94 年度「環保署/國科會空污防制科研合作計畫」

成果完整報告

氣象因子變化及異常天候對我國特定疾病發生之衝擊

子計畫二：氣象因子變化及異常天候狀況與我國心臟血管疾病及呼吸道疾病之關係

計畫類別：整合型計畫
計畫編號：NSC 94－EPA－Z－006－002－
執行期間：九十四年　一月　一日至九十四年十二月三十一日

總計畫主持人：蘇慧貞

計畫主持人：郭浩然
共同主持人：
計畫參與人員：鐘雅齡、陳保凱、黃志隆

執行單位：國立成功大學

中　華　民　國　九十五　年　一　月　三十一

目錄

中文摘要

隨著人類科技的進步，慢性疾病如心臟血管疾病、呼吸道疾病的威脅越來越重要。以台灣而言，近年的國人十大死因統計，心臟疾病、腦血管疾病、呼吸系統疾病（含肺炎、慢性阻塞性肺疾病、氣喘等）一直名列前矛。在諸多影響心臟血管疾病與呼吸系統疾病流行的因素當中，氣象因子變化及異常天候狀況的影響逐漸受到重視。雖然國內外已有一些相關研究發表，但仍是一個相當待開發的議題。臺灣的氣候變化極大，有其特殊的考量，需要我們自己進行研究與發展。心臟血管疾病與呼吸系統疾病的預防與控制比治療還要重要，但是，傳統的疾病監視系統並不常包括對氣象因子的考慮。本研究的目的便是要找出臺灣地區心臟血管疾病與呼吸系統疾病資料之常規收集管道，探討氣象因子變化及異常天候狀況對本土心臟血管疾病與呼吸系統疾病之影響，進而評估以氣候因子建構對臺灣之心臟血管疾病與呼吸系統疾病之監視系統的可行性。我們首先以標準化死亡比（SMR）來評估兩種極端氣候事件（颱風與寒流）與心臟血管疾病與呼吸系統疾病之關係；其計算方式是事件前二星期之疾病個案數為分母，以事件後二星期之疾病個案數為分母。我們發現寒流過後的二星期內全臺灣地區心臟血管疾病的死亡率普遍升高，男性之 SMR 為 109.3（95% 信賴區間 107.0 至 111.5），女性之 SMR 為 112.7（95%信賴區間 110.0 至 115.5）。呼吸系統疾病之死亡率也普遍升高，男性之 SMR 為 110.8（95%信賴區間 109.0 至 112.6），女性之 SMR 為 108.7（95%信賴區間 106.1 至 111.3）。利用氣象資料將寒潮影響區域界定出來後，進一步分析發現寒潮過後影響區域二星期內心臟血管疾病的死亡率仍普遍升高，男性之 SMR 為 110.5（95%信賴區間為 108.6 至 112.4），女性之 SMR 為 111.5（95%信賴區間為 107.9 至 115.2）；呼吸道疾病的死亡率亦普遍升高，男性之 SMR 為 111.5（95%信賴區間為 108.0 至 115.2），女性之 SMR 為 112.7（95%信賴區間為 107.9 至 117.7）。將心臟血管疾病進一步細分後發現缺血性心臟病與腦血管疾病不論在男女性都有顯著上升之情況發生；將呼吸道疾病進一步細分後發現肺炎、急性支氣管炎及細支氣管炎與氣喘（哮喘）不論在男女性也都有顯著上升之情況發生。然而颱風的效應較不明顯，需要進一步的分析來釐清。依本研究結果，建議在寒潮來襲前應宣導心臟血管與呼吸系統疾病患者採取禦寒措施，以減少死亡率。

英文摘要

With the advancement of technology, the threats of chronic diseases such as cardiovascular diseases and respiratory diseases are increasingly important. In Taiwan, the statistics of the ten leading causes of death in the recent years showed that heart diseases, cerebrovascular diseases, and respiratory diseases have been the leading ones. Among the factors affecting the spread of cardiovascular diseases and respiratory diseases, the effects of changes in weather factors and abnormal weather conditions have drawn increasing attentions. Some studies have been published in Taiwan and other countries in the world, but this is an area still under-developed. The climate in Taiwan often changes dramatically, and the special considerations need to be taken account call for the research and development of our own. For cardiovascular diseases and respiratory diseases, prevention is far more important than treatment. Nonetheless, the traditional surveillance systems do not take climate factors into account. The objectives of the proposed study are to identify the mechanisms for collecting data on cardiovascular diseases and respiratory diseases in Taiwan on a routine basis, to evaluate the effects of changes in weather factors and abnormal weather conditions on cardiovascular diseases and respiratory diseases, and thus to evaluate the feasibility of establishing a surveillance system for cardiovascular diseases and respiratory diseases in Taiwan that takes climate factors into account. We first evaluated the associations between two types of extreme weather events (typhoon and extreme cold weather) and cardiovascular and respiratory diseases using a standardized mortality ratio (SMR) with the number of deaths due to one of the disease categories (cardiovascular diseases or respiratory diseases) in the 2-week period after the weather event as the nominator and the number of deaths due to that disease categories in the 2-week period before the weather event as the denominator. We found that in the whole Taiwan area the mortality of cardiovascular diseases in the 2-week period after extreme cold weather episodes generally increased with an SMR of 109.3 (95% confidence interval [CI]: 107.0 to 111.5) in men and an SMR of 112.7 (95% CI: 110.0 to 115.5) in women. As to respiratory diseases, the mortality in the 2-week period also generally increased, with an SMR of 110.8 (95% CI: 109.0 to 112.6) in men and an SMR of 108.7 (95% CI: 106.1 to 111.3) in women. When we further defined the affected areas according to the weather data, we found that in the 2-week period after extreme cold weather episodes the mortality of cardiovascular diseases generally increased in the affected areas with an SMR of 110.5 (95% CI: 108.6 to 112.4) in men and an SMR of 111.5 (95% CI: 107.9 to 115.2) in women. Likewise, the mortality due to respiratory diseases in the 2-week period generally increased, with an SMR of 111.5 (95% CI: 108.0 to 115.2) in men and an SMR of 112.7 (95% CI: 107.9 to 117.7) in women. When we broke down cardiovascular diseases into smaller categories, we found that the mortality due to ischemic heart disease and cerebrovascular disease increased significantly in both men and women after extreme cold weather episodes. Similarly, when we broke down respiratory diseases into smaller categories, we found the mortality due to pneumonia and acute bronchitis and bronchiolitis as well as asthma also increased significantly in both genders. However, the effects of typhoons on health appeared to be less prominent, and further analyses are needed to better characterize the associations. The results of this study suggest the issue of warning to patients of cardiovascular and respiratory diseases before the attacks of extreme cold weather, so that they can take preventative measures to decrease the mortality rate.

INTRODUCTION

With the advancement of modern technology, we have found treatment for many health problems of the human beings, but new challenges keep emerging. In the developing countries, the major life-threatening diseases are mainly infectious diseases, but in the developed countries they are mainly the chronic diseases. In Taiwan, according to the statistics published by the Department of Heath, cardiovascular diseases (especially particularly heart diseases and cerebrovascular diseases) and respiratory diseases (including pneumonia, chronic obstructive pulmonary diseases [COPD], and asthma) have been among the leading causes of death for decades. In particular, cerebrovascular accident (stroke) has been the second leading cause of death since 1983 except for 1999 (as the third), and heart diseases has been the fourth leading cause of death from 1982 to 1999 except for 1998 (as the third) and the third leading cause of death since 2000. Among respiratory diseases, pneumonia alone has been the seventh or eighth leading cause of death in the past decade (Department of Health, 2005).

A study encompassing 12 cities in the United States found that high temperature was related to the mortality of both myocardial infarction and COPD (Braga et al., 2002), and a study in the New Zealand found each increase of 1°C in the temperature was associated with a 3% increase in the mortality of respiratory diseases (Hales et al., 2000). On the other hand, decreases in the temperature were also found to be associated with increases in hospital visits due to myocardial infarction and COPD in London, the United Kingdom. (Hajat and Haines, 2002). In addition, a study in the tropical area, like the southern part if Taiwan, found climatic variables accounted for 18% of the hospitalizations and visits to the emergency department due to asthma, and the most significant variables included pressure, changes in temperature, the speed of winds, and relative humidity (Ivey et al., 2003).

In a previous study of our research team, we found the diurnal changes in the temperature was related the visits to the emergency department due to asthma (Kuo and Guo, 2004). An analysis of the ten leading causes of death in the mountain areas in Taiwan from 1968 to 1980 found the number of deaths due to pneumonia was highest from June to August, the high season of typhoon (Liu, 1983). While the effects of air pollutants on respiratory diseases have been extensively studied, a study on asthmatic patients in Taipei found climate factors had greater impacts than air pollutants (Yang, 2001).

