Characteristics of Human Mortality in Japan Concerning Global Warming

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ABSTRACT

Urban effects on climate change by human activities were analysed for air temperature in 16 cities of Japan in the past four decades by using meteorological observation data. The result shows that the urban warming in the cities is 0.1 to 0.3°C (difference) per decade for the anthropogenic effect to temperature rise. It should be noticeable that the urban warming is going on at a rate of twice to ten times as fast as global warming of the rate of increase in 0.3 to 0.6°C (difference) per one hundred years.

Death rates of Cerebrovascular disease (C.V.D.) in every month and monthly mean air temperature during the recent twenty years were used for other analysis. The relationship between death rate and temperature indicates existence of a minimum of death rate when in high air temperature in summer. The minimum is equivalent to air temperature about 22°C in Hokkaido, about 25°C in Tokyo and other middle districts, and 28°C in Okinawa. Temperature difference 3°C between districts is supposed to depend on difference of acclimatization to heat in each district. It makes the neutral temperature of the environment higher in summer, which implies reducing the risk of C.V.D. death from the heat.

The relationship between death rate and temperature in Kyoto city in July indicates statistically significant in the former decade from 1972 to 1981 but non-significant in the latter decade from 1982 to 1991. According to the transition of decades air-conditioners in households have been remarkably diffused in Kyoto. The spread rate of air-conditioners is supposed to be an index of the change of life style of the people. Operation of room cooling equipment in the hot summer eases heat stress on the human body. Currently, this change of life style would account for elimination of the relation of the death rate from C.V.D. to climatic heat.

In addition, the transition of impact of the heat in summer on human deaths in an urban area is discussed through advanced analyses using day-to-day number of deaths and day-to-day meteorological observation data.

In conclusion, at present when urban warming is advancing more rapidly than global warming, invalid and aged persons should be protected against heat in summer by using air-conditioners in the greater part of Japan. On the other hand, healthy and young persons should stand the heat in summer to get acclimatized to it, which would help keep their healthy state as they age.

Key words : cerebrovascular disease, death rate, heat in summer, neutral temperature in environment, urban effect

1. URBAN EFFECT ON CLIMATE CHANGE IN JAPAN IN THE PAST FOUR DECADES

Global warming, represented as climate change, is caused by human activities on the earth. It is analysed by relating meteorological observation data. But analysis only by observation data might be distorted by the effects of human activities, because observation data in urban areas include anthropogenic effects as well as geographical effects. Hense, in the analysis the anthropogenic effects need to be separated from the data.

Meteorological observation data in a city should be considered to include the following three items ; (1) values supposed to be observed in a geographically plane land without the city, (2) a deviation produced by existence of local geographical features at the location, and (3) a deviation produced by existence of the city at the location (Lowry, 1977). The deviation produced by existence of the city is called the "urban effect" in the text which follows. If no city existed in the location really observed, the data would not include the urban effect. Besides, if another observation was carried out in an other location, say a reference location, not far from the city but included in the same climate zone, items (1) and (2) in both locations would be supposed not to be changed so much. Thus, the urban effect of the city is considered to be obtained by subtracting the value of data observed at the reference location from the value observed in the city. This method makes it possible to extract the anthropogenic effects of the city from the meteorological observation data.

