

Analysis of the Effect of Climate on Mortality over Time

Kyoko Aoyama ^{1*}, Taro Mori¹, and Motoya Hayashi¹

¹Hokkaido University, Japan

Abstract. Malignant neoplasms, cardiac disease, and cerebrovascular disease are Japan's most common causes of death, with cardiac disease and cerebrovascular disease increasing during the winter season. The indoor environment of Japanese houses is poor in winter. To reduce medical costs for the further aging of the population, it is essential to study the relationship between mortality and the indoor environment. This paper analysed mortality rates by location, age group, year of death, and energy efficiency classification to clarify the relationship between climate and mortality rates in each region. Data were constructed by merging mortality data with climate data. Mortality sensitivity measures the mortality rate increases when the outside temperature falls by 1 °C. We also found that mortality among those who died in residential settings was more strongly affected by the cooler outside temperature environment than in nonresidential settings. It suggests that the mortality rate was more strongly affected by residential areas, which tend to have cooler indoor temperatures during the winter, than non-residential buildings such as hospitals and elderly care facilities. The analysis by age group showed that the sensitivity was higher for older age groups and warmer energy efficiency classification categories in Kyushu and Okinawa.

1 Background

In recent years, the relationship between indoor environment and health has been attracting increasing attention. According to the results of the Basic Survey of Social Life¹⁾, Japanese people spend more than half of their time a day in their homes and creating a good living environment is an extremely important issue for the health of the nation. The number of deaths from heart disease and cerebrovascular disease is reported to increase during the winter season.

In this study, using the Vital Statistics Mortality Tables, we will clarify the causal relationship between outdoor temperature and mortality in each region by analysing the data by energy conservation category. By doing so, we aim to improve winter lifestyles in each region and the insulation performance of houses in each region, and to provide an indicator for healthy and safe urban planning and a new standard for the living environment.

2 Methods

2.1 Subject of analysis

We conducted our analysis using Vital Statistics Death Certificates obtained from the Ministry of Health, Labour and Welfare for the period 1972-2015 and AMeDAS weather data obtained from the Japan Meteorological Agency's Meteorological Statistics Information. The Building Energy Conservation Law established by the Ministry of Land, Infrastructure, Transport and Tourism divides Japanese municipalities

into energy conservation categories I through VIII, each of which is given a standard value for the average heat transfer coefficient of the external envelope [W/m²K] and the average solar heat gain rate [-] during the cooling season.

2.2 Study design

We constructed our data with reference to previous studies²⁾. Information on time of death, location of residence, date of birth, age, sex, and cause of death was obtained from the Vital Statistics Death Schedule. Municipal codes were used to link the location of the residence to information on energy conservation zones I through VIII. Municipal codes are codes for statistical processing introduced by the Ministry of Internal Affairs and Communications, which give five-digit (or six-digit) numbers to local governments in Japan. The location information of the city/town/village code and the location information of AMeDAS stations were used to find AMeDAS stations close to the city/town/village code using QGIS³⁾, and then the data were linked based on the city/town/village code and the AMeDAS station number. The data was constructed by matching mortality data with meteorological data.

3 Data analysis

* Corresponding author: iroirogoromo-kosho@eis.hokudai.ac.jp

3.1 Change in Place of Death from Vital Statistics

From the Vital Statistics Death Table, Figure 1 shows the annual change of death place from 1972 to 2015. In Figure 1, the percentage of deaths occurring at home is shown as “house”, and the percentage of deaths occurring in hospitals and nursing homes is shown as “non-house”. The “house” death rate exceeded the “non-house” in 1975, but both rates were similar in 1980. And the “non-house” death rate exceeded 70% in 1990.

This study analysed mortality rates by location, age group, year of death, and energy efficiency classification to clarify the relationship between climate and mortality rates in each region. We divided the period into 1972-1989 and 1990-2015 for considering the above situation.

3.2 Comparison of Mortality Rates at Different Locations of Death

The formula for calculating death ratio is defined as (1).

$$\text{Death ratio}[-] = \frac{f_m}{f_y} \quad (1)$$

f_m : Total number of deaths in the group to which the person belonged in the month of death.

f_y : Total number of deaths in the group to which the person belonged in the year of death.