As to cerebrovascular diseases, a study in the Ilan area found the colder the weather the higher the incidence of stroke (Chen et al., 1995), and a study in Kaohsiung found that the temperature could affect the effects of air pollutants on stroke (Tsai et al., 2003). For cardiovascular diseases, a study in the northern Taiwan found the mortality of myocardial infarction reached the peak in cold weather (Liu, 2002).

It is feasible to predict cardiovascular diseases and respiratory diseases on the basis of weather factors. Storms have been found to be associated with asthmatic attacks among children in both the United Kingdom and Australia (Higham et al., 1997; Girgis et al., 2000), and a study in Chicago found heat waves increased the hospitalizations due to cardiovascular diseases and emphysema (Semenza et al., 1999). Dust storms are special natural events in the Asia, and a study in Korea found associated increases in the mortality of both cardiovascular diseases and respiratory diseases (Kwon et al., 2002).

The weather in Taiwan is different from most of the other countries, and therefore we need to conduct our own study to evaluate the effects of weather factors and extreme weather events on cardiovascular and respiratory diseases.

OBJECTIVES

The goal of this project is to evaluate the effects of weather factors and extreme weather events on cardiovascular diseases and respiratory diseases. The specific aims include the following:

1. Collect and review the literature on the effects of weather factors and extreme weather events on cardiovascular diseases and respiratory diseases.
2. Identify weather factors and extreme weather events that may affect the occurrence of cardiovascular diseases and respiratory diseases in Taiwan.
3. Collect the data on weather factors, extreme weather events, cardiovascular diseases and respiratory diseases in Taiwan.
4. Evaluate the effects of weather factors and extreme weather events on cardiovascular diseases and respiratory diseases.

Considering the situation of Taiwan, we decided to start with two types of distinct extreme weather events after an initial evaluation: typhoon and extreme cold weather event, which is defined as a sudden drop in the temperature greater than 8 °C.

REVIEW OF LITERATURE

The possible effects of cold weather on cardiovascular diseases have been noted for more than a decade. A comparison of the seasonal variation in total mortality and deaths from cardiovascular, respiratory, and malignant disease between North-East Scotland (Grampian region) and Kuwait found similar seasonal differences, in both timing and degree, for deaths from circulatory disease, and the peak mortality was during winter in both areas; specifically, the cardiovascular deaths had an about 20% increase in January (Douglas et al., 1991). A prospective study on 517 elder patients (mean age 81 ± 8 years) with congestive heart failure after prior myocardial infarction who died in a nursing home in New York City with 24-hour on-site physician coverage found 321 deaths (62%) of them occurred during the months of December, January, February, March, July, and August (p <0.0001) and concluded that the number of deaths in cold weather and warm weather months was significantly higher than those in spring and fall months (Aronow and Ahn, 2004). A study in South Australia collected data on atrial fibrillation-related admissions to a coronary care unit during the 30 hottest and coldest days (60 days in total) during the calendar year 2001 and found significantly more admissions on "cold" as compared to "hot" days (90 *vs.* 54 patients, p < 0.001) (Kiu et al., 2004). A group of researchers analyzed the data on 5458 patients of non-fatal acute coronary syndromes who admitted to five major hospitals in the greater Athens area in Greece from January 2001 to August 2002 and found a negative correlation between hospital admissions and mean daily temperature—a 1°C decrease was associated with a 5% increase in admissions ($p < 0.05$). They found the association was stronger in females and the elderly ($p < 0.01$) (Panagiotakos et al., 2004). A study in Washington, United States on 62,125 out-of-hospital cardiac-related deaths among persons 55 years and older occurred between 1980 and 2001 observed a significant negative association between daily average temperature and cardiac mortality—a 5 °C increase in temperature was associated with a decrease in death rate by a factor of 0.971 (95% CI: 0.961, 0.982). The researchers concluded that cold temperatures may be an important triggering factor in bringing on the onset of life-threatening cardiac events, even in regions with relatively mild winters and suggested that public health efforts stressing cold exposure while out of doors may play a prominent role in encouraging a reduction in cold stress, especially among seniors and those already at higher risk of cardiac death (Cagle and Hubbard, 2005). A investigation on winter North Atlantic Oscillation (NAO), which exerts a fundamental control on the nature of the winter climate over Western Europe, and mortality due to ischemic heart disease applied a climate index that represents the interaction between the NAO and temperature across England for the winters 1974-1975 to 1989-1999 and found significant inverse associations between the index and the mortality were found. The researcher concluded that because winter climate is able to explain a good proportion of the inter-annual variability of winter mortality, long-lead forecasting of mortality due to ischemic heart disease in winter appears to be feasible (McGregor, 2005). A worldwide study analyzed the data from a 21 country register made between 1980 and 1995 of people aged 35 to 64 years and found in cold periods, coronary event rates increased more in populations living in warm climates than in populations living in cold climates, and the increase was greater in women than in men (odd ratio [OR] = 1.07, 95% confidence interval [CI]: 1.03 to 1.11). The effects of cold periods were similar in those with and without a history of a previous myocardial infarction, and the researchers suggested people living in warm climates, particularly women, should keep warm on cold days (Barnett et al., 2005). In particular, a study in Taiwan found levels of all hemostatic parameters, except prothrombin time, were statistically different between days with mean temperature > 20 °C and days with temperature ≤ 20 °C ($p < 0.01$) and conclude that there was a greater tendency to clot in circulatory system in cold weather (Yeh, et al., 1996).

The possible effects of cold weather on respiratory diseases have been noted for several decades. A study on 195 ex-servicemen from Victoria New South Wales and Queensland found weather conditions, especially cold weather, affected chest symptoms (Tandon, 1976), and a study in the Greater London Area found a tendency for influenza epidemics to follow cold spells, while the association seen in the 1950s and early 1960s between daily mortality and air pollution in the conurbation is no longer apparent (Macfarlane, 1977). A questionnaire survey in Goteborg, where the average winter temperature there is about freezing point, found about two-thirds of the asthmatic patients reported cold to be a factor causing breathing difficulties, while the control group reported very few respiratory symptoms (Millqvist et al., 1987). An analysis of deaths in Massachusetts, Michigan, Washington, Utah, North Carolina, and Mississippi from 1930 to 1985 found that a temperature increase throughout the year was associated with fewer deaths from all causes combined, including deaths from infectious diseases, heart diseases, cerebrovascular diseases, pneumonia, and influenza and that unusually cold weather was followed by more deaths (Larsen, 1990). A study found the cooling of the skin of the face seems to be the trigger for the bronchoconstriction during resting nasal ventilation at cold ambient temperature both in asthmatic and nonasthmatic subjects (Koskela and Tukiainen, 1995), and another study found that environmental exposure to low ambient air temperature caused an increase of ventilatory function tests in healthy subjects and a decrease in asthmatics, particularly in flow rates at lower lung volumes (Zuskin et al., 1996). While a study on 19 patients with stable COPD found cold air reduces breathlessness in COPD (Spence et al., 1993), a study on 20 patients with COPD in stable condition and 13 healthy subjects found cooling of the facial skin is predominantly responsible for the bronchoconstriction due to cold weather both in patients with COPD and in healthy subjects and speculated that some patients with severe COPD might benefit from wearing protective clothing over their face in cold weather (Koskela et al., 1996). An analysis of 160,062 deaths in Michigan, United States, among persons who were 65 years of age or older, covered by Medicare, and had a previous hospital admission for heart and lung disease defined “cold days” as those less than the 1st percentile temperature of all days and found persons with COPD had elevated risks of dying on cold days (relative risk [RR] = 1.19, 95 % CI: 1.07 to 1.33) (Schwartz, 2005).