Applying this method to 16 cities in Japan, urban

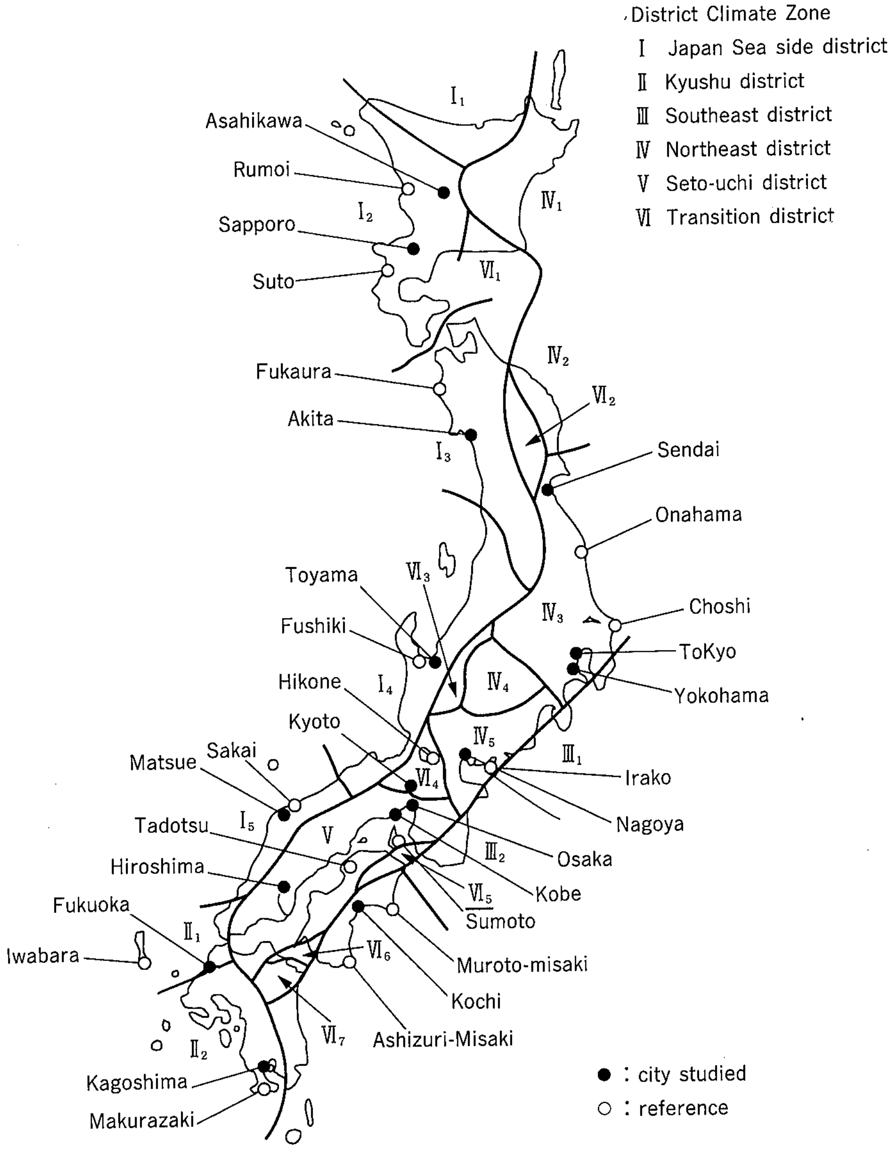

Fig. 1 16 cities and their reference locations distributed throughout the climate zones in Japan. The urban effect on temperature rise is represented by subtracting the mean of the observation data of the past four decades at the reference location from that in the city (Nakamura and Hasegawa, 1993).

effects in climate change during the past four decades have been investigated (Nakamura and Hasegawa, 1993). Every city was chosen to be on a big scale with over 100 thousand population and to be distributed in different climate zones in Japan. A location without a city or a city on a smaller scale existing in the same climate zone was chosen as the reference location for each city. The four decades 1951 to 1990 were chosen, excluding any year before 1950 which was considered under the influence of urban destruction by the Second World War. Meteorological observation data used in the analysis were monthly mean air temperature and water vapor pressure in both February and August. Figure 1 shows 16 cities analysed regarding the urban effect and the reference locations and the climate zones (Sekiguti, 1952) in Japan.

Variations of monthly mean air temperature for both February and August have shown increasing trends for a decade excluding a few cases. Exceptions are Toyama in February, Kobe in February, and Matsue in February and August, which would be almost meaningless. In five cities in the northeastern region, Asahikawa, Sapporo, Akita, Sendai and Toyama, the increasing trends are lower in February than in August, and they would be considered to be under influence of high latitude and snowy climate in winter. Excluding these cities, the increasing trends are generally higher in February than in August, and that corresponds to our understanding about the characteristics of heat islands with high intensity in winter.

Figure 2 shows urban effects on temperature rise in 16 cities in both February and August, which have been obtained by using data in the reference locations. Almost all of the rate of increase data for the decade indicate considerable change : 0.3°C (difference) per decade for a metropolis of over 2 million population such as Tokyo and Osaka and 0.1 to 0.2°C (diffe-