Figure 2 shows a graph representing the relationship between outdoor temperature and mortality rate at residential building and non-residential building under 65 years old in the Energy Conservation Category II region. The case where the place of death is a hospital or nursing home is shown as “residential building”. The case where the place of death is a residence is shown as “non-residential building”. We applied quadratic curve for the estimation. We compared the mortality change to outdoor temperature in in cold season using slope of the approximation line. The mortality change in residential building is more sensitive than that in non-residential building. We conducted same analysis in other age groups. The results are not different each other.

3.3 Comparison of mortality rates by age group

The relationship between outdoor temperature and mortality for those under 65, between 65 and 75, between 75 and 85, and 85 and older in Region II and Region VII are shown in Figure 3 and Figure 4 respectively. In Region II, there was no significant difference in the age groups. On the other hand, in Region VII, the mortality rate of higher age groups is higher than that of lower age groups, increases as the age group.

Therefore, in Region VII, outdoor temperature seems to have a greater effect on mortality in the higher the age group than that in Region II.

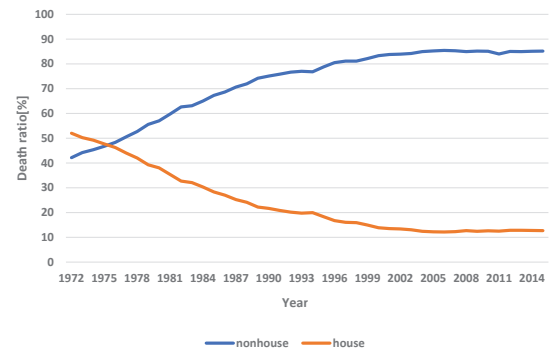


Figure 1. Annual change in composition of deaths by location.

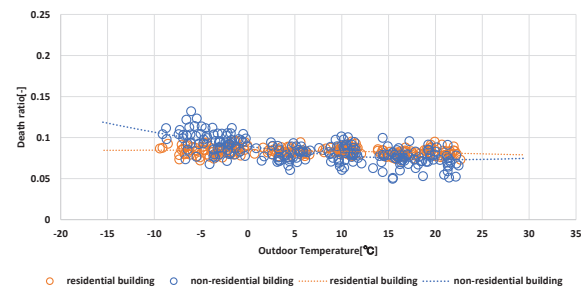


Figure 2. Relationship between mortality and outdoor temperature in Region II under 65 years of age. (1972-1989)

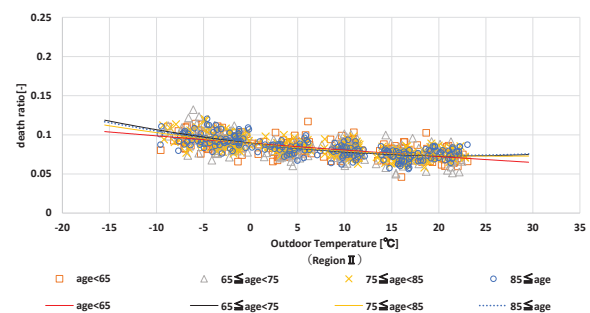


Figure 3. Relationship between outdoor temperature and mortality by age group in Region II.

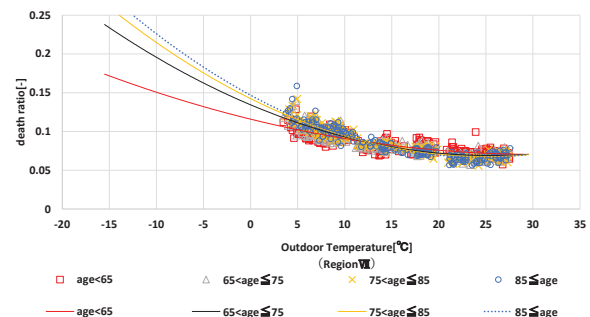


Figure 4. Relationship between outdoor temperature and mortality by age group in Region VII.

3.4 Comparison of mortality rates by energy conservation category

3.4.1 Definition of Mortality Sensitivity

Approximate curves were obtained based on four categories of data: age group, place of death, year of death, and energy conservation category. The slope of the tangent line of the approximate curve in the first and third quartiles of each outdoor temperature was determined, and the slope of the tangent line was defined as the mortality sensitivity. Mortality sensitivity is an index that indicates how much the mortality rate increases when the outside temperature decreases by 1°C. A larger negative value in the mortality sensitivity in the first quartile is an indicator that a person is more likely to die during the winter season.

