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Article · May 2013

DOI: 10.1002/wcc.211

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Winter mortality in a warming climate: a reassessment

Kristie L. Ebi[1]* and David Mills[2]

In temperate climates, mortality is higher in the winter than the summer. Most wintertime deaths are attributed to cardiovascular and respiratory disease, with hypothermia from extreme cold accounting for a negligible share of all recorded deaths. International and national assessments of the health risks of climate change often conclude that increased temperatures from climate change will likely reduce winter mortality. This article examines the support for this hypothesis. We find that although there is a physiological basis for increased cardiovascular and respiratory disease mortality during winter months, the limited evidence suggests cardiovascular disease mortality is only weakly associated with temperature. Although respiratory disease mortality shows a stronger seasonal relationship with colder temperatures, cold alone does not explain infection rates. Further, respiratory disease mortality is a relatively small proportion of winter deaths. Therefore, assuming no changes in acclimatization and the degree to which temperature-related deaths are prevented, climate change may alter the balance of deaths between winters and summers, but is unlikely to dramatically reduce overall winter mortality rates.

How to cite this article:
WIREs Clim Change 2013. doi: 10.1002/wcc.211

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INTRODUCTION

Assessments of the health risks of climate change often conclude that the general warming associated with climate change and corresponding reduction in the severity and length of the winter season could considerably decrease deaths attributable to cold temperatures.[1–3] Determining the degree to which warming temperatures could affect cold-related mortality requires understanding the role of temperature in the etiology of specific cold-related health outcomes and in cold season mortality patterns, and the mechanisms whereby climate change could alter temperature–mortality relationships. This information is critical for assessing how the balance of hot and cold-temperature-related mortality could alter in a changing climate. This information also is needed by public health officials to support their efforts to reduce cold season mortality.[4]

At the outset, it is critical to distinguish between seasonal mortality patterns and mortality due to extreme temperature events. More deaths occur in temperate regions in the winter, generally defined as the three coldest months of the year, is well documented.[5,6] The question is how much of this seasonal variation is directly dependent on temperature versus other factors that vary with the seasons.

This article explores the nature and evidence of the relationship between daily mortality, cold spells, and the cold season by first discussing the health impacts of cold temperatures and differentiating between mortality due to cold spells and general winter mortality. We then explore the evidence for the assumption that elevated winter mortality is due directly to temperature to draw conclusions regarding how the balance of hot- and cold-temperature-related mortality could be affected by a changing climate.

FACTORS INFLUENCING WINTER MORTALITY

Cardiovascular disease (including hypertension, ischemic heart disease, myocardial infarction, and cerebrovascular disease) accounts for the majority of

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excess deaths during the winter season.[7] Roughly 50% of the remaining excess deaths are due to respiratory diseases. While different studies use different definitions of excess deaths, this study refers to the increased mortality during the winter season.

A wide range of biologically important processes that can lead to cardiovascular stress have different patterns between winter and summer. Specifically, systolic and diastolic blood pressure, vasoconstriction, blood viscosity, red blood cell count, plasma low-density lipoprotein cholesterol, plasma fibrinogen, and, possibly, C-reactive protein have higher values in the winter when compared with the summer.[8–14] Rapid deaths can occur due to the rupture of atheromatous plaques during hypertension and cold-induced coronary spasms.

Similarly, colder winter temperatures can be linked to increased respiratory infections as colder air induces broncho-constriction and suppresses mucociliary defenses, resulting in local inflammation. However, cold air alone does not appear to be a significant factor in respiratory infections. For example, experiments have found no effect of cold exposure on susceptibility to infection with the common cold viruses, even then inoculated directly into the nose during periods of cold exposure.[15]

At the same time, exposure to extreme cold temperatures can cause death. Studies of this direct mortality impact of cold temperatures often focus on deaths attributed to hypothermia, a reduction in the body's core temperature below 35°C from its typical 37°C.[16] In the United States, over the period 1999–2002, there were 4607 death certificates that had hypothermia-related diagnoses listed as the underlying cause of death, with 2622 deaths due to exposure to excessive natural cold.[17] Almost half the deaths were in adults over the age of 65, 67% were males, and only 23% were at home. Deaths occurred in all 50 states, with the highest average annual rates in Alaska, Montana, Wyoming, and New Mexico, states with wide variations in winter temperatures.

