Seasonal Variation in Mortality from Ischemic Heart Disease and Cerebrovascular Disease in Okinawa and Osaka: the Possible Role of Air Temperature

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Okinawa is located in a subtropical area and is well-known for low mortality due to ischemic heart disease (IHD) and cerebrovascular disease (CVD). However, the factors that contribute to these low mortality rates remain unclear. We examined the seasonal variation in the mortality due to IHD and CVD among Okinawa and Osaka residents, aged 45 to 84 years, between 1992 and 1996. In addition, we studied if there was a relationship between the monthly mortality rate from IHD or CVD and the monthly mean daily air temperature in Naha City and Osaka City. Data on the monthly mean daily air temperature was obtained from the meteorological stations in Naha City and Osaka City. Our results showed that there were inverse correlations between the monthly mean daily temperature in a city and each of the monthly mortality from IHD in Okinawa (r=-0.794, p<0.01), the monthly mortality from CVD in Okinawa (r=-0.837, p<0.001), and the monthly mortality from CVD in Osaka (r=-0.954, p<0.001). In Osaka, the monthly mortality rate from IHD was at or near its minimum value when the mean daily temperature was approximately 25°C (in September), and it increased in a linear fashion as the mean monthly temperature fell (r=-0.975, p<0.001). The difference between the monthly mortality from IHD or CVD among the Okinawa and the Osaka residents increased in the winter season in comparison with that in the other seasons, with the exception for IHD in July and in August. These findings indicate that the lower mortality from IHD and CVD in Okinawa is affected, at least in part, by Okinawa’s warm winter. J Epidemiol, 2000 ; 10 : 392-398

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INTRODUCTION

Okinawa is located in a subtropical area between the East China Sea and the Pacific Ocean, and is approximately 1000 kilometers from Honshu Island. Okinawa is well-known for its low mortality from ischemic heart disease (IHD) and cerebrovascular diseases (CVD). In 1995, the age-standardized mortality (per 105, based on the standard population in Japan in 1985) from IHD in Okinawa was 50 among males and 23 among females, which is 12% and 24% lower, respectively, than those among the Japanese population 6. However, the reasons for the lower mortalities from IHD and CVD in Okinawa remain unclear. According to recent nutrition surveys performed in Japan, the proportion of people with either hypertension or borderline hypertension, hypercholesterolemia, or who smoke in Okinawa does not differ from the respective proportion among the Japanese people as a whole 5,6.

Seasonal variation in mortality due to IHD and/or CVD has been noted in both the northern 4-7 and southern 8,9 hemispheres, with higher death rates during the winter than in the summer. Twenty years ago, the seasonal pattern of CVD
deaths on the Japanese main islands was examined, and the monthly mortality from CVD was found to be inversely correlated with the mean monthly temperature, except on Hokkaido Island. These deaths may have resulted from thrombosis due to haemoconcentration in the cold, or other effects on the cardiovascular reflex that are briefly induced by low temperature. Together, these findings suggest that the lower mortality from IHD and CVD in Okinawa is due, in part, to lower mortality during the warm winters.

To support this hypothesis, it is necessary to demonstrate that the seasonal variation in mortality from IHD and CVD is inversely associated with the seasonal variation in air temperature in both Okinawa and other areas in Japan, and that the difference in the mortality between the two areas increases in the winter season compared with that in the other seasons. In this study, we investigated if there is a correlation between the monthly mortality from IHD or CVD and the daily air temperature in Okinawa and in Osaka, and assessed the seasonal variation of the difference between the mortality rates in these two areas.

**METHODS**

Okinawa Prefecture (1995 population: 1.3 million) consists of the Ryukyu-archipelago including Okinawa Island, which is located between latitudes 26 and 27 degrees north. Approximately 92% of the Okinawa people reside on Okinawa Island. Osaka Prefecture (1995 population: 8.8 million) lies between latitudes 34 and 35 degrees north. The metropolitan areas on Honshu Island are located around this latitude. We obtained data from the annual reports of the Meteorological Agency of Japan, on the monthly mean 24-hour air temperature in each month of the years between 1992 and 1996 that was recorded by the meteorological station in Naha City located on Okinawa Island, and the meteorological station in Osaka City. The monthly values in each year between 1992 and 1996 were averaged to obtain the mean daily temperature in each month of the year in each prefecture.