Some studies have studied the effects on the cardiovascular and respiratory diseases simultaneously. A analysis of the 1992 data in Athens and Palermo found that high indices of cold-related mortality were associated with high mean winter temperatures, low living-room temperatures, limited bedroom heating, low proportions of people wearing hats, gloves, and anoraks, and inactivity and shivering when outdoors at 7 ºC ($p < 0.01$ for all-cause mortality and respiratory mortality; $p > 0.05$ for mortality from ischemic heart disease and cerebrovascular disease) (Anonymous, 1997). The study comparing the seasonal variation in mortality between the Grampian region and Kuwait mentioned above found similar seasonal differences in deaths from respiratory diseases as well. For both areas the timing of respiratory deaths peaked in February, but the amplitude was 46% in Kuwait compared to 33% in Grampian (Douglas et al., 1991). A study in the United States compared days of "extreme" climatic conditions (snowfall greater than 3 cm and temperatures -7 ºC) with days of milder conditions found the mortality due to ischemic heart diseases tripled among men aged 35-49 years (RR = 3.54, 95 % CI: 2.35 to 5.35), increased for men aged 50-64 years (RR = 1.77, 95 % CI: 1.32 to 2.38), and rose for men aged 65 years and older (RR = 1.58, 95 % CI: 1.37 to 1.82). Among women, mortality for those aged 65 years and older increased for both respiratory causes (RR = 1.68, 95 % CI: 1.28 to 2.21) and cerebrovascular causes (RR = 1.47, 95 % CI: 1.13 to 1.91). Accordingly, the authors conclude cold and snow exposure may be hazardous among men as young as 35 years old (Gorjanc et al., 1999). A study analyzed the consultation data from 45 to 47 London practices contributing to the General Practice Research Database between January 1992 and September 1995, which included between 38 452 and 42 772 registered patients aged 65 years or older, to determine whether there were relationships between cold temperatures and cardio-respiratory mortality in the elderly and to assess the lag time at which the effects were observed. After controlling for possible confounders and adjusting for overdispersion and serial correlation, it found little relationship of consultations for respiratory disease with the mean temperature on the same day but observed a strong association with temperature levels up to 15 days previously, particularly when the temperature dropped below 5 ºC—for every 1 ºC decrease in mean temperatures below 5 ºC was associated with a 10.5% (95% CI: 7.6% to 13.4%) increase in all respiratory consultations. However, the study found no relationship between cold temperatures and cardiovascular disease consultations. The researchers conclude that such information could be used to help healthcare providers to anticipate increases in respiratory consultation rates after the attacks of low temperatures (Hajat and Haines, 2002). Another study in the United States obtained data on 12 cities found that in cold cities both high and low temperatures were associated with increased deaths due to cardiovascular diseases, but, the effect of cold temperatures persisted for days, whereas the effect of high temperatures was restricted to the day of the death or the day before. The effect of hot days on myocardial infarction was twice as large as the cold-day effect, but for all cardiovascular disease deaths combined, the hot-day effect was five times smaller than the cold-day effect. On the other hand, in cities with hot weather, neither hot nor cold temperatures had significant effects on deaths due to cardiovascular diseases or pneumonia (Braga et al., 2002). A group of researchers in Spain analyzed the data on a total of 133,000 deaths occurred on 1,815 winter days over the period 1986-1997 in Madrid among people older than 65 and found the daily maximum temperature to be the best thermal indicator of the impact of climate on the mortality. After a temperature extreme, the maximum impact on circulatory disease mortality occurred with a lag between 7 and 14 days, and when respiratory mortality was considered, two mortality peaks were evident at 4 to 5 and 11 days. In comparison with summer extremes, the impact of winter extreme temperatures occurred over a longer term and appeared to be more indirect (Diaz et al., 2005). A study examined further the lag of effects using the data from the three largest Scottish cities (Glasgow, Edinburgh, and Aberdeen) between January 1981 and December 2001 and found temperature was a significant predictor of mortality with the strongest association with respiratory mortality. The association between mortality and temperature was non-linear—mortality increased as temperatures fell throughout the range, but the rate of increase was steeper at below 11 °C. In particular, the association persisted at lag periods beyond two weeks but the effect size generally decreased with increasing lag. For temperatures < 11 °C, a 1 °C drop in the daytime mean temperature on any one day was associated with an increase in mortality of 2.9% (95% CI: 2.5 to 3.4), 3.4% (95% CI: 2.6 to 4.1), 4.8% (95% CI: 3.5 to 6.2) and 1.7% (95% CI: 1.0 to 2.4) over the following month for all cause, cardiovascular, respiratory, and "other" cause mortality respectively (Carder et al, 2005). These studies have the benefit to compare the effects on cardiovascular diseases and respiratory diseases, and overall the findings suggest the effects are different, while both are generally remarkable.

Unlike the health effects of cold weather, literature on the effects of typhoon on the health of human beings is very limited. Using "typhoon" and "hurricane," the same extreme weather event in the Atlantic Ocean as typhoon in the Pacific Ocean, combining "cardiovascular disease," "myocardial ischemia," "coronary disease," "cerebrovascular accident," and “hypertension” as key words to search using Medline, we found only one article on Hurricane Iniki, a Class III/IV storm passing directly over Kauai on September 11, 1992 and damaging 70% of the homes (Hendrickson et al, 1997). The authors claimed that it was the first attempt to measure increases in injuries and other health outcomes among an entire population in the impact zone of a hurricane. They abstracted medical chart data were from all facilities providing primary and emergency care on Kauai to assess incidence of injury, cardiovascular disease, and asthma for the 2-week period following the Hurricane and were compared the data to those for the preceding 2-week period. In addition the increase in injuries, they found physician visits for asthma and cardiovascular disease were also significantly increased in the post-Iniki period with relative risks of 2.81 and 2.73 and 95% CIs of 1.93 to 4.09 and 1.51 to 4.94, respectively. However, no changes occurred in the proportion of patients needing hospitalization. Using the names of the authors, we found one additional article on the topic (Hendrickson and Vogt, 1996), which compared mortality data for the 5 years preceding Hurricane Iniki with mortality data for the 12 months immediately following. The study found the hurricane did not appear to significantly increase the risk of dying of Kauai residents in the 12 months immediately following the disaster, and the only significant increase was in the rate of diabetes mellitus-related deaths (RR = 2.61, 95% CI: 1.44 to 4.74).

Using “lung diseases,” “respiratory tract diseases,” “bronchitis,” “lung diseases, obstructive,” “asthma,” and “pneumonia” as key words, we found two additional articles on the health effects on respiratory diseases, both on asthma. The first was on the outbreaks of asthma attack on 345 Japanese patients in relation to the atmospheric phenomena and found about 76% of days in which multiple attacks took place were fit with the trough of atmospheric pressure, the approach of typhoon, or the cold advection. (Kanaya, 2001) The common feature of these different atmospheric conditions are the tendency to turn excess vapor into fine water particles (fine mist), and the author hypothesized that fine mist could stimulate irritable airway to asthma attacks ("fine mist" hypothesis). To verity this hypothesis the author studied further and found the frequency of attacks varied in every month in the fitting group but was nearly constant in non-fitting group. The author the graphic pattern of the average daily change of vapor density was similar to that of asthmatic attack frequency. The other study correlated outbreaks of asthma attack and meterologic parameters in the Okinawa Island, which belongs to the subtropics like the northern part of Taiwan (Hanashiro et al., 1998). The number of patients carried to hospitals by ambulance on asthma attacks was investigated for 3 years, and the authors found that the changes of meteorologic parameters on the passing over of typhoon, especially the decrease of temperature and barometric pressure, were related to asthma attacks.

MATERIALS AND METHODS

The first part of the work in this project is the review of the literature. In addition to "weather," we used "typhoon," "hurricane," "cold climate," "cold weather," "low temperature," and "cold front" as key words to search literature on the health effects of typhoon and extreme cold weather. In addition, we used "cardiovascular disease," "myocardial ischemia," "coronary disease," "cerebrovascular accident," and "hypertension" as key words to search literature on cardiovascular diseases and "respiratory tract diseases," "bronchitis," "lung diseases, obstructive," "asthma," and "pneumonia" as key words to search literature on respiratory diseases. The results of the literature search have been summarized in the previous section.

We started the evaluation of the association between extreme weather events and cardiovascular and respiratory diseases with the overall mortality. As described previously, we looked at two types of distinct extreme weather events: typhoon, with a focus on those affect the whole Taiwan area, and extreme cold weather events, which is defined as a sudden drop in the temperature greater than 8 °C. Consequently, a total of 24 episodes of extreme cold weather were identified from 1994 to 2003, and 156 episodes of typhoon affecting the whole Taiwan area were identified from 1971 to 2003.

The associations were evaluated using a standardized mortality ratio (SMR) with the number of deaths due to one of the disease categories (cardiovascular diseases or respiratory diseases) in the 2-week period after the weather event as the nominator and the number of deaths due to that disease categories in the 2-week period before the weather event as the denominator. This approach was adopted from a previous study (Hendrickson et al, 1997). In the cases when there were overlaps between the two study periods associated with more than one event, the pre- and post-episode periods was defined by the first event of the episode. The computerized data base of death certificates in the whole Taiwan area was obtained from the Department of Health, and the data on the population size in each township in Taiwan by gender and age were adopted from reports of the Department of Interior. To identify specific diseases associated with the weather factors, we further divided cardiovascular diseases into "chronic rheumatic heart disease," "primary hypertension," "hypertensive heart disease," "ischemic heart disease," "inflammatory heart disease," "cardiogenic arrhythmia," and "cerebrovascular disease" and respiratory diseases into "upper respiratory tract infection," "influenza," "chronic bronchitis," "emphysema," "asthma," and "pneumonia and acute bronchitis and bronchiolitis."