3.4.2 Box plot analysis of mortality sensitivity

We visualize the mortality sensitivity with age group, death place, periods, and region (Energy conservation category). The mortality sensitivity as the objective variable was the slope of the approximation line at the first quartile of outdoor temperature.

Figure 5 shows the results of the box plots of mortality sensitivity by age group, Figure 6 shows the results of the box plots of mortality sensitivity by year of death, and Figure 7 shows the results of the box plots of mortality sensitivity by age. Figure 8 shows a box plot of mortality sensitivity by energy conservation category.

In Figure 5, the medians and 25percentiles are lower in the higher age groups.

It indicates that through all Japanese tendency, people are more likely to die as their age increases when the outdoor temperature is low.

In Figure 6, all percentile in home is lower than those in non-home. The median value of mortality sensitivity is around -5.0×10^{-4} for the non-residential location, while the median value is below -2.0×10^{-3} for the residential location.

It suggests that the home group was more affected by the outside temperature than the non-home group.

In Figure 7, there is the little difference between 1972-1989 and 1990-2015. This result is due to an worsen in the impact of outdoor temperature on mortality. However, this is likely since it is offset by the aging of the population. So, I should be considered with even finer chronological delimitation.

Figure 8 shows the box plot of mortality sensitivity by energy conservation category. In Figure 8, the median values differ significantly. The decrease in value is gradual from Region III to Region VII, but the sensitivity increases as one moves toward colder regions. It can also be seen that the difference between the maximum and minimum values increases as one approaches warmer regions.

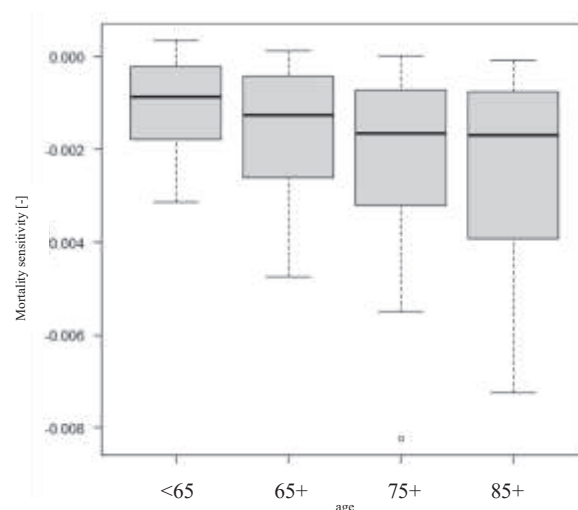


Figure 5. Box plot of mortality sensitivity by age group

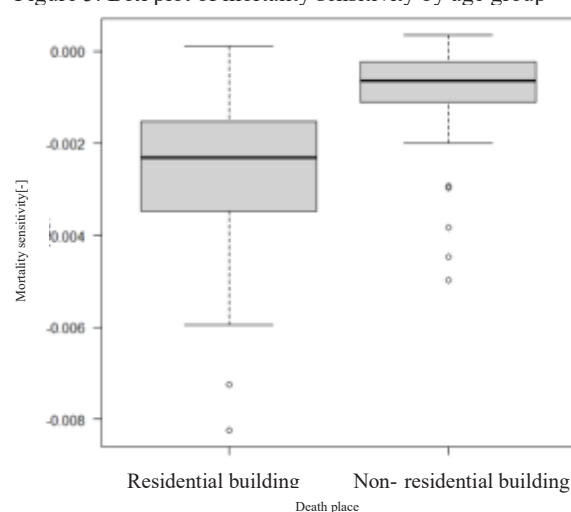


Figure 6. Box plot of mortality sensitivity by death place

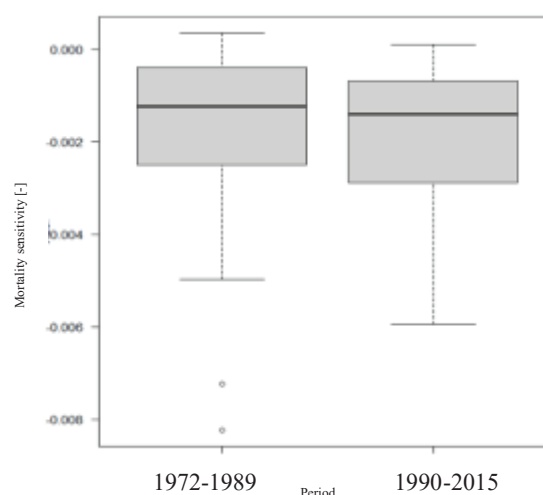


Figure 7. Box plot of mortality sensitivity by period

3.4.3 Analysis of Mortality Sensitivity Using Linear Regression Models

Table 1 shows the results of the analysis using a linear regression model with the objective variable as the mortality sensitivity at 25% temperature. The explanatory variables are age group, place of death, year