While conceptually appealing, care must be used in projecting changes in the pattern of hypothermia deaths due to changes in seasonal temperatures because hypothermia deaths occur throughout the year, often with relatively mild temperatures, especially if the deceased was exposed to water and/or used alcohol or other drugs.[18,19] For example, mortality rates in 2002 for hypothermia in South Carolina (a warmer state in the United States) were higher than the equivalent national average.[18] Similarly, in Sydney, Australia, 54% of hypothermia deaths over the period 2001–2005 occurred in non-winter months.[19] The majority of these deaths involved persons who had significant preexisting disease and only 12% of deaths were found outdoors.

Personal and residential characteristics identified as increasing an individual's risk of dying due to cold exposure include: older ages (age ≥65); underlying medical diseases; lower muscularity and physical fitness; lower subcutaneous fat; substance abuse; mental impairment; lower levels of education; lack of central heating or homelessness; inadequate intake of (warm) food and drinks; and limited use of protective clothing.[8,18,20–24] Environmental factors contributing to hypothermia include temperature, wind movement, and humidity.

A decrease in core body temperature less extreme than hypothermia can alter cardiovascular, physiological, and immunological parameters that can affect mortality.[9,25–28] The biological mechanisms include reducing heat loss from the body's core by decreasing peripheral blood circulation, which results in the blood becoming more concentrated.[10] Some of the smaller molecules in the blood plasma are able to redistribute through the capillary walls, but the red and white blood cells, platelets, fibrinogen, and cholesterol are too large to redistribute and increase in concentration. This promotes viscosity and hypercoagulability, which increase blood pressure. In addition, cellular and humoral immunity are altered, increasing the likelihood of respiratory infections.[16,28]

Many winter respiratory deaths are due to influenza, although studies have not consistently found an association between ambient temperature and incidence of influenza and other respiratory mortality. Huynen et al.[29] found an increase in respiratory mortality during a cold spell only when it coincided with an influenza epidemic; otherwise respiratory mortality was not increased. Support for the importance of influenza in determining the timing and magnitude of winter cardiovascular disease mortality comes from analyses of monthly mortality in the United States.[30] Midwinter peaks for pneumonia and influenza, ischemic heart disease, cerebrovascular disease, and diabetes varied in size and differed widely in mean value and seasonal variation. However, about 85% of the time, peak months of mortality for ischemic heart disease, cerebrovascular disease, and diabetes mellitus coincided with peaks in pneumonia and influenza. Mortality was significantly larger in seasons dominated by influenza A(H2N2) and A (H3N2) than in seasons dominated by A(H1N1) or B viruses. Evidence that influenza vaccination and naturally acquired immunity may reduce mortality also supports the role of influenza in winter mortality.[31,32] Recent evidence suggests that seasonal

variations in influenza mortality may be associated with absolute humidity, not temperature[33] or with episodes of cold, dry air.[34]

Donaldson and Keatinge[35] analyzed monthly mortality in southeast England to determine whether excess winter mortality could be attributed to influenza or cold stress. Excess daily mortality for all causes and for influenza were analyzed to give the strongest relationships between temperature and mortality. Excess deaths were those that occurred below the temperature (in 3°C bands) at which mortality was the lowest. Of the annual 1265 excess winter deaths per million over the last 10 years of the analysis, 2.4% were directly or indirectly due to influenza. There was a decline in influenza deaths over the period that was likely due to increased vaccination and to a reduction in new viral strains. The authors concluded that cold weather was a more important risk factor for winter mortality than influenza.

MORTALITY FROM EXTREME COLD SPELLS

Extreme cold spells are discrete periods within the cold season characterized by a sudden large drop in temperatures to levels far below seasonal norms. Cold waves cause excess mortality even in warm regions.[36] Attributing excess mortality during cold spells to temperature is similar to analyzing the health impacts of heatwaves: (1) establishing a set of meteorological criteria to define when conditions constitute a cold spell and then (2) calculating the excess deaths as the difference between daily mortality totals for cold spells, minus the daily mortality expected based on mortality during previous years when a cold spell was not experienced. For example, in a study of 50 cities in the United States., the risk of dying from any cardiovascular disease on extremely cold days (daily maximum temperature less than the 1st percentile of its distribution) increased more than the risk of dying from other causes (OR = 1.053, 95% CI 1.036–1.070); the association was strongest for cardiac arrest (OR = 1.137; 95% CI 1.051–1.230).[37] The cut-off points used to define extremely cold days varied from −17°C in Minneapolis, Minnesota to approximately 9°C in San Francisco, California. However, a recent analysis for 99 cities in the United States over 14 years that removed the general effects of temperature found increases in deaths associated with cold waves were generally small and not statistically significant, with evidence of decreased risk during the coldest waves.[38]