Details data on the areas affected by each extreme cold weather episodes were obtained from another sub-project of the program project, which were constructed on the basis of information obtained from the Central Weather Bureau.

Because the typhoons included in our analysis affects the whole Taiwan area within one day, we studied their effects on the Taiwan area as a whole. However, in terms of the extreme cold weather events, there were more remarkable differences in the affecting time across different areas in Taiwan, and therefore, we divided the Taiwan Island into four divisions, namely “north,” “central,” “south,” and “east.” All statistical tests were performed using the SAS software at the two-tailed significance level of 0.05.

RESULTS

After the 24 extreme cold weather episodes that affected the whole Taiwan area from 1994 to 2003, the mortality of cardiovascular diseases in the 2-week period generally increased with an SMR of 109.3 (95% CI: 107.0 to 111.5) in men and an SMR of 112.7 (95% CI: 110.0 to 115.5) in women. When we broke down cardiovascular diseases into smaller categories (chronic rheumatic heart disease, primary hypertension, hypertensive heart disease, ischemic heart disease, inflammatory heart disease, cardiogenic arrhythmia, and cerebrovascular disease), we found that the mortality due to all the seven cardiovascular diseases increased, with the highest for inflammatory heart disease (SMR = 117.9, 95%CI: 106.5 to 130.2) and the lowest for primary hypertension (SMR = 107.6, 95%CI: 102.3 to 113. (Table 1)

However, when we broke down respiratory diseases into smaller categories (upper respiratory tract infection, influenza, chronic bronchitis, emphysema, asthma, and pneumonia and acute bronchitis and bronchiolitis), we found only the mortality due to pneumonia and acute bronchitis and bronchiolitis (SMR = 113.5, 95%CI: 110.2 to 116.9) as well as asthma (SMR = 116.9, 95%CI: 111.3 to 122.7) increased significantly. (Table 1) In addition, non-significant increases were observed for the mortality due to chronic bronchitis (SMR = 106.7, 95%CI: 95.6 to 118.7) and emphysema (SMR = 106.3, 95%CI: 96.0 to 117.5). (Table 1) Whereas a decreased mortality was observed for upper respiratory tract infection (SMR = 9643, 95%CI: 85.1 to 108.7) and influenza (SMR = 92.3, 95%CI: 68.1 to 122.4), the decreases were not statistically significant. (Table 1)

When the whole Taiwan Island was divided into north, central, south, and east divisions, the mortality was generally increased over the years in all divisions in both genders. Among them, the increases were statistically significant in seven episodes in the north and central, eight in the south, and two in the east in men. In addition, the episode on Jan 22, 2000 was associated with increased mortality of cardiovascular diseases in all four divisions. (Table 2) In women, the increases were statistically significant in four episodes in the north, nine in the central, eight in the south, and five in the east. None of the episodes was associated with significantly increased mortality of cardiovascular diseases in all four divisions. (Table 3) Nonetheless, in men, the mortality of cardiovascular diseases decreased in three episodes in the southern division, two episodes in the eastern division, and one episode each in the northern and central divisions. (Table 2) In women, the mortality of cardiovascular diseases decreased in one episode each division. (Table 3) None of the episodes was associated with significantly decreased mortality of cardiovascular diseases in all four divisions in either gender. (Tables 2 and 3)

Because extreme cold weather episode may affect only a portion of the whole Taiwan area, we defined the affected areas of each episode by township and analyze the data in greater details. When we further defined the affected areas according to the weather data, we found that in the 2-week period after extreme cold weather episodes the mortality of cardiovascular diseases generally increased in the affected areas with an SMR of 110.5 (95% CI: 108.6 to 112.4) in men and an SMR of 111.5 (95% CI: 107.9 to 115.2) in women, both were statistically significant. Among the 24 episodes, there were twice in which the mortality of cardiovascular diseases in men was significantly decreased (Table 6), and once in which the mortality of cardiovascular diseases in women was significantly decreased (Table 7). The mortality of cardiovascular diseases was significantly increased in 13 episodes in both men and women. (Tables 6 and 7)

When we broke down cardiovascular diseases into smaller categories (chronic rheumatic heart disease, primary hypertension, hypertensive heart disease, ischemic heart disease, inflammatory heart disease, cardiogenic arrhythmia, and cerebrovascular disease), we found that the mortality was increased for all seven types of the diseases in both genders, except for Inflammatory heart disease among women (SMR = 98.2, 95%CI: 80.4 to 118.7). In particular, the mortality due to ischemic heart disease (SMR = 109.5, 95%CI: 106.0 to 113.1 in men and SMR = 112.4, 95%CI: 107.8 to 117.3 in women) and cerebrovascular disease (SMR = 111.8, 95%CI: 109.2 to 114.4 in men and SMR = 110.1, 95%CI: 107.0 to 113.1 in women) increased significantly in both men and women after extreme cold weather episodes. In addition, among men, significant increases were also observed for inflammatory heart disease (SMR = 127.8, 95%CI: 111.7 to 145.7) and cardiogenic arrhythmia (SMR = 112.4, 95%CI: 102.4 to 123.1). (Table 8) Among women, a significant increase was also observed for hypertensive heart disease (SMR = 126.0, 95%CI: 116.2 to 136.3). (Table 9)

As for respiratory diseases, the mortality in the 2-week period also generally increased, with an SMR of 110.8 (95% CI: 109.0 to 112.6) in men and an SMR of 108.7 (95% CI: 106.1 to 111.3) in women. When the whole Taiwan Island was divided into four divisions, the mortality of respiratory diseases was generally increased over the years in all divisions in both genders, except for that the increase in men in the eastern division was not statistically significant, with an SMR of 105.8 (95% CI: 98.4 to 113.7). Among them, the increases were statistically significant in six episodes in the north, eight in the central, ten in the south, and four in the east in men. None of the episodes was associated with significantly increased mortality of respiratory diseases in all four divisions. (Table 4) In women, the increases were statistically significant in nine episodes in the north, seven in the central, five in the south, and three in the east. None of the episodes was associated with significantly increased mortality of respiratory diseases in all four divisions. (Table 5) Nonetheless, the mortality of respiratory diseases decreased in both genders the southern division in one episode. Furthermore, in men, the mortality of respiratory diseases decreased in one episode each in the eastern and central divisions (Table 4), and in women, the mortality of respiratory diseases decreased in two episodes in the southern division and one episode in the northern division (Table 5). None of the episodes was associated with significantly decreased mortality of respiratory diseases in all four divisions in either gender. (Tables 5 and 6)

Likewise, when we further defined the affected areas according to the weather data, we found the mortality due to respiratory diseases in the 2-week period generally increased, with an SMR of 111.5 (95% CI: 108.0 to 115.2) in men and an SMR of 112.7 (95% CI: 107.9 to 117.7) in women. Again, both were statistically significant. Among the 24 episodes, there were twice in which the mortality of respiratory diseases in men was significantly decreased (Table 6), and once in which the mortality of respiratory diseases in women was significantly decreased (Table 7). The mortality of respiratory diseases was significantly increased in 8 episodes in men and 7 episodes in women. (Tables 6 and 7)

When we broke down respiratory diseases into smaller categories (upper respiratory tract infection, influenza, chronic bronchitis, emphysema, asthma, and pneumonia and acute bronchitis and bronchiolitis), we found the mortality due to pneumonia and acute bronchitis and bronchiolitis (SMR = 112.9, 95%CI: 108.3 to 117.6 in men and SMR = 115.3, 95%CI: 109.0 to 121 in women) as well as asthma (SMR = 112.6, 95%CI: 104.9 to 120.8 in men and SMR = 114.8, 95%CI: 105.2 to 125.1 in women) also increased significantly in both genders. In addition, among men, a significant increase was also observed for chronic bronchitis (SMR = 116.3, 95%CI: 100.2 to 135.9). (Table 8) Among women, a significant increase was also observed for emphysema (SMR = 136.4, 95%CI: 104.1 to 175.5). (Table 9) In addition, non-significant increases in the mortality were observed for upper respiratory tract infection (SMR = 101.6, 95%CI: 84.6 to 121.0) and emphysema (SMR = 101.6, 95%CI: 89.5 to 115.0） among men. (Table 8)

The effects of typhoon on health seemed less prominent. Among the 156 typhoon episodes that affected the whole Taiwan area from 1971 to 2003, mortality of cardiovascular diseases increased in 16 in men and in 6 in women, but none in both genders. However, the mortality of cardiovascular diseases decreased in 5 in men, in 20 in women, and in 4 in both genders. In 2 episodes, the mortality of cardiovascular diseases increased in men but decreased in women. As to the mortality of respiratory diseases, it increased in 11 in men, in 7 in women, and in 3 in both genders. But, the mortality of respiratory diseases decreased in 12 in men, in 23 in women, and in 6 in both genders. In 4 episodes, the mortality of respiratory diseases increased in men but decreased in women, but in another episode the mortality of respiratory diseases decreased in men but increased in women. Therefore, for typhoons, we did not observe a consistent pattern of the changes in the mortality due to cardiovascular diseases or respiratory diseases following their attacks.