Cause-specific mortality figures were obtained from the annual statistics prepared by Okinawa and Osaka Prefectures, and accumulated by 5-year age and month of death between 1992 and 1996. The underlying cause of death was defined according to the International Classification of Diseases (ICD), 9th revision for 1992-94, and 10th revision for 1995-96, according to the coding rule prepared by the World Health Organization. We defined IHD as 410-414 in the ICD 9th revision and as I20-I25 in the ICD 10th revision. We defined CVD as 430-438 in the ICD 9th revision, and as I60-I67 and I69 in the ICD 10th revision. Consistency was maintained between the 9th and 10th ICD series by excluding ICD I68 from the 10th series, which is the code for cerebrovascular disorders in diseases classified elsewhere after 1995. The age-standardized monthly mortality rate due to IHD or CVD was calculated for individuals between 45-84 years, using the Japanese population in 1985 as the standard population. To adjust for differing number of days in the twelve months, the denominators were prepared by multiplying \( \{ A \times 5(\text{yrs})\} \times \{ B/365.4\} \), where \( A \) is the total age-specific population in 1995 in each group and \( B \) is either 31, 30, or 28.4, according to the number of days in the given month.

To investigate if there was a relationship between the monthly mean daily temperature and the monthly mortality rate due to IHD or CVD in each of the two areas, the data were plotted and Pearson's correlation coefficient was calculated. To assess the difference in the monthly mortality rate from IHD and CVD between the two prefectures, we calculated the age-standardized rate ratios using the rate in Okinawa as a reference. The rate ratio and its 95% confidence interval (CI) were calculated based on the Poisson distribution. If the 95% CI of the rate ratio did not contain 1.0, the ratio was considered to be statistically significant (\( p<0.05 \)).

**RESULTS**

Figure 1 shows the average monthly mean daily air temperatures in Naha City and Osaka City between 1992 and 1996. In Naha, the lowest monthly mean daily air temperature was in February at 16.4°C, while the highest mean daily air temperature was in July at 28.9°C, a difference of 12.5°C. In Osaka, the lowest mean daily air temperature was in February at 6.3°C, while the highest mean daily air temperature was in August at 28.7°C, a difference of 22.4°C, which is 9.9°C greater than that in Okinawa.

The monthly mortality from IHD was inversely correlated with the monthly mean daily temperature in Okinawa (\( r=-0.794, p<0.01 \)) (Figure 2). The mortality was significantly higher during the winter than during the summer, with a 62% higher rate in January than in August (\( p<0.05 \)). In Osaka, the mortality from IHD was at or near the minimum value when the mean daily temperature was approximately 25°C (in September), and it increased linearly as the mean daily temperature fell (\( r=-0.975, p<0.001 \)). The mortality from IHD in January was 76% higher than that in September (\( p<0.05 \)) (Figure 2). In both Okinawa and Osaka, there was an inverse correlation between the monthly mortality from CVD and the monthly mean daily temperature (Okinawa, \( r=-0.837, p<0.001 \); Osaka, \( r=-0.954, p<0.001 \)) (Figure 3). In Okinawa, the mortality from CVD in January was 27% higher than that in October (\( p<0.05 \)), whereas in Osaka, the mortality in January was 38% higher than that in August (\( p<0.05 \)) (Figure 3). The monthly mortality from both IHD and CVD in Okinawa was always lower than that in Osaka in the mean daily temperature range of 16°C to 29°C.

The monthly mortality rates from IHD were significantly higher in Osaka than in Okinawa in all months of the year except September (Figure 4). As to IHD, the mortality rate...
Figure 1. The average monthly mean daily air temperature in Naha City and Osaka City between 1992 and 1996.