COLD SEASON MORTALITY

Respiratory and cardiovascular diseases are the leading causes of winter mortality.[7] For example, among adults ≥45 years of age in the South Yorkshire Coalfields Health Action Zone, United Kingdom, there was an excess of deaths (observed vs expected) from cardiovascular and respiratory disease during December–March, with little fluctuation during other months.[39] Cardiovascular disease accounted for 48% of total deaths, and respiratory disease accounted for 14%. Excess winter mortality ratios for females and males were 1.70 and 1.58 for respiratory disease, 1.25 and 1.20 for cardiovascular disease, and 1.09 and 1.07 for all other causes of death. Respiratory disease accounted for more of the winter excess deaths in relative terms, and showed more fluctuation over the years. Excess winter mortality ratios decreased significantly over the 18-year study period for cardiovascular and other diseases, but not for respiratory disease.

The relationship between daily mortality and temperature in temperate and cold regions generally is J-shaped, with a temperature at which mortality is at a minimum and an increase in mortality as temperatures decrease and increase from this point. A global meta-analysis of 15 studies of daily mean temperature and mortality among 13 million older adults found that both hot and cold temperatures increased all-cause mortality among the elderly, with the heat effects larger than cold effects (2–5% increase for a 1°C temperature increase during hot weather and a 1–2% increase for a 1°C temperature decrease during cold weather).[40] The lag between exposure to high ambient temperatures and mortality is short (1 or 2 days), while the lag for cold temperatures is typically much longer.

The largest proportional increases in winter mortality are in countries with less severe, milder climates.[41] There is limited correlation between seasonal mortality and ambient temperature: mortality in Norway begins to increase when ambient temperature falls below about 0°C, while mortality in Ireland begins to increase at temperatures below 10–15°C, indicating it is relative not absolute temperature that is of importance.[7]

Using a complete heat budget, perceived temperature model to investigate daily mortality by season over 30 years in SW Germany, Laschewski and Jendritsky[42] found across all seasons that a change to warmer perceived temperatures increased mortality, whereas a change to colder perceived temperatures decreased mortality, even in winter (December–February), suggesting that temperature variability may be of more importance than absolute temperature.

SEASON VERSUS TEMPERATURE

A limited number of studies compare whether seasonality mortality patterns are due to temperature or whether cardiovascular and respiratory diseases are seasonal for other reasons, with most concluding that winter mortality patterns are due to factors other than temperature. von Klot et al.[43] provided a simple graphical illustration comparing daily temperature in Detroit, Michigan and Honolulu, Hawaii with the mean cardiac mortality rate. The two cities have similar increases in winter mortality despite Honolulu having both an order of magnitude lower oscillation in temperature and much warmer winter temperatures than Detroit, supporting that absolute temperature does not appear to be driving winter mortality.

Based on an examination of monthly mortality patterns in 28 U.S. cities over more than 30 years and an assessment of the role of influenza in winter mortality, Davis et al.[44] concluded that cold weather spells do not significantly raise mortality rates, suggesting seasonal mortality is largely independent of the climate and insensitive to climate fluctuations. Using a synoptic air mass approach, Kalkstein and Greene[45] found little variation in causes of wintertime mortality by temperature based on analyses for 44 major metropolitan areas in the United States. Mortality during summer (June–August) and winter (December–February) was expressed as the deviation around a standardized trend line. Determination of winter air masses strongly associated with mortality was more difficult than for summer air masses, with mortality increasing only slightly during the winter. Threshold meteorological conditions leading to higher mortality were either nonexistent or difficult to find, leading the authors to conclude that variations in meteorology appeared not to be responsible for increased winter mortality.