While we tried to limit our analyses on the effects of extreme cold weather episodes to the townships that were actually affected by each episode, we did not observe a remarkable improvement in the associations between the attacks and the changes in mortality. Therefore, the results indicated that in issuing warning to people at risk, it is not necessary to predict precisely the affected area of the extreme cold weather episode.

In summary, we found the temperature as represented by extreme cold weather episodes is a good predictor of mortality due to both cardiovascular diseases and respiratory diseases, not only for the affected areas, but also for the whole Taiwan Island. In particular, extreme cold weather episodes had most consistent significant impact on the mortality due to ischemic heart disease, cerebrovascular disease, and asthma. Therefore, it is feasible to issue warning to the population at risk on the basis of weather factors. Since many weather parameters are collected by the Central Weather Bureau on a routine basis, it is cost beneficial to establish surveillance system on the basis of weather factors. Nonetheless, temperature may not be the only useful weather in predicting can affect the health of human beings, and it is very likely that other weather episodes may also have impacts on human health. Furthermore, the effects of weather may not be limited to those on cardiovascular diseases and respiratory diseases. Therefore, further studies should be conducted to identify other weather factors that may affect the occurrence of diseases of human beings and to identify other diseases that may be affected by weather factors. In particular, since many parameters of air quality are also collected by the government agencies on a routine basis and many air pollutants are known to affect human heath, further studies should be conducted to evaluate the possible interactions between weather factors and air pollutants on the health of human beings.

SUGGESTIONS

Suggestion	Rationale	Executive Organization
Establish a warning system for health effects of cold temperature.	The results of our study showed that extreme cold weather episode may increase the mortality of both cardiovascular and respiratory diseases, and therefore it is feasible to establish a surveillance system that can issue warnings when an extreme cold weather episode is expected.	Main: Central Weather Bureau Supporting: Department of Health
Design educational materials on the health effects of cold temperature.	The results of our study showed that extreme cold weather episode may increase the mortality of both cardiovascular and respiratory diseases, and therefore it is very important to design education materials to raise awareness of the general public the potential hazards of extreme cold weather episodes.	Main: Department of Health Supporting: mass media
Conduct further studies on the health effects of other weather event.	Our study showed cold temperature can affect the health of human beings, and it is very likely that other weather events may also have impacts on human health.	Main: National Science Council or National Health Research Institute Supporting: Central Weather Bureau and Center for Disease Control

EVALAUTIONS

The contents of the study fit the original proposal with the focus on tow major extreme weather events. Although the results on the effects of typhoon do not appear as useful as we expected, the results on the effects of extreme cold weather episode are clear and have both scientific and application value. In short, we found extreme cold weather episodes had significant impacts on the mortality of both cardiovascular and respiratory diseases, which are compatible with findings in most studies conducted in other areas in the world. We believe the results are suitable to be published in the scientific journals and will try to prepare manuscript(s) accordingly.

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Table 1. Standardized mortality ratios (SMRs) and associated 95% confidence intervals (CIs) of various cardiovascular and respiratory diseases during the two-week period following extreme cold weather events in comparison with the two-week period prior to the events, 1994 to 2003.

Diseases	Cases		SMR	95% CI
	Observed	Expected		
Cardiovascular diseases				
Chronic rheumatic heart disease	399	358	111.5	100.8, 122.9*
Primary hypertension	1529	1421	107.6	102.3, 113.1*
Hypertensive heart disease	1478	1307	113.1	107.4, 119.0*
Ischemic heart disease	7078	6404	110.5	108.0, 113.1*
Inflammatory heart disease	389	330	117.9	106.5, 130.2*
Cardiogenic arrhythmia	964	872	110.6	103.7, 117.8*
Cerebrovascular disease	14712	13358	110.1	108.4, 111.9*
Respiratory diseases				
Upper respiratory tract infection	264	274	96.4	85.1, 108.7
Pneumonia and acute bronchitis and bronchiolitis	4385	3863	113.5	110.2, 116.9*
Influenza	48	52	92.3	68.1, 122.4
Chronic bronchitis	336	315	106.7	95.6, 118.7
Emphysema	386	363	106.3	96.0, 117.5
Asthma	1632	1396	116.9	111.3, 122.7*

* $p<0.05$

Table 2. Standardized mortality ratios (SMRs) and associated 95% confidence intervals (CIs) of cardiovascular diseases among men during the two-week period following extreme cold weather events in comparison with the two-week period prior to the events by geographic area, 1994 to 2003.

Date	North	Central	South	East
1994/1/16	126.32 (107.94, 146.93) *	115.79 (95.16, 139.56)	90.76 (74.45, 109.57)	70.83 (41.24, 113.42)
1994/2/28	107.43 (91.38, 125.49)	94.06 (76.10, 114.98)	77.14 (63.28, 93.14) *	153.85 (93.93, 237.62)
1995/1/1	108.96 (92.00, 128.13)	96.51 (76.87, 119.64)	96.77 (80.23, 115.72)	180.00 (118.59, 261.90) *
1995/1/28	100.64 (85.51, 117.67)	150.00 (125.76, 177.54) *	115.17 (98.37, 134.03)	138.89 (89.86, 205.04)
1995/3/1	95.24 (80.11, 112.39)	74.58 (59.81, 91.88) *	78.15 (63.08, 95.74) *	22.73 (7.32, 53.04) *
1995/3/22	102.24 (85.83, 120.86)	109.57 (89.44, 132.89)	92.23 (74.62, 112.75)	162.50 (86.44, 277.90)
1995/12/27	119.05 (99.09, 141.84)	111.76 (90.42, 136.63)	92.38 (74.91, 112.70)	55.00 (27.42, 98.42) *
1996/1/5	105.38 (88.48, 124.58)	78.72 (61.81, 98.83) *	125.00 (102.73, 150.66) *	140.00 (76.47, 234.91)
1996/1/30	92.86 (78.26, 109.39)	127.50 (103.96, 154.78) *	126.74 (104.07, 152.89) *	100.00 (57.12, 162.40)
1996/2/17	116.18 (98.77, 135.77)	111.88 (92.20, 134.51)	101.72 (84.20, 121.82)	66.67 (31.92, 122.61)
1996/12/2	117.39 (98.42, 138.95)	104.88 (83.89, 129.53)	108.33 (87.22, 133.01)	133.33 (76.16, 216.54)
1997/1/6	103.25 (86.07, 122.85)	88.54 (70.72, 109.48)	111.46 (91.34, 134.69)	136.36 (76.27, 224.93)
1997/1/20	96.77 (80.23, 115.72)	89.01 (70.68, 110.63)	110.19 (91.28, 131.85)	86.67 (46.10, 148.21)
1997/2/13	123.68 (104.11, 145.87) *	123.33 (101.46, 148.53) *	102.54 (85.09, 122.53)	140.00 (86.63, 214.02)
1998/1/20	116.88 (100.72, 134.88) *	160.98 (134.68, 190.90) *	171.11 (145.15, 200.37) *	143.75 (91.10, 215.71)
1998/2/1	87.43 (74.68, 101.75)	100.80 (83.97, 120.02)	106.57 (89.98, 125.33)	95.24 (58.15, 147.10)

* $p<0.05$

Table 2 (continued). Standardized mortality ratios (SMRs) and associated 95% confidence intervals (CIs) of cardiovascular diseases among men during the two-week period following extreme cold weather events in comparison with the two-week period prior to the events by geographic area, 1994 to 2003.