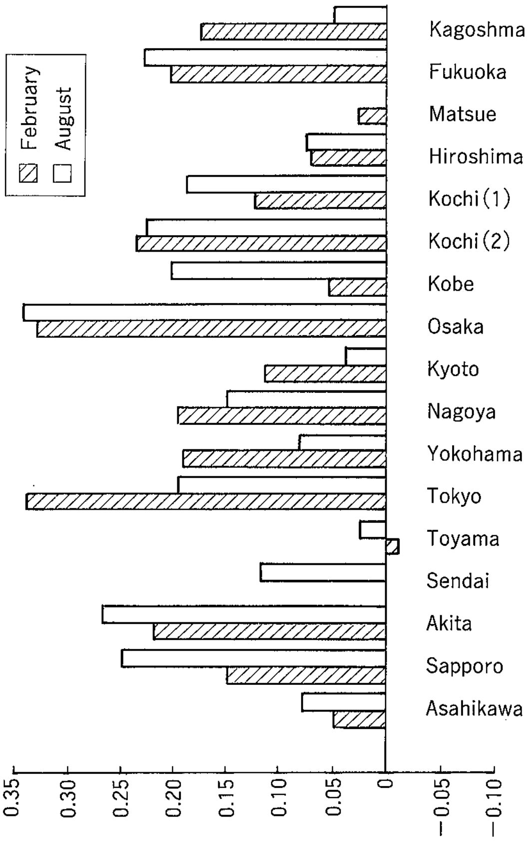

Fig. 2 Urban effects on temperature rise in 16 cities in both February and August, obtained by using data in reference locations. Almost all of the rate of increase for the decade indicate considerable effects ; 0.3°C (difference) per decade for metropolises such as Tokyo and Osaka and nearly 0.2°C (difference) per decade for medium-sized cities (Nakamura and Hasegawa, 1993).

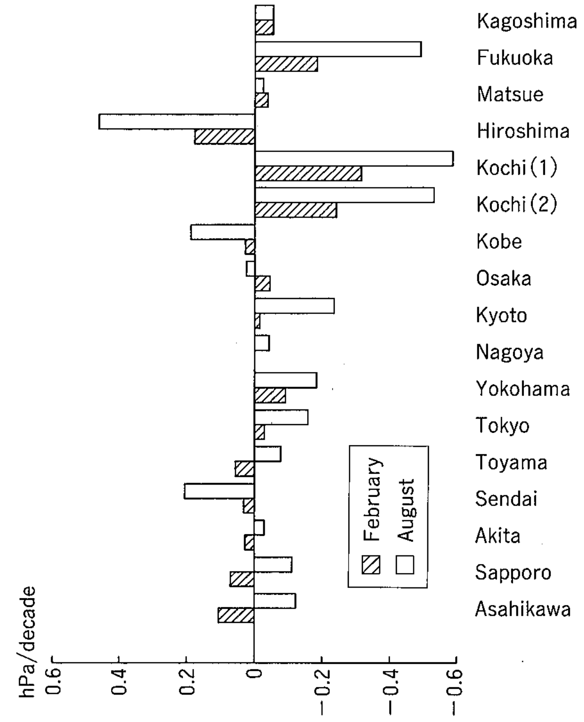

Fig. 3 Urban effects on vapor pressure variation in 16 cities in both February and August, obtained by using data in reference locations. The mean rate of increase for the 16 cities is about 0.0 hPa per decade and almost all are in a narrow range between ±0.2 hPa per decade (Nakamura and Hasegawa, 1993).

rence) per decade for medium-sized cities of over 300 thousand population. Differences between February and August are not always remarkable, but in the northeastern region such as Asahikawa, Sapporo and Akita the rate of increase is lower in February than in August. Urban effects in the northeastern region also appear to be lowered by the influences of snowy climate in winter. A high rate of increase in metropolises is considered reasonable because of their vast energy consumption. In all cases, the figure shows that regardless of the scale and population of a city the urban effect in temperature rise is a rate of increase of 0.1 to 0.3°C (difference) per decade for any city and for any season.

Global warming is generally grasped to be the rate of increase in 0.3 to 0.6°C (difference) per one hundred years for air temperature observed on earth surfaces, while, as aforementioned, urban warming is 0.1 to 0.3°C (difference) per decade for the anthropogenic effect of temperature rise. It should be noticeable that urban warming is going on at a rate of twice to ten times as fast as global warming.