of death, and energy conservation category. Table 2 shows the results of the analysis using a linear regression model with the objective variable as the mortality sensitivity at 75% temperature.

In Table 1, the estimated regression coefficient decreases as the age group increases. Table 1 shows the results of the analysis using a linear regression model with the sensitivity to death in the first quartile of outdoor temperature as the objective variable and the age group, place of death, year of death, and energy conservation category as the explanatory variables.

Based on the box-and-whisker analysis of mortality sensitivity in 3.4.2, analyses were conducted by age group, place of death, year of death, and energy conservation category. The comparison of age groups shows that the regression coefficient estimates decrease as the age group increases, and that there is a significant difference in p-values between those under 65 and over 65, $p < 0.001$. and between those under 65 and over 75, $p < 0.001$.

In the comparison of death place, the regression coefficient estimate was higher for the "non-house" group than for the "house" group, indicating a significant difference.

In the comparison of period, the regression coefficient estimates for "1990+" was lower than that for "1990-", indicating a significant difference.

On the other hand, no significant difference was found between Regions I and II with respect to energy conservation categories, but significant differences were found in other regions, with the regression coefficient estimates decreasing as one approached colder regions.

Similarly, Table 2 shows the results of the analysis using a linear regression model with the objective variable as mortality sensitivity in the third quartile of outdoor temperature.

Comparisons by age group showed significant differences between those under 65 and over 75 years of age.

Comparisons of death place and year of death did not yield significant differences.

About the region, significant differences were found in the difference between Region I and Region VIII, but no significant differences were found in the other regions.

3.5 Discussion

Findings from this study are as follows.

1. there was a greater relationship between mortality and outdoor temperature in the group that died in residences than in the group that died non-residences.

2. Outside temperature seems to have a greater effect on mortality in Area VII than in Area II, with older age groups more susceptible to the effect of outside temperature.

3. Analysis of mortality sensitivity using box plot indicated that deaths in residences tended to be greatly affected by low outdoor temperatures, and that in the energy conservation category, the effect of low outdoor temperatures was more pronounced as one approached the VIII region, and especially in the VIII region.

4. Comparison of mortality sensitivity in the year of death showed little difference.

5. In the analysis of the linear regression model about mortality sensitivity, the regression coefficient estimates for the first quartile of outdoor temperature decreased as age group increased, and for the energy conservation category, the regression coefficient estimates decreased as one approached the VIII region.

On the other hand, in the third quartile of outdoor temperature, significant differences were found in the comparison between the age groups below 65 and above 85, and in the difference between region I and region VIII.

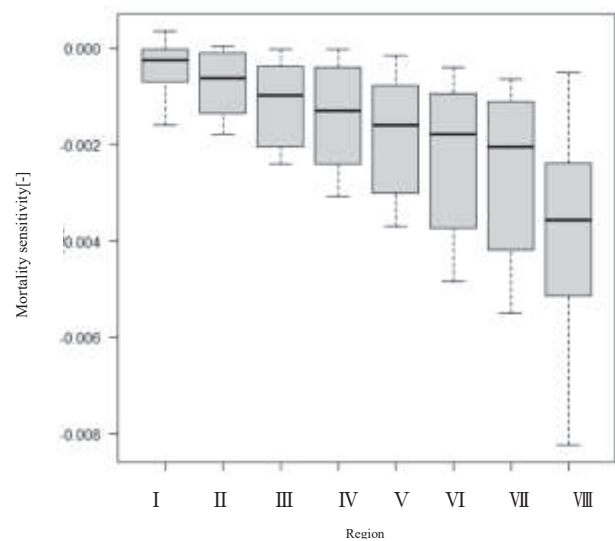


Figure 8. Box plot of mortality sensitivity by region

Table 1. Analysis of mortality sensitivity using linear regression models (low temperature)