Date	North	Central	South	East
1999/1/11	97.71 (81.52, 116.18)	93.90 (74.10, 117.36)	88.54 (70.72, 109.48)	78.95 (44.15, 130.22)
1999/1/30	82.40 (67.26, 99.94) *	102.53 (81.42, 127.44)	137.21 (113.57, 164.32) *	133.33 (85.40 198.40)
1999/2/15	146.08 (123.56, 171.51) *	112.20 (90.44, 137.60)	108.40 (90.50, 128.81)	112.50 (74.12, 163.69)
1999/12/17	133.33 (113.93, 155.09) *	150.00 (121.50, 183.18) *	151.85 (126.20, 181.18) *	111.11 (53.19, 204.35)
2000/1/22	137.40 (117.46, 159.75) *	170.69 (138.72, 207.81) *	139.58 (116.95, 165.32) *	200.00 (128.10, 297.60) *
2001/12/20	124.58 (105.25, 146.42) *	88.00 (68.06, 111.96)	122.47 (100.56, 147.74) *	123.08 (70.30, 199.88)
2001/12/30	109.46 (93.25, 127.67)	87.18 (67.69, 110.52)	131.18 (108.94, 156.63) *	153.85 (93.93, 237.62)
2003/1/24	85.55 (72.32, 100.50)	123.81 (101.16, 150.02) *	112.12 (92.23, 135.02)	133.33 (85.40, 198.40)

* $p<0.05$

Table 3. Standardized mortality ratios (SMRs) and associated 95% confidence intervals (CIs) of cardiovascular diseases among women during the two-week period following extreme cold weather events in comparison with the two-week period prior to the events by geographic area, 1994 to 2003.

Date	North	Central	South	East
1994/1/16	98.92 (79.74, 121.32)	147.06 (119.65, 178.87) *	78.26 (62.93, 96.20) *	157.14 (78.34, 281.19)
1994/2/28	117.78 (96.42, 142.45)	108.86 (87.07, 134.44)	107.79 (85.85, 133.63)	154.55 (89.98, 247.46)
1995/1/1	89.22 (71.83, 109.54)	146.15 (118.24, 178.67) *	162.90 (132.68, 197.94) *	200.00 (103.22, 349.38) *
1995/1/28	121.35 (99.54, 146.51)	107.78 (87.40, 131.48)	105.66 (87.00, 127.14)	150.00 (68.45, 284.77)
1995/3/1	79.21 (62.80, 98.58) *	92.22 (73.45, 114.33)	84.55 (69.08, 102.45)	50.00 (13.45, 128.01)
1995/3/22	97.80 (78.54, 120.36)	100.00 (79.65, 123.97)	100.00 (81.18, 121.87)	200.00 (103.22, 349.38) *
1995/12/27	115.19 (92.74, 141.43)	132.20 (104.50, 165.00) *	130.30 (104.22, 160.93) *	88.89 (38.27, 175.16)
1996/1/5	111.76 (90.42, 136.63)	108.11 (85.72, 134.55)	137.33 (112.09, 166.56) *	100.00 (43.06, 197.05)
1996/1/30	84.31 (67.44, 104.13)	104.62 (81.23, 132.63)	89.87 (70.19, 113.37)	116.67 (46.74, 240.39)
1996/2/17	98.04 (79.77, 119.24)	126.67 (102.48, 154.85) *	110.00 (88.22, 135.53)	81.82 (37.33, 155.33)
1996/12/2	138.60 (109.72, 172.74) *	94.44 (73.34, 119.73)	171.74 (135.96, 214.04) *	157.14 (78.34, 281.19)
1997/1/6	121.13 (96.88, 149.59)	104.17 (81.93, 130.58)	117.65 (93.28, 146.42)	175.00 (70.11, 360.59)
1997/1/20	103.75 (82.63, 128.62)	112.33 (89.34, 139.43)	103.90 (82.38, 129.31)	85.71 (31.30, 186.57)
1997/2/13	104.71 (84.08, 128.85)	95.96 (77.63, 117.31)	101.09 (81.59, 123.84)	240.00 (123.87, 419.26) *
1998/1/20	103.74 (85.34, 124.93)	150.70 (123.50, 182.11) *	121.59 (121.21, 146.93) *	250.00 (241.76, 459.79) *
1998/2/1	107.55 (88.71, 129.20)	117.17 (96.82, 140.54)	117.20 (96.23, 141.38)	130.00 (69.15, 222.32)

* $p<0.05$

Table 3 (continued). Standardized mortality ratios (SMRs) and associated 95% confidence intervals (CIs) of cardiovascular diseases among women during the two-week period following extreme cold weather events in comparison with the two-week period prior to the events by geographic area, 1994 to 2003.

Date	North	Central	South	East
1999/1/11	119.12 (94.59, 148.05)	142.11 (112.85, 176.63) *	114.47 (91.69, 141.20)	110.00 (54.84, 196.83)
1999/1/30	92.11 (71.80, 116.37)	69.51 (52.64, 90.06) *	87.80 (68.70, 110.58)	50.00 (20.03, 103.02)
1999/2/15	113.70 (90.56, 140.95)	147.17 (116.33, 183.68) *	121.33 (97.69, 148.97)	214.29 (119.85, 353.45) *
1999/12/17	128.57 (103.38, 158.04) *	152.83 (121.36, 189.96) *	155.10 (122.20, 194.14) *	100.00 (47.87, 183.92)
2000/1/22	150.00 (123.39, 180.64) *	126.09 (100.99, 155.53) *	143.94 (116.45, 175.96) *	128.57 (58.67, 244.08)
2001/12/20	135.06 (110.36, 163.66) *	120.00 (92.80, 152.67)	118.33 (92.42, 149.26)	77.78 (31.16, 160.26)
2001/12/30	119.78 (98.35, 144.49)	109.09 (85.35, 137.38)	150.91 (120.19, 187.08) *	85.71 (31.30, 186.57)
2003/1/24	104.00 (84.97, 126.01)	103.75 (82.63, 128.62)	110.13 (88.20, 135.84)	111.11 (53.19, 204.35)

* $p<0.05$

Table 4. Standardized mortality ratios (SMRs) and associated 95% confidence intervals (CIs) of respiratory diseases among men during the two-week period following extreme cold weather events in comparison with the two-week period prior to the events by geographic area, 1994 to 2003.

Date	North	Central	South	East
1994/1/16	127.81 (110.42, 147.18) *	104.72 (87.68, 124.11)	105.80 (89.33, 124.42)	107.41 (71.92, 154.26)
1994/2/28	98.95 (85.35, 114.11)	92.47 (77.53, 109.45)	103.11 (88.02, 120.04)	100.00 (68.39, 141.18)
1995/1/1	129.81 (112.81, 148.66) *	117.32 (99.24, 137.75)	112.18 (96.17, 130.09)	121.21 (86.59, 165.06)
1995/1/28	98.52 (85.34, 113.16)	90.70 (77.02, 106.10)	102.81 (88.45, 118.83)	75.00 (50.59, 107.07)
1995/3/1	89.50 (76.87, 103.62)	78.88 (65.76, 93.86) *	69.19 (58.09, 81.80) *	97.56 (69.69, 132.85)
1995/3/22	103.93 (89.49, 120.04)	100.68 (85.11, 118.27)	96.64 (81.50, 113.78)	100.00 (67.46, 142.76)
1995/12/27	98.10 (83.26, 114.82)	142.86 (121.58, 166.79) *	98.01 (82.86, 115.14)	95.45 (59.06, 145.92)
1996/1/5	111.92 (95.68, 130.13)	116.42 (98.86, 136.19)	126.95 (109.03, 146.97) *	100.00 (64.05, 148.80)
1996/1/30	102.38 (87.65, 118.88)	121.01 (102.05, 142.47) *	88.82 (75.22, 104.18)	103.57 (69.35, 148.75)
1996/2/17	110.53 (95.33, 127.46)	100.65 (85.43, 117.80)	145.80 (125.86, 168.01) *	100.00 (68.82, 140.44)
1996/12/2	117.02 (99.85, 136.30)	140.22 (117.06, 166.61) *	120.87 (101.61, 142.72) *	83.33 (50.88, 128.71)
1997/1/6	86.31 (72.83, 101.56)	131.53 (111.06, 154.68) *	104.27 (89.22,121.12)	75.00 (46.41, 114.65)
1997/1/20	136.69 (117.94, 157.57) *	95.83 (80.51, 113.22)	97.63 (83.30, 113.72)	95.45 (59.06, 145.92)
1997/2/13	102.16 (88.11, 117.81)	98.22 (83.85, 114.36)	110.91 (95.42, 128.20)	163.16 (110.84, 231.60) *
1998/1/20	119.77 (106.91, 133.76) *	158.18 (139.57, 178.58) *	139.31 (122.27, 158.05) *	108.57 (76.82, 149.03)
1998/2/1	100.98 (90.02, 112.92)	128.45 (114.28, 143.89) *	113.60 (100.18, 128.31) *	135.14 (100.29, 178.16) *

* $p<0.05$

Table 4 (continued). Standardized mortality ratios (SMRs) and associated 95% confidence intervals (CIs) of respiratory diseases among men during the two-week period following extreme cold weather events in comparison with the two-week period prior to the events by geographic area, 1994 to 2003.