Evidence from analyses in Europe supports the findings from the United States. The Eurowinter Group[46] analyzed daily mean mortality for ages 50–59 and 65–74 years during winter months (October–March) from ischemic heart disease, cerebrovascular disease, respiratory disease, excluding deaths from influenza, and all causes in Finland (two regions), Germany, the Netherlands, London, north Italy, Athens, and Sicily. Across all regions, mortality increased from a minimum at or near 18°C. The number of days per year colder than 18°C was not directly related to mean winter temperature; London and north Italy have identical mean winter temperatures, but London has 345 days colder than 18°C while there are only 248 days in north Italy. Baseline estimated deaths per million people per day varied from 31.0 in Baden-Wurttemberg to 43.0 in south Finland; baseline mortality rates for all outcomes except respiratory disease were significantly higher in colder countries and older age groups. However, increases in mortality per 1°C fall in temperature were greater in warm than cold regions, both absolutely and as a percentage of mortality at 18°C. For example, the mean percent increase in mortality for each 1°C fall in temperature from 18°C was less than 0.3 in Finland, 1.37 in London, and 2.15 in Athens.

Analyses of seasonal variation over 25 years in all-cause and cause-specific mortality rates for male British civil servants suggested that older adults were not more sensitive to seasonal effects, but rather were more likely to die from causes with a seasonal pattern.[47] Respiratory diseases and ischemic heart disease together accounted for three-quarters of the difference between summer and winter mortality. Although men with prevalent ischemic heart disease at baseline were at increased risk across the study, men at increased risk of all-cause, coronary, stroke, or respiratory mortality did not experience greater seasonal effects than those at lower risk. Further, regression models based on temperature and daily deaths from the United Kingdom Office for National Statistics explained only 7% of the variance in winter mortality.[48] The models based on excess deaths and temperature explained only 1% of the variance in excess mortality in winter. Overall, there was a weak but significant relationship between temperature and mortality in both the summer and winter months. The authors concluded that although winter mortality increases as it gets colder, winter mortality is variable and high mortality can occur on relatively mild days.

On the other hand, a population-based cohort study of 119,389 person-years follow-up of adults > 75 years of age in England found that month-to-month variation accounted for 17% of annual all-cause mortality, but only 7.8% after adjustment for temperature, and 5.2% after adjustment for temperature and influenza.[24] Thus, more of the seasonal variation appeared to be due to the cold. The overall winter to non-winter rate ratio was 1.31 (95% CI 1.26–1.36). There was little evidence that this ratio varied by geographic region, age, or a range of personal, clinical, or socioeconomic factors, with two exceptions: mortality was higher in women than men, and those with a self-reported history of respiratory illness had higher cardiovascular disease mortality. Preexisting respiratory disease was the single strongest predictor of excess winter death; it was most strongly associated with mortality from cardiovascular disease.

These results are supported by a recent analysis of the contribution of temperature, hours of sunshine, and air pollution to the variation in coronary heart

disease mortality rates across England.[49] After adjusting for socioeconomic factors, an index measuring the healthiness of the lifestyle of populations, and urbanicity, the climate variables had a small but independent association with coronary heart disease mortality rates, explaining at least 15% of the variation in coronary heart disease rates. Applying the excess winter mortality to temporal differences in temperature suggested an increase in coronary heart disease mortality of approximately 3 deaths per 100,000 for males and 2 deaths per 100,000 for females.

Eight of 12 studies analyzing the effects of temperature on myocardial infarction found a statistically significant increase risk at lower temperatures, suggesting an influence not only just of cold but also of unusual temperature decreases.[50,51] This is supported by a study of acute myocardial infarctions among winter tourists in Austria; most events occurred within the first 2 days of arrival and within the first 2 days of physical activity, suggesting that change in temperature (from home) may be a risk factor.[52] A study conducted in 48 U.S. cities to determine how much of the seasonal pattern in cardiac deaths could be explained by influenza and season concluded there was little confounding between influenza and season, and that a temperature decrease from 0 to −5°C increased the risk of cardiac mortality by 1.6% (95% CI = 1.1–2.1%).[43] However, a recent study in Denmark found no evidence of an association between low temperatures and cardiovascular disease.[53]