	Coefficients	Regression coefficient	Pr
Age	65<	0(reference)	
	65+	-5.35×10^{-4}	5.01×10^{-3} **
	75+	-1.12×10^{-3}	2.77×10^{-8} ***
	85+	-1.33×10^{-3}	9.41×10^{-11} ***
Death Place	house	0(reference)	
	non-house	1.80×10^{-3}	8.31×10^{-26} ***
Period	1990-	0(reference)	
	1990+	-2.67×10^{-4}	4.54×10^{-2} *
Region	region_1	0(reference)	
	region_2	-3.31×10^{-4}	2.13×10^{-1} †
	region_3	-7.27×10^{-4}	7.11×10^{-3} **
	region_4	-0.108×10^{-3}	1.95×10^{-4} ***
	region_5	-1.39×10^{-3}	6.81×10^{-7} ***
	region_6	-1.83×10^{-3}	2.51×10^{-10} ***
	region_7	-2.20×10^{-3}	1.96×10^{-13} ***
	region_8	-3.49×10^{-3}	9.35×10^{-25} ***

Table 2. Analysis of mortality sensitivity using linear regression models (high temperature)

	Coefficients	Regression coefficient	Pr
Age	65<	0(reference)	
	65+	8.27×10^{-5}	6.14×10^{-1}
	75+	4.07×10^{-4}	1.44×10^{-2} *
	85+	3.66×10^{-4}	2.71×10^{-2} *
Death Place	house	0(reference)	
	non-house	4.59×10^{-4}	1.27×10^{-4}
Period	1990-	0(reference)	
	1990+	-3.93×10^{-5}	7.35×10^{-1}
Region	region_1	0(reference)	
	region_2	3.75×10^{-5}	1.08×10^{-1}
	region_3	2.16×10^{-4}	3.53×10^{-1}
	region_4	3.89×10^{-5}	8.67×10^{-1}
	region_5	2.04×10^{-4}	3.79×10^{-1}
	region_6	1.82×10^{-4}	4.33×10^{-1}
	region_7	-1.96×10^{-4}	3.99×10^{-1}
	region_8	7.45×10^{-4}	1.67×10^{-3} **

Acknowledgement

References:

1. Statistics Bureau, Ministry of Internal Affairs and Communications, “2011Basic Survey of Social Life.”
<http://www.stat.go.jp/data/shakai/2011/gaiyou.html> ,2011, 2022/1/20 Access
2. Mai Hasegawa, Hirofumi Hayama, et al
 “Temporal analysis of seasonal dependence of deaths due to disease using demographic statistics”
Transactions of the Architectural Institute of Japan, Environmental Systems (2021): p557~566.
3. Geographic Information System
<https://qgis.org/ja/site/>

IKAGA Toishiharu, et al

“Higher thermal insulation and energy efficiency of buildings and prevention of diseases and long-term care.” *Journal of the Real Estate Institute of Japan*. Vol.35 No.1(2021)

Wataru Umishio, Toshiharu Ikaga, et al

“Cross-Sectional Analysis of the Relationship Between Home Blood Pressure and Indoor Temperature in Winter A Nationwide Smart Wellness Housing Survey in Japan. ” *HYPERTENSIONAHA*, (2022)

Benjamin-Samuel Schlüter , Bruno Masquelier, et al “Long-term trends in seasonality of mortality in urban Madagascar: the role of the epidemiological transition.”*GLOBAL HEALTH ACTION*,(2020)

Akihiro Toyota, et al “Seasonal variation in stroke incidence in Japan: 46,000 cases in Rosai Hospitals. ’ registries, 2002–2008” *Jpn J Stroke* (2011)

Kenji OBAYASHI and Keigo SAEKI et al, “Thermal and Lighting Housing Environments and Circadian Blood Pressure Variability: Findings from the HEIJO-KYO Cohort. ”, *Jpn. J. Hyg*, (2018)

Lina Madaniyazi1, Yeonseung Chung “Seasonality of mortality under a changing climate: a time-series analysis of mortality in Japan between 1972 and 2015.”*BMC*(2021)

Yuri MITSUMOTO, Toshiharu IKAGA, et al, "Field Survey on Resident's Health Impact Affected by Space Heating System and Usage.", *The Society of Heating, Air-Conditioning and Sanitary Engineers of Japan*, (2019)