Figure 2. Relationship between the monthly age-standardized mortality rate from IHD in individuals between 45-84 years and the average monthly mean daily air temperature between 1992-1996 in Okinawa and Osaka. Correlation analysis in Osaka was limited to between September and June because of its linearity. The age-standardized mortality rate from IHD was inversely correlated with the monthly mean daily air temperature in Osaka and in Okinawa.
Figure 3. Relationship between the monthly age-standardized mortality rate from CVD in individuals between 45-84 years and the average monthly mean daily air temperature between 1992-1996 in Okinawa and Osaka. The age-standardized mortality rate from CVD was inversely correlated with the monthly mean daily air temperature in Osaka and in Okinawa.

Figure 4. The age-standardized rate ratios of monthly IHD mortality (Osaka/Okinawa) among 45-to-84-year-old individuals between 1992-1996.
ratios were high in July (1.66), August (1.60), October (1.61), December (1.61), January (1.52), February (1.69), and March (1.94), using the rate in Okinawa as a reference (Figure 4). The monthly mortality from CVD was significantly higher in Osaka than in Okinawa throughout the year, with a rate ratio ranging between 1.20 and 1.40 (Figure 5). During the year, the monthly mortality rate ratios from CVD were higher from October to February (1.35 to 1.40)

DISCUSSION

Our results demonstrate that in the 45-84-year age group, the monthly mortalities from IHD and CVD in Okinawa were inversely correlated with the monthly daily temperature. These findings are consistent with reports of seasonal variation in cardiovascular mortality in regions with a warm winter such as Athens, Hawaii, and Hong Kong. The data suggest that even a relatively small seasonal change in temperature has a significant effect on mortality from coronary artery disease and cerebrovascular disease among middle-aged and elderly people. Donaldson and Keatinge demonstrated in the population of southeast England that the mortalities lagged a temperature change by 3 days for IHD and 12 days for respiratory diseases. This finding and those of the seasonal analysis indicate that cold exposure can cause rapid IHD death by inducing an increase in arterial pressure and thrombosis possibly due to haemoconcentration. Further IHD deaths can be expected secondary to respiratory diseases, since the incidence of respiratory disease increases in cold weather, and since influenza and other respiratory infections are reported to be accompanied by increased IHD mortality. Other seasonal factors such as sunlight exposure, humidity, and maximum and minimum temperatures, that have been assumed to affect mortality from cardiovascular disease, must be studied in detail.

Although the monthly mean daily air temperatures during the summer in Osaka were similar to the monthly mean daily air temperatures during the summer in Okinawa, the rate of mortality from IHD in Osaka in July and August remained elevated in comparison with that in the previous month, while the rate of mortality from IHD in Okinawa in July and August continued to decline linearly as the temperature rose. In a metropolitan city, there are many buildings and highways, and few green areas. Often, we experience a so-called heat-island phenomenon in metropolitan cities in Japan, in which the daily temperature is actually much higher than the temperature reported from meteorological stations. Extremely hot weather may induce dehydration and/or an increase in cardiac overload, resulting in the occurrence of IHD. Reports from New Orleans and Kuwait support this hypothesis, in which they observed a higher mortality rate from coronary artery disease during hot weather than during cool weather.

Our results demonstrate that the difference between the mortality from IHD or CVD in Okinawa and Osaka increased in

Figure 5. The age-standardized rate ratios of monthly CVD mortality (Osaka/Okinawa) among 45-to-84-year-old individuals between 1992-1996.
the winter season, with the exception of IHD in July and in August. This finding, together with the correlation analysis, indicates that the lower mortality from IHD and CVD in Okinawa may be affected by Okinawa’s warm winter. However, our data also showed that the monthly mortality from both IHD and CVD in Okinawa was always lower than that in Osaka in the same temperature range. This finding suggests the existence of other substantial causal factors inducing the different mortalities we observed. Further epidemiological studies are required to clarify the factors that contribute to the lower IHD and CVD mortalities in Okinawa, focusing on life styles at the individual level.

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