Regarding water vapor pressure, meteorological observation data for four decades indicate decreasing trends, especially remarkable in August. The rate of decrease in August is several times as high as in February. The mean rate of increase for 16 cities is −0.1 hPa per decade in February, and −0.4 hPa per decade in August. There are few notable features in the rate of decrease for any city. Besides, clear differences in rate of decrease are not found between cities and their reference locations. Therefore, urban effects on vapor pressure variation are not evident. Figure 3 shows urban effects on vapor pressure variation of 16 cities in both February and August, which have been obtained by using data in the reference locations. The maximal rate of increase reaches −1.0 hPa per decade in the observation data, while one is −0.6 hPa per decade with urban effects. In addition, the mean rate of increase for 16 cities with urban effects is about 0.0 hPa per decade and almost all are in a narrow range between ±0.2 hPa per decade.

In the past four decades features in the cities, especially metropolises in Japan, have been changed by urbanization that includes extended asphalt and concrete pavement replacing soil, increased number of buildings and energy consumption, extension of urban districts, and so on. The aforementioned matters show that the influence of urbanization has appeared in air temperature but not in water vapor pressure.

Ultimately, over the past four decades in the cities of Japan air temperature has shown a continuous rate of increase of 0.1 to 0.3°C (difference) per decade as an anthropogenic effect, while water vapor pressure has not changed due to human activities.

2. CHARACTERISTICS OF C. V. D. MORTALITY IN SUMMER IN JAPAN

Cerebrovascular disease (C. V. D.) mortality in Japan has undergone conspicuous change, both chronologically and regionally, since the turn of the century (Momiyama, 1977). Statistical surveys have obtained associations that seasonal variation in Tokyo showed a marked peak in summer in the 1900 s ; two peaks appeared in the 1920s and 1930s due to the gradual flattening of the summer peak and the rising upcurve in the cold months ; and the winter peak was predominant in the 1950s and 1960s.

The death rate from C. V. D. is generally high in the northeastern region of Japan, while it is low in the southwestern region. There is a clear difference in patterns between Hokkaido and other districts of Japan. The wide diffusion of central heating systems in Hokkaido has apparently contributed to reduced seasonal variation of C. V. D. mortality.

In 1968-1971 statistics separating cerebral hemorrhage and cerebral thrombosis/embolism from cerebrovascular disease, Momiyama (1977) found interesting facts. That is, as for cerebral hemorrhage, the seasonal variation is quite moderate in Hokkaido and shows a winter concentration in the other districts of Japan. But, in the case of the seasonal variation of deaths from cerebral thrombosis/embolism, the whole country can be devided into four zones : (I) Hokkaido, with a moderate variation pattern ; (II) a zone with one sharp peak in the cold months ; (III) a zone which shows bimodal variation with a high peak in winter and a small hill in summer ; and (IV) a zone with the bimodal pattern of a peak in winter and a slight upcurve in the hot months. Climatically, it is cool in summer and very cold in winter in the first zone, rather cool even in summer in the second zone, hot with high humidity in the third zone, and subtropical in the fourth zone.

In other words, it is particularly notable that deaths from cerebral thrombosis/embolism are inclined to curve upward in the hot months, in contrast to the downturn for cerebral hemorrhage. Cerebral hemorrhage frequently happens among the middle-aged (40-60 years old), while, on the other hand, cerebral thrombosis/embolism affects mostly older people. Momiyama (1977) has indicated that the four patterns of seasonal variation for thrombosis/embolism mortality may be interpreted as indicating acclimatization of the aged to the meteorological environment, and to seasonal changes in particular. At any rate, more investigation concerning C. V. D. mortality in summer would be necessary from the viewpoint of urban warming.

Regarding the impact of hot climate on mortality, Al-Yusuf *et al.* (1986), Keatinge *et al.* (1986) and Auliciems *et al.* (1989) have also indicated that the rate of mortality increases with rising air temperature in summer. Hot climates could be stressful for human bodies, because the heat puts a physiological load on the body.

The following are with regard to surveys on neutral temperature relating to air temperature based on data of C. V. D. mortality in some prefectures (Yamanaka and Nakamura, 1997). Death rates from C. V. D. every month and monthly mean air temperature during the recent twenty years have been used for analysis. The excess death index has been defined to analyse relationships between air temperature and mortality. The