Further support for a limited association between cold temperatures and cardiovascular disease mortality comes from studies of cardiovascular disease at higher altitudes. A review of the epidemiologic data and physiological mechanisms associated with acute, intermittent, and chronic exposure to altitude, concluded that although interpretation is difficult due to many confounders, studies indicate that living at altitude provides cardiovascular protection.[54] Studies in Switzerland and Greece found protective effects of living at higher altitude on coronary heart disease mortality, with the Swiss study suggesting the effects were likely due to factors related to climate.[55,56] Potential confounders of this association include solar radiation and vitamin D; there is increasing evidence that vitamin D may be a risk factor for cardiovascular disease, with a significant proportion of Europeans and North Americans deficient in vitamin D.[57,58] Vitamin D concentrations are largely influenced by season, geographic latitude, daily outdoor activities, and the percentage of body surface exposed to solar radiation, suggesting that studies of the association between mortality and cold temperatures may be confounded by vitamin D status.

The strength of the winter temperature–mortality relationship over time may be declining due to improvements in social, environmental, behavioral, and health care factors,[44,59,60] although not all studies report a reduction.[61] The ratio of winter (December–March) to non-winter mortality for London during four periods over the last century declined in the most recent period: the ratios were 1.24 (95% CI 1.16–1.34) for 1900–1910; 1.54 (95% CI 1.42–1.68) for 1927–1937; 1.48 (95% CI 1.35–1.64) for 1954–1964; and 1.22 (95% CI 1.13–1.31) for 1986–1996.[59] Decreasing population sensitivity to cold temperatures was suggested by the decrease in mortality per 1°C decrease in temperature below 15°C for the four periods: 2.52, 2.34, 1.64, and 1.17% (not statistically significant), respectively. The largest attributable fraction in each period was for deaths from respiratory disease, from a low of 16.1% in 1986–1996 to a high of 35.8% in 1954–1964. The percentage of cardiovascular deaths attributable to cold was greatest in 1927–1937 at 14%; this declined to less than 7% in 1986–1996. Christidis et al.[60] used formal detection and attribution methods to investigate changes in winter season mortality among adults over 50 years of age in England and Wales. Although winter temperatures decreased over the period 1976–2005, the authors concluded that warmer temperatures were not the reason for the reduction in mortality; mortality declined primarily due to adaptation to cold temperatures.

GEOGRAPHIC VARIATION IN COLD-RELATED MORTALITY

Cold-related mortality increases to a greater extent with a given fall in temperature in regions with warmer winters. The United Kingdom has much higher winter deaths rates than other countries with similar or more severe climates, implying that it is not outdoor exposure to cold that is the key determinant.[46] Winter excess mortality is approximately twice as high in England and Wales than in Norway, although the associations with influenza are of similar magnitude.[62] After adjusting for age and influenza, the excess winter morality in England and Wales is 2 per 10,000 population ≥45 years of age per 1°C decrease in temperature. Winter excess mortality was highest in winters with more influenza-associated deaths. There was a weak and statistically insignificant decline in winter excess mortality between 1970 and 1991.

Healy conducted a cross-country analysis of 14 European countries and reached similar conclusions: excess mortality is higher in the winter than summer, with the largest proportional increases in countries

with less severe, milder climates (including Portugal, Ireland, Spain, England, Wales, North Ireland, Scotland, Greece, and Italy).[41] Finland, Germany, and the Netherlands had the lowest proportional mortality increases in winter. Contributing factors included not only temperature but also housing standards, macroeconomic factors, socioeconomic factors, and public health expenditures. Analyses of the effects of cold weather on mortality in 15 European cities found larger effects in cities with smaller temperature variability, less humid cities, and cities at lower latitudes.[5]

Two studies in the United States reached broadly similar conclusions.[63,64] Curriero et al.[63] analyzed associations between temperature and mortality for 11 large eastern U.S. cities and explored characteristics associated with the observed variations. There was a greater effect of colder temperatures on mortality risk in more southern cities and of warmer temperatures in more northern cities. Mortality associations with colder temperatures were larger for cities with higher proportions of elderly and smaller for cities with a greater access to heating systems. Braga et al.[64] used time-series analyses in 12 U.S. cities to estimate both the acute effects and the lagged influence of weather on respiratory and cardiovascular disease deaths. In cold cities, high and low temperatures were associated with increased cardiovascular disease deaths. Greater variance of winter temperature was associated with larger effects for cold days on respiratory deaths.