Date	North	Central	South	East
1999/1/11	94.76 (82.57, 108.24)	106.45 (90.83, 123.99)	98.77 (84.10, 115.26)	126.92 (87.35, 178.25)
1999/1/30	116.04 (101.99, 131.48) *	105.63 (90.30, 122.81)	103.75 (88.57, 120.79)	89.29 (57.76, 131.81)
1999/2/15	110.76 (98.12, 124.57)	112.88 (97.16, 130.43)	142.68 (124.98, 162.18) *	178.26 (127.91, 241.84) *
1999/12/17	112.83 (99.41, 127.57)	129.66 (111.78, 149.57) *	126.75 (109.75, 145.64) *	131.82 (88.26, 189.32)
2000/1/22	129.72 (114.84, 145.99) *	156.49 (137.36, 177.55) *	134.71 (117.82, 153.33) *	92.86 (60.64, 136.06)
2001/12/20	110.55 (97.03, 125.43)	110.67 (94.47, 128.84)	98.01 (84.80, 112.69)	42.86 (25.39, 67.74) *
2001/12/30	102.54 (90.03, 116.31)	109.49 (93.78, 127.08)	124.59 (108.94, 141.86) *	204.17 (151.03, 269.93) *
2003/1/24	106.46 (94.36, 119.69)	105.98 (91.62, 121.94)	126.32 (111.54, 142.51) *	97.30 (68.14, 134.71)

* $p<0.05$

Table 5. Standardized mortality ratios (SMRs) and associated 95% confidence intervals (CIs) of respiratory diseases among women during the two-week period following extreme cold weather events in comparison with the two-week period prior to the events by geographic area, 1994 to 2003.

Date	North	Central	South	East
1994/1/16	105.80 (82.92, 133.03)	95.00 (71.95, 123.09)	69.89 (53.94, 89.09) *	72.73 (31.31, 143.31)
1994/2/28	94.85 (76.46, 116.32)	87.01 (67.43, 110.51)	110.81 (88.13, 137.55)	77.78 (31.16, 160.26)
1995/1/1	123.17 (100.32, 149.67) *	156.36 (125.07, 193.11) *	117.98 (96.49, 142.82)	125.00 (69.91, 206.18)
1995/1/28	102.02 (83.09, 123.97)	79.00 (62.54, 98.46) *	100.00 (82.49, 120.13)	76.47 (40.68, 130.78)
1995/3/1	60.95 (46.94, 77.84)	87.06 (68.36, 109.30)	62.14 (47.85, 79.35)	84.62 (42.18, 151.41)
1995/3/22	130.16 (103.52, 161.56) *	101.43 (79.21, 127.94)	87.84 (67.79, 111.96)	111.11 (53.19, 204.35)
1995/12/27	97.18 (75.61, 122.99)	110.34 (84.97, 140.91)	115.19 (92.74, 141.43)	72.73 (31.31, 143.31)
1996/1/5	129.82 (101.94, 162.99) *	96.92 (74.47, 124.01)	92.41 (72.43, 116.19)	400.00 (228.49, 649.62) *
1996/1/30	93.15 (72.33, 118.09)	104.05 (82.11, 130.05)	133.87 (106.62, 165.96) *	64.29 (29.33, 122.04)
1996/2/17	139.13 (112.69, 169.90) *	89.33 (69.23, 113.45)	91.86 (72.72, 114.49)	122.22 (60.93, 218.70)
1996/12/2	77.05 (56.61, 102.46)	141.51 (111.30, 177.39) *	138.60 (109.72, 172.74) *	122.22 (60.93, 218.70)
1997/1/6	109.88 (88.24, 135.21)	107.89 (85.81, 133.93)	106.25 (84.87, 131.38)	85.71 (31.30, 186.57)
1997/1/20	89.66 (70.87, 111.90)	83.13 (64.68, 105.21)	94.32 (75.12, 116.92)	116.67 (46.74, 240.39)
1997/2/13	108.05 (87.31, 132.22)	97.62 (77.64, 121.17)	89.89 (71.27, 111.87)	220.00 (109.67, 393.67) *
1998/1/20	110.92 (92.81, 131.54)	205.26 (169.75, 246.01) *	126.97 (104.64, 152.65) *	125.00 (59.84, 229.90)
1998/2/1	118.18 (99.60, 139.22)	166.67 (141.84, 194.59) *	155.14 (132.44, 180.62) *	166.67 (93.21, 274.91)

* $p<0.05$

Table 5 (continued). Standardized mortality ratios (SMRs) and associated 95% confidence intervals (CIs) of respiratory diseases among women during the two-week period following extreme cold weather events in comparison with the two-week period prior to the events by geographic area, 1994 to 2003.

Date	North	Central	South	East
1999/1/11	101.98 (83.24, 123.68)	103.70 (82.72, 128.39)	105.56 (83.16, 132.12)	350.00 (191.19, 587.28) *
1999/1/30	81.19 (64.57, 100.78)	90.00 (70.42, 113.34)	130.56 (105.50, 159.77) *	142.86 (68.39, 262.74)
1999/2/15	136.71 (112.14, 165.06) *	131.94 (106.75, 161.30) *	116.84 (96.12, 140.71)	90.91 (43.52, 167.20)
1999/12/17	137.33 (112.09, 166.56) *	102.74 (80.81, 128.79)	123.29 (99.13, 151.54)	150.00 (68.45, 284.77)
2000/1/22	131.46 (108.72, 157.55) *	135.82 (109.35, 166.76) *	98.99 (80.36, 120.64)	166.67 (93.21, 274.91)
2001/12/20	111.00 (91.31, 133.67)	119.75 (97.11, 146.09)	80.87 (65.27, 99.07) *	53.33 (22.96, 105.09)
2001/12/30	134.31 (112.76, 158.78) *	96.67 (77.42, 119.24)	95.19 (77.37, 115.89)	122.22 (60.93, 218.70)
2003/1/24	133.65 (112.36, 157.81) *	135.71 (109.80, 165.91) *	98.28 (81.06, 118.06)	109.09 (56.30, 190.57)

* $p<0.05$

Table 6. Standardized mortality ratios (SMRs) and associated 95% confidence intervals (CIs) of cardiovascular and respiratory diseases among men in the affected areas during the two-week period following extreme cold weather events in comparison with the two-week period prior to the events, 1994 to 2003.

Date	Disease	Cases		SMR	95% CI
		Observed	Expected		
1994/1/16	Cardiovascular	491	472	104.0	95.0-113.7
	Respiratory	128	88	145.5	121.4-173.0*
1994/2/28	Cardiovascular	432	416	103.9	94.3-114.1
	Respiratory	97	191	74.1	60.0-90.3*
1995/1/1	Cardiovascular	607	548	110.8	102.1-120.0*
	Respiratory	161	121	133.1	113.3-155.3*
1995/1/28	Cardiovascular	703	592	118.8	110.1-127.9*
	Respiratory	190	180	105.6	91.1-121.7
1995/3/1	Cardiovascular	497	558	89.1	81.4-97.3*
	Respiratory	148	176	84.1	71.1-98.8*
1995/3/22	Cardiovascular	350	404	86.6	77.8-96.2*
	Respiratory	97	109	89.0	72.2-108.6
1995/12/27	Cardiovascular	562	515	109.1	100.3-118.5*
	Respiratory	148	126	117.5	99.3-138.0
1996/1/5	Cardiovascular	441	420	105.0	95.4-115.3
	Respiratory	121	102	118.6	98.4-141.8
1996/1/30	Cardiovascular	625	558	112.0	103.4-121.1*
	Respiratory	145	140	103.6	87.4-121.9
1996/2/17	Cardiovascular	493	483	102.1	93.3-111.5
	Respiratory	130	113	115.0	96.1-136.6
1996/12/2	Cardiovascular	445	358	124.3	113.0-136.4*
	Respiratory	99	78	127.0	103.2-154.5*
1997/1/6	Cardiovascular	526	465	113.1	103.7-123.1*
	Respiratory	115	122	94.3	77.8-113.2
1997/1/20	Cardiovascular	436	434	100.5	91.3-110.4
	Respiratory	108	89	121.4	99.5-146.5
1997/2/13	Cardiovascular	378	344	109.9	99.1-121.5
	Respiratory	104	98	106.1	86.7-128.6

* $p<0.05$

Table 6 (continued). Standardized mortality ratios (SMRs) and associated 95% confidence intervals (CIs) of cardiovascular and respiratory diseases among men in the affected areas during the two-week period following extreme cold weather events in comparison with the two-week period prior to the events, 1994 to 2003.