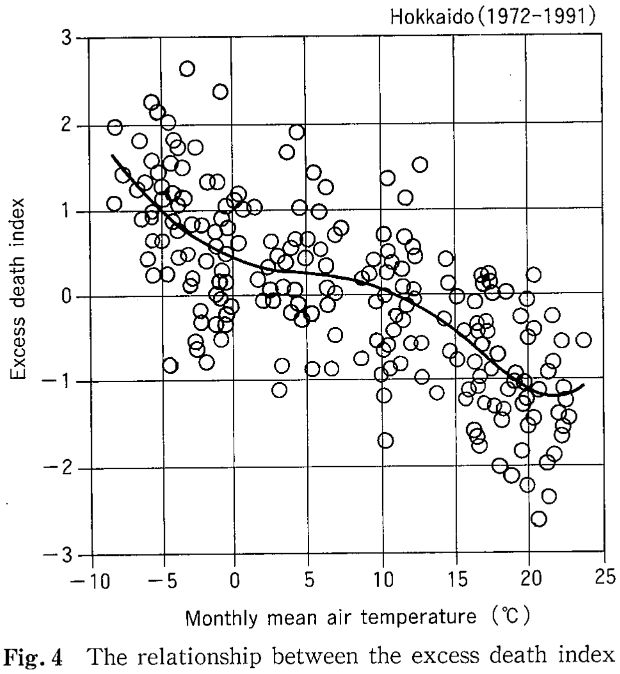

Fig. 4 The relationship between the excess death index of C. V. D. and monthly mean air temperature, Hokkaido, 1972-1991. The solid curve is a regression line estimated on the fifth order equation, which has been more suitable than the other order equations (Yamanaka and Nakamura, 1997).

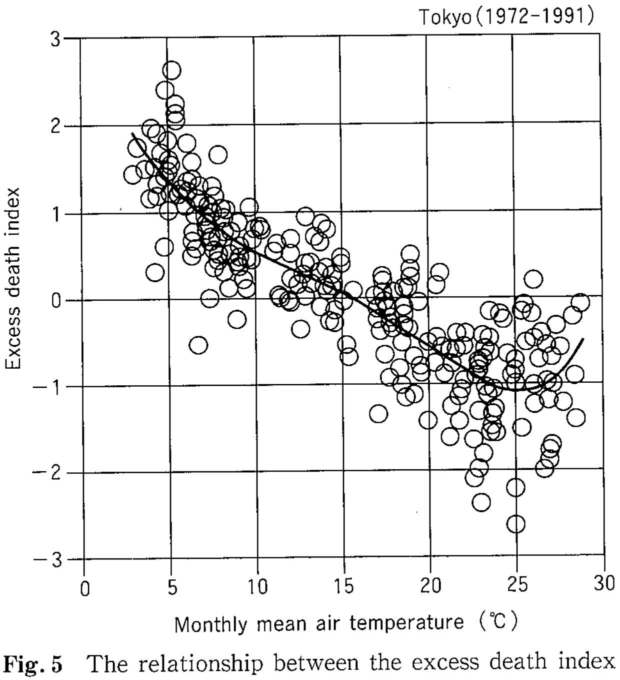

Fig. 5 The relationship between the excess death index of C. V. D. and monthly mean air temperature in Tokyo. The minimum on the regression line is nearly 25°C and clearer than in Hokkaido (Yamanaka and Nakamura, 1997).

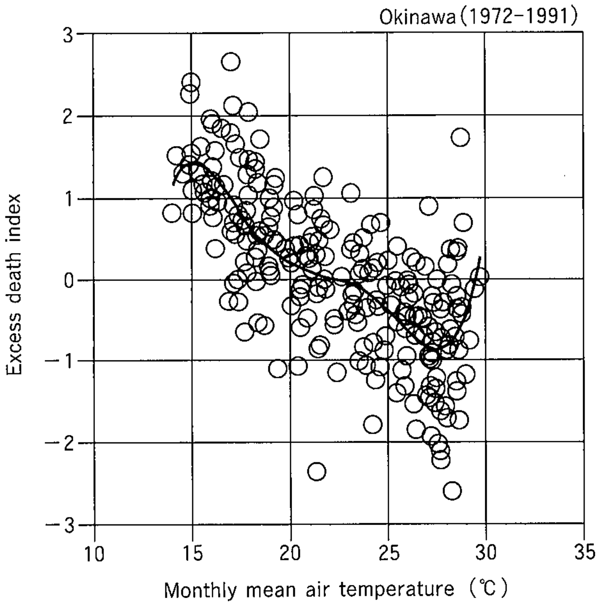

Fig. 6 The relationship between the excess death index of C. V. D. and monthly mean air temperature in Okinawa prefecture. Temperature corresponding to the minimum on the regression line is higher than in Tokyo and the neutral temperature is 28°C (Yamanaka and Nakamura, 1997).

