unwell and/or is admitted to hospital.[11] This has relevance to both the specific timing of the observed increase in mortality and how long it took for that increase to subside. As such, our current analyses of the correlates of the specific timing of mortality can only inform future research directions rather than identify specific causality. For example, in the future we do plan to access all data from additional profiling “waves” subsequently performed on some HUNT participant. In our statistical analyses at least, we were able to robustly test the timing of mortality and the Christmas period; our findings consistently confirming a strong temporal relationship that warrants further investigation.

**Conclusions**

During long-term follow-up of the HUNT population cohort, there was a distinctive pattern of a seasonal increase in mortality during winter when compared to summer months. Over and above this broad pattern, a distinctive pattern of excess mortality predominantly, but not exclusively linked to CVD, was evident over the Christmas holiday period. The number of excess deaths over Christmas was substantial. If present at the same levels within the entire age-matched population in Norway (a minimum of 3 million adults alive in 1980), there would have been more than 11,000 deaths (around 350 per annum) over the Christmas holidays alone in the past 30 years.

**Abbreviations**

AMI – acute myocardial infarction

BP – blood pressure
Declarations

Availability of data and materials

The Trøndelag Health Study has invited persons aged 13 - 100 years to four surveys between 1984 and 2019. Comprehensive data from more than 140,000 persons having participated at least once and biological material from 78,000 persons are collected. The data are stored in HUNT databank and biological material in HUNT biobank. HUNT Research Centre has permission from the Norwegian Data Inspectorate to store and handle these data. The key identification in the data base is the personal identification number given to all Norwegians at birth or immigration, whilst de-identified data are sent to researchers upon approval of a research protocol by the Regional Ethical Committee and HUNT Research Centre. To protect participants’ privacy, HUNT Research Centre aims to limit storage of data outside HUNT databank, and cannot deposit data in open repositories. HUNT databank has precise information on all data exported to different projects and are able to reproduce these on request. There are no restrictions regarding data export given approval of applications to HUNT Research Centre. For more information see: http://www.ntnu.edu/hunt/data

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Author contributions
TM and SS contributed to the conception of the work. CA contributed to the analysis of study data. PS, CM and LB contributed to the interpretation of study data. TM and SS drafted the manuscript. CA, PS, CM and LB critically revised the manuscript. All gave their approval and agree to be accountable for all aspects of the work, ensuring its integrity and accuracy.

Ethics declarations

The Nord-Trøndelag Health Study conforms to the Declaration of Helsinki and was originally approved by the relevant ethics committee. [15, 17] All study participants provided written informed consent to be studied and followed-up. The present study was approved by the Regional Committee for Ethics in Medical Research (REK-midt, no. 2018/1509).

Conflict of interest

The authors have no conflicts of interest to declare.

Consent for publication

Not applicable

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**Figures**

**Figure 1**

SEASONAL PATTERNS OF MORTALITY Legend: Total all-cause and cause-specific deaths are plotted for each of the four seasons during the study period. Snowflakes denote each winter.
Figure 2

SEASONAL COMPARISONS OF MORTALITY Legend: The number of deaths occurring in spring, autumn, and winter above and below the reference (low mortality) season of summer are shown for all-cause and cause-specific mortality.
Figure 3

3-DAY MORTALITY ACROSS THE CALENDAR YEAR Legend: The average number of all-cause deaths occurring every 3 days during the study period.

Figure 4

EXCESS CHRISTMAS MORTALITY Legend: The number of deaths occurring on the 25th – 27th of the remaining months (January to November) each year above and below the reference 3-day period 25th –
27th December are shown for all-cause and cause-specific mortality.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- ChristmasMortalityintheHUNT Cohort BMCPublicHealthDec2020 SUPPLEMENTARY MATERIAL.docx