Date	Disease	Cases		SMR	95% CI
		Observed	Expected		
1998/1/20	Cardiovascular	652	474	137.6	127.2-148.5*
	Respiratory	233	159	146.5	128.3-166.6*
1998/2/1	Cardiovascular	641	623	102.9	95.1-111.2
	Respiratory	268	217	123.5	109.2-139.2*
1999/1/11	Cardiovascular	569	566	100.5	92.4-109.1
	Respiratory	166	181	91.7	78.3-106.8
1999/1/30	Cardiovascular	520	526	98.9	90.5-107.7
	Respiratory	150	166	90.4	76.5-106.0
1999/2/15	Cardiovascular	438	361	121.3	110.2-133.2*
	Respiratory	143	112	127.7	107.6-150.4*
1999/12/17	Cardiovascular	682	505	135.1	125.1-145-6*
	Respiratory	202	149	135.6	117.5-155.6*
2000/1/22	Cardiovascular	698	490	142.5	132.1-153.4*
	Respiratory	136	129	105.4	88.5-124.7
2001/12/20	Cardiovascular	586	510	114.9	105.8-124.6*
	Respiratory	184	165	111.5	96.0-128.8
2001/12/30	Cardiovascular	563	512	110.0	101.1-119.4*
	Respiratory	161	143	112.6	97.9-131.4
2003/1/24	Cardiovascular	565	520	108.7	99.9-118.0
	Respiratory	191	156	122.4	105.7-141.1*

* $p<0.05$

Table 7. Standardized mortality ratios (SMRs) and associated 95% confidence intervals (CIs) of cardiovascular and respiratory diseases among women in the affected areas during the two-week period following extreme cold weather events in comparison with the two-week period prior to the events, 1994 to 2003.

Date	Disease	Cases		SMR	95% CI
		Observed	Expected		
1994/1/16	Cardiovascular	358	337	106.2	95.5-117.8
	Respiratory	49	64	76.6	56.6-101.2
1994/2/28	Cardiovascular	306	295	103.7	92.4-116.0
	Respiratory	58	69	84.1	63.8-108.7
1995/1/1	Cardiovascular	444	387	114.7	104.3-125.9*
	Respiratory	122	77	158.4	131.6-189.2*
1995/1/28	Cardiovascular	456	419	108.8	99.1-119.3
	Respiratory	120	114	105.3	87.3-125.9
1995/3/1	Cardiovascular	379	447	84.8	76.5-93.8*
	Respiratory	65	90	72.2	55.7-92.1*
1995/3/22	Cardiovascular	246	264	93.2	81.9-105.6
	Respiratory	52	50	104.0	77.7-136.4
1995/12/27	Cardiovascular	423	340	124.4	112.8-136.9*
	Respiratory	88	74	118.9	95.4-146.5
1996/1/5	Cardiovascular	333	292	114.0	102.1-127.0*
	Respiratory	70	54	129.6	101.1-163.8*
1996/1/30	Cardiovascular	377	413	91.3	82.3-101.0
	Respiratory	81	77	105.2	83.5-130.8
1996/2/17	Cardiovascular	329	302	108.9	97.5-121.4
	Respiratory	58	66	87.9	66.7-113.6
1996/12/2	Cardiovascular	320	242	132.2	118.1-147.5*
	Respiratory	49	50	98.0	72.5-129.6
1997/1/6	Cardiovascular	385	317	121.5	109.6-134.2*
	Respiratory	86	66	130.3	104.2-161.0*
1997/1/20	Cardiovascular	283	305	92.8	82.3-104.3
	Respiratory	68	73	93.2	72.3-118.1
1997/2/13	Cardiovascular	271	235	115.3	102.0-130.0*
	Respiratory	61	42	145.2	111.1-186.6*

* $p<0.05$

Table 7 (continued). Standardized mortality ratios (SMRs) and associated 95% confidence intervals (CIs) of cardiovascular and respiratory diseases among women in the affected areas during the two-week period following extreme cold weather events in comparison with the two-week period prior to the events, 1994 to 2003.

Date	Disease	Cases		SMR	95% CI
		Observed	Expected		
1998/1/20	Cardiovascular	433	351	123.4	112.0-135.6*
	Respiratory	139	85	163.5	137.5-193.1*
1998/2/1	Cardiovascular	477	399	119.6	109.1-130.8*
	Respiratory	178	128	139.1	119.4-161.1*
1999/1/11	Cardiovascular	413	365	113.2	102.5-124.6*
	Respiratory	94	89	105.6	85.4-129.3
1999/1/30	Cardiovascular	351	381	92.1	82.7-102.3
	Respiratory	87	73	119.2	95.5-147.0
1999/2/15	Cardiovascular	294	275	106.9	95.0-119.9
	Respiratory	71	64	111.0	86.6-140.0
1999/12/17	Cardiovascular	472	355	133.0	121.2-145.5*
	Respiratory	94	81	116.1	93.8-142.0
2000/1/22	Cardiovascular	483	343	140.8	128.5-154.0*
	Respiratory	66	66	100.0	77.3-127.2
2001/12/20	Cardiovascular	413	368	112.2	101.7-123.6*
	Respiratory	90	109	82.6	66.4-101.5
2001/12/30	Cardiovascular	409	349	117.2	106.1-129.1*
	Respiratory	84	80	105.0	83.8-130.0
2003/1/24	Cardiovascular	379	352	107.7	97.1-119.1
	Respiratory	119	77	154.6	128.0-185.0*

* $p<0.05$

Table 8. Standardized mortality ratios (SMRs) and associated 95% confidence intervals (CIs) of various cardiovascular and respiratory diseases among men in the affected areas during the two-week period following extreme cold weather events in comparison with the two-week period prior to the events, 1994 to 2003.

Diseases	Cases		SMR	95% CI
	Observed	Expected		
Cardiovascular diseases				
Chronic rheumatic heart disease	145	131	110.7	93.4-130.2
Primary hypertension	671	654	102.6	95.0-110.7
Hypertensive heart disease	574	552	104.0	95.7-112.9
Ischemic heart disease	3664	3347	109.5	106.0-113.1*
Inflammatory heart disease	225	176	127.8	111.7-145.7*
Cardiogenic arrhythmia	462	411	112.4	102.4-123.1*
Cerebrovascular disease	7258	6492	111.8	109.2-114.4*
Respiratory diseases				
Upper respiratory tract infection	126	124	101.6	84.6-121.0
Pneumonia and acute bronchitis and bronchiolitis	2275	2015	112.9	108.3-117.6*
Influenza	15	18	83.3	46.6-137.5
Chronic bronchitis	172	147	117.0	100.2-135.9*
Emphysema	252	248	101.6	89.5-115.0
Asthma	786	698	112.6	104.9-120.8*

* $p<0.05$

Table 9. Standardized mortality ratios (SMRs) and associated 95% confidence intervals (CIs) of various cardiovascular and respiratory diseases among women in the affected areas during the two-week period following extreme cold weather events in comparison with the two-week period prior to the events, 1994 to 2003.

Diseases	Cases		SMR	95% CI
	Observed	Expected		
Cardiovascular diseases				
Chronic rheumatic heart disease	199	175	113.7	98.5-130.7
Primary hypertension	525	492	106.7	97.8-116.2
Hypertensive heart disease	621	493	126.0	116.3-136.3*
Ischemic heart disease	2185	1943	112.5	107.8-117.3*
Inflammatory heart disease	106	108	98.2	80.4-118.7
Cardiogenic arrhythmia	359	343	104.7	94.1-116.1
Cerebrovascular disease	5039	4579	110.1	107.0-113.1*
Respiratory diseases				
Upper respiratory tract infection	92	107	86.0	69.3-105.5
Pneumonia and acute bronchitis and bronchiolitis	1248	1082	115.3	109.0-121.9*
Influenza	17	18	94.4	55.0-151.2
Chronic bronchitis	105	108	97.2	79.5-117.7
Emphysema	60	44	136.4	104.1-175.5*
Asthma	527	459	114.8	105.2-125.1*

* $p<0.05$