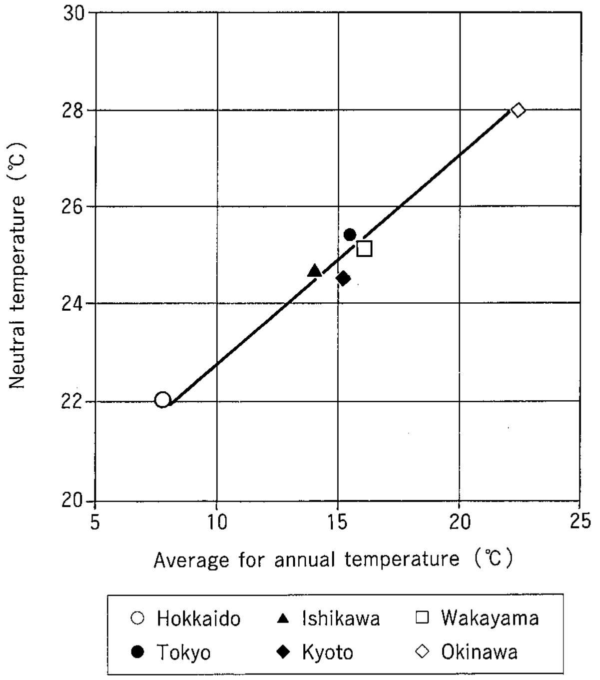

Fig. 7 Typical relationship between the neutral temperature of the environment and the average annual mean air temperature in Japan. Symbols : ○ Hokkaido, ▲ Ishikawa pref., □ Wakayama pref., ● Tokyo, ◆ Kyoto city, ◇ Okinawa pref. The straight line : $Tn = 0.43 \times Ta + 18.4$, where Tn (°C) is the temperature corresponding to the minimal excess death index, equivalent to the neutral temperature of the environment. Ta (°C) is the average annual mean air temperature (Yamanaka and Nakamura, 1997).

death rate descended year-by-year during the twenty years to be analysed, which could be supposed to be due to diffusion of medical care and development of the medical system. The excess death index is the difference between the observed actual death rate and the death rate on a descending regression curve of annual mean death rates during the twenty years. A recent span of twenty years was chosen from 1972 to 1991, but for the 19 years from 1973 in the case of Wakayama prefecture. A linear exponential equation was adopted as the regression line. As Hokkaido has vast open space unlike the other prefectures, values of air temperature were estimated by multiplying the weighting factor of population in each city distributed in Hokkaido by each value obtained at five meteorological observatories ; Asahikawa, Sapporo, Otaru, Kushiro and Hakodate.

Figure 4 shows a relationship between the excess death index and monthly mean air temperature in Hokkaido. The circle corresponds to every month and every year during the twenty years. An assembly of data shows a tendency to be high in winter and low in summer, which is equivalent to the result obtained by Momiyama (1977). A solid curve written in the figure is a regression line estimated on the five order equation to clearly express the property of annual variation. The curve indicates existence of a minimum when in high air temperature in summer. The minimum is equivalent to an air temperature about 22°C.

The neutral temperature of an environment has been defined as corresponding to a state in which the value of physiological strain is null (Nakamura *et al.*, 1996). In the text, therefore, the air temperature equivalent to the minimum of the excess death index might be interpreted one of the neutral temperatures of the environment, which is considered to be minimally stressful for human bodies from the viewpoint of thermo-physiology.

Figure 5 shows the relationship between the excess death index and monthly mean air temperature in Tokyo. A minimum on the regression line appears more clearly than in Hokkaido. The neutral temperature in the above-mentioned meaning is supposed to be nearly 25°C, which is higher than in Hokkaido. In addition, the width of deviation of the excess death index around the regression line is narrower than in Hokkaido, which is assumed to be owing to a big population in Tokyo. Figure 6 shows the relationship between the excess death index and monthly mean air temperature in Okinawa prefecture. The temperature corresponding to the minimum on the regression line rises higher than in Tokyo and the neutral temperature reaches 28°C.