PROTECTION AGAINST THE COLD

Behaviors to protect against cold exposure are key determinants of winter mortality in Europe and Russia.[21,22,46,65,66] Two surveys in Russia assessed indoor temperatures and the amount of clothing worn outdoors in relation to daily mortality during cold months.[65,66] In eastern Siberia,[65] mortality from all causes and from ischemic heart and respiratory disease were unaffected by decreasing temperatures (to as low as −51.5°C). Mortality from respiratory disease (daily deaths per million) rose from 4.7 (range: 4.3–5.1) to 5.1 (range: 4.4–5.7); this was offset by a fall in deaths from injury. Surveys of adults 50–59 and 65–74 years of age found that living room temperatures and layers of clothes increased with falling temperatures, and the proportion of people who went outdoors in very cold temperatures decreased. A more detailed survey of adults 50–59 and 65–74 years of age in another region of Russia yielded similar results concerning clothing worn during cold weather.[66] As mean daily temperatures fell to 0°C, the amount of clothing worn outdoors increased and physical activity became more continuous. Mortality from ischemic heart disease, cerebrovascular disease, respiratory disease, and all causes did not change. As temperature fell below 0°C, the number of items of clothing worn reached a plateau at 16. Mortality, after declining slightly, rose for each 1°C drop in temperature from 0°C to −29.6°C after adjusting for deaths from influenza.

The Eurowinter Group[46] reported personal exposure factors varied by region, with bedroom heating less common and living room temperatures lower in regions with warm winters. Outdoors at 7°C, people living in regions with warm winters were less likely to wear a hat, an anorak, or gloves. These factors were strongly correlated, with groups with warmer living rooms very likely to heat their bedrooms, to wear hats and anoraks, and to keep active outside at 7°C. Respiratory disease mortality was independently associated with shivering outdoors (as an indicator of outdoor cold stress) and living room temperature. Associations with cardiovascular disease and ischemic heart disease were weak and not statistically significant.

FACTORS AFFECTING THE BALANCE OF HEAT- AND COLD-WEATHER MORTALITY

Frost and Auliciems[67] hypothesized that the number of potential victims of acute myocardial infarction is limited to a pool of susceptible individuals, and that the size of the pool influences the strength of associations between ambient temperature (both summer and winter) and myocardial infarction death rates. Analyses of data from Montreal and Brisbane supported this, showing that lower than average temperatures in the winter were more strongly associated with myocardial infarction in the years in which the size of the susceptible pool was larger. In both cities, higher death rates occurred in early winter, despite colder temperatures later in the winter.

Studies in Korea, Italy, and Sweden support a related hypothesis, that high winter mortality reduces heat-related mortality the following summer.[68–70] Any reduction in winter mortality due to climate change might then increase the pool of individuals susceptible to heatwaves the following summer.

Kinney et al.[71] reviewed the relationship between ambient temperature and mortality, and concluded that if the shape of the relationship were to remain constant with climate change, then winter mortality would decrease. However, the assumption of a constant temperature relationship was poorly supported by analyses in cities in Europe and the United States; with warmer temperatures, the

shape of the temperature–mortality curve for colder temperatures becomes steeper. This suggests that in a warmer world, winter season mortality would occur across a narrower and warmer range of ambient temperatures than today. The authors conclude it is unlikely that warmer winters due to climate change would result in substantially lower winter season mortality, and that health risks of cold spells would remain.

CONCLUSION

Answering the question of whether and how climate change could affect winter mortality requires consideration of complex and intertwined relationships. As noted earlier, it is important to distinguish between mortality during cold spells and seasonal mortality patterns. The evidence suggests a warming climate will likely reduce the frequency and severity of extreme cold spells compared with current conditions, with a corresponding reduction in associated mortality. However, it should be recognized that cold spells are a marginal contributor to overall winter mortality. As a result, changes in mortality attributable to cold spells have little potential to shape overall winter mortality. Because colder temperatures during the winter season will continue to occur in a warmer climate, it is reasonable to expect that relatively cold days will continue to increase mortality in susceptible individuals, particularly if temperature variability in winter is a more important risk factor than absolute temperature.

Although temperate regions have much higher mortality rates during the winter, the association between actual temperature and mortality is relatively weak, calling into question the assumption that temperature is the reason for the strong seasonality of, particularly, cardiovascular disease mortality. Cardiovascular disease mortality may be the leading cause of winter deaths, but its association with temperature is weak, with temperature contributing to at most a small proportion of deaths. The relationship between temperature and respiratory disease mortality is stronger, but these deaths are a much smaller proportion of winter deaths. An additional consideration is that winter mortality rates have been decreasing because of infrastructure, health care, and other factors; it is unclear the rate at which this trend will continue, but it would be expected to contribute to a further decline in winter deaths. On the other hand, if populations in regions with newly milder winters adopt protective environmental and behavioral practices similar to those of currently warmer regions, then the rate of mortality decline may slow.

Because in many regions temperature–mortality relationships show a steeper rise at hot than cold extremes[71,72], increasing annual temperatures could lead to larger increases in heat-related mortality than reductions in cold-related mortality.[1–3]

Overall, assuming current relationships and trends, the balance of evidence suggests that climate change is unlikely to dramatically reduce winter mortality.

ACKNOWLEDGMENT

This work was partially funded by Health Canada under contract number 4500180510.

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QUERIES TO BE ANSWERED BY AUTHOR

IMPORTANT NOTE: Please mark your corrections and answers to these queries directly onto the proof at the relevant place. DO NOT mark your corrections on this query sheet.

Queries from the Copyeditor:

AQ1. Please note that as per journal style we have introduced "INTRODUCTION" section.

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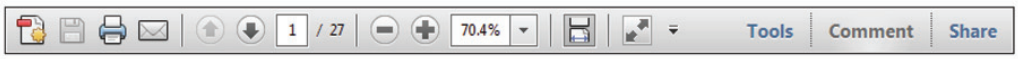
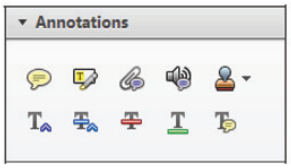
Required software to e-Annotate PDFs: Adobe Acrobat Professional or Adobe Reader (version 7.0 or above). (Note that this document uses screenshots from Adobe Reader X)
The latest version of Acrobat Reader can be downloaded for free at: http://get.adobe.com/uk/reader/

Once you have Acrobat Reader open on your computer, click on the Comment tab at the right of the toolbar:



This will open up a panel down the right side of the document. The majority of tools you will use for annotating your proof will be in the Annotations section, pictured opposite. We've picked out some of these tools below:

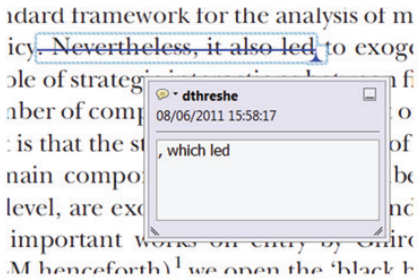


1. Replace (Ins) Tool – for replacing text.

Strikes a line through text and opens up a text box where replacement text can be entered.

How to use it

- Highlight a word or sentence.
- Click on the Replace (Ins) icon in the Annotations section.
- Type the replacement text into the blue box that appears.

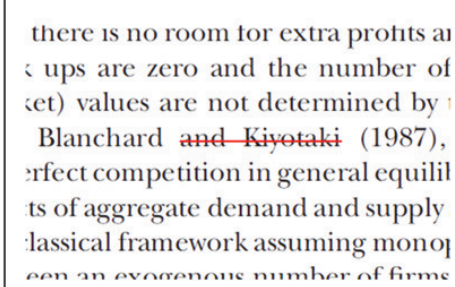


2. Strikethrough (Del) Tool – for deleting text.

Strikes a red line through text that is to be deleted.

How to use it

- Highlight a word or sentence.
- Click on the Strikethrough (Del) icon in the Annotations section.

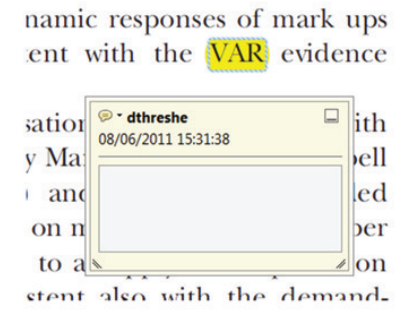


3. Add note to text Tool – for highlighting a section to be changed to bold or italic.

Highlights text in yellow and opens up a text box where comments can be entered.