Characteristics common to the three prefectures are differences of neutral temperature and temperature corresponding to null of the index. For 15°C of monthly mean air temperature, for instance, the index in Tokyo holds null but the one in Hokkaido decreases and the one in Okinawa prefecture increases over 1.0. For the same temperature, the death rate is lower in Hokkaido and higher in Okinawa than in the average year. The relationship will become more evident in the

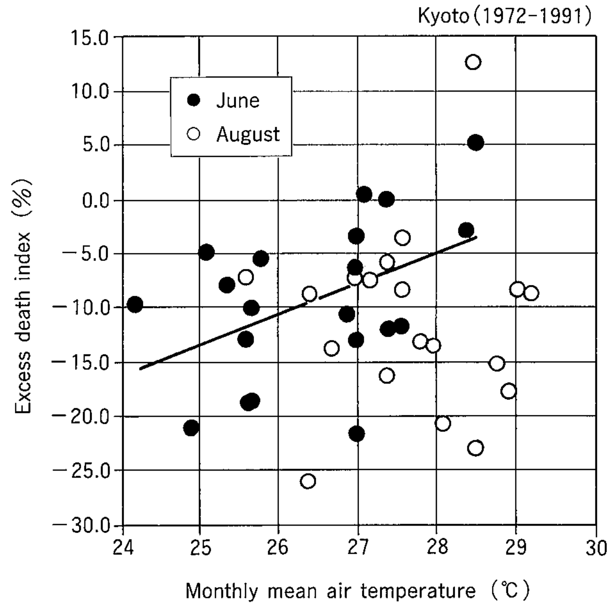

Fig. 8 The relationship between the excess death index of C. V. D. and monthly mean air temperature in Kyoto city, in which data are separately illustrated for July (●) and August (○). The index for July increased with statistical significance of $P<0.05$. The straight line in the figure is the regression line for July. But for August there was no statistical significance (Yamanaka and Nakamura, 1995).

following.

Figure 7 shows a typical relationship between the neutral temperature of the environment and the average annual mean air temperature in Japan. In addition to aforementioned three prefectures, new districts such as Ishikawa prefecture, Wakayama prefecture and Kyoto city are taken into account. The result indicates that the whole of Japan could be separated into three parts regarding temperature ; high, middle and low. Excluding Hokkaido and Okinawa, large areas of Japan are assumed to occupy the middle part.

Auliciems *et al.* (1989) have found existence of the minimal death rate for cardiovascular disease in Brisbane, which is located in the subtropical zone, in summer and induced an experiential equation concerning outdoor temperature corresponding to the minimal death rate. According to their method, a straight line suitable for the present result has been induced as follows (Yamanaka and Nakamura, 1979)

$$Tn = 0.43 \times Ta + 18.4 \qquad (1)$$

where Tn (°C) is air temperature corresponding to the minimal excess death index by C. V. D., which is equivalent to the neutral temperature of the environment. Ta (°C) is the average annual mean air temperature. The line is drawn in the figure.

Yoshida (1987) has indicated that mean weight of clothing put on by each human in daily life differs little all over Japan in the each season except winter, and in summer there are no differences between districts except Hokkaido, but even that is not very different. In addition, Okinawa prefecture belongs to the tropical zone. By these findings it could be surmised that the difference of about 3°C (difference) of the neutral temperature of the environment between the middle part, such as Tokyo, Kyoto city, etc., and the lower part, Okinawa prefecture, depends on acclimatization of the human body experienced in each district. Besides, existence of acclimatization would be also suggested for the difference of about 3°C (difference) between the higher part, Hokkaido, and the middle part. From the viewpoint of urban warming, acclimatization would be greatly welcome. Acclimatization to heat makes the neutral temperature of the environment higher in summer, which implies reducing the risk of C. V. D. death from the heat.

3. TRANSITION OF DEATH RATE FROM C. V. D. IN SUMMER DUE TO CHANGE OF LIFE STYLE

Thus far here, recent tendencies of the death rate from C. V. D. in Japan have been discussed, giving attention to summer, using the neutral temperature of the environment. Next, a transition of the death rate from C. V. D. in summer will be explained (Yamanaka and Nakamura, 1995).

Figure 8 shows the relationship between the excess death index and monthly mean air temperature in Kyoto city, in which data are separately illustrated for July (●) and August (○). The index for July increased with statistical significance of $P<0.05$. The straight line in the figure is the regression line for July. But for August there was no statistical significance.

With regard to these findings the following discussion might be made. In Japan, except Hokkaido, there is a peculiar term called "tsuyu", in which hot humid climate continues from June to July, rarely to August. As soon as the hot humid climate terminates, rapidly