How to use it

- Highlight the relevant section of text.
- Click on the Add note to text icon in the Annotations section.
- Type instruction on what should be changed regarding the text into the yellow box that appears.

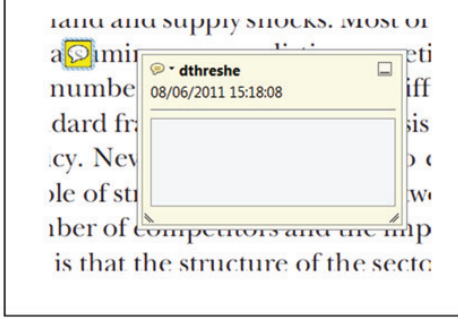


4. Add sticky note Tool – for making notes at specific points in the text.

Marks a point in the proof where a comment needs to be highlighted.

How to use it

- Click on the Add sticky note icon in the Annotations section.
- Click at the point in the proof where the comment should be inserted.
- Type the comment into the yellow box that appears.



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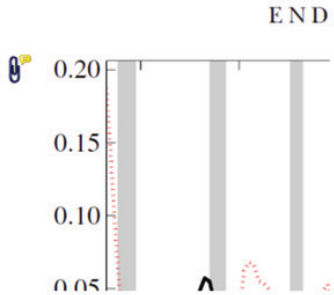
5. Attach File Tool – for inserting large amounts of text or replacement figures.

Inserts an icon linking to the attached file in the appropriate pace in the text.

How to use it

- Click on the Attach File icon in the Annotations section.
- Click on the proof to where you'd like the attached file to be linked.
- Select the file to be attached from your computer or network.
- Select the colour and type of icon that will appear in the proof. Click OK.

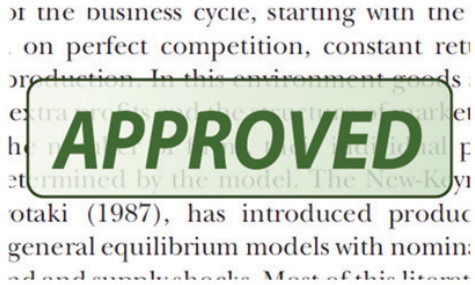


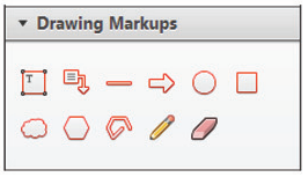
6. Add stamp Tool – for approving a proof if no corrections are required.

Inserts a selected stamp onto an appropriate place in the proof.

How to use it

- Click on the Add stamp icon in the Annotations section.
- Select the stamp you want to use. (The Approved stamp is usually available directly in the menu that appears).
- Click on the proof where you'd like the stamp to appear. (Where a proof is to be approved as it is, this would normally be on the first page).



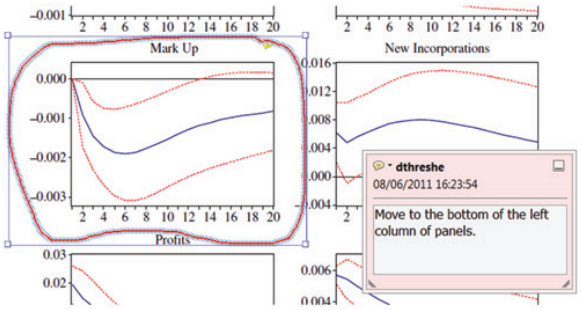


7. Drawing Markups Tools – for drawing shapes, lines and freeform annotations on proofs and commenting on these marks.

Allows shapes, lines and freeform annotations to be drawn on proofs and for comment to be made on these marks..

How to use it

- Click on one of the shapes in the Drawing Markups section.
- Click on the proof at the relevant point and draw the selected shape with the cursor.
- To add a comment to the drawn shape, move the cursor over the shape until an arrowhead appears.
- Double click on the shape and type any text in the red box that appears.



For further information on how to annotate proofs, click on the Help menu to reveal a list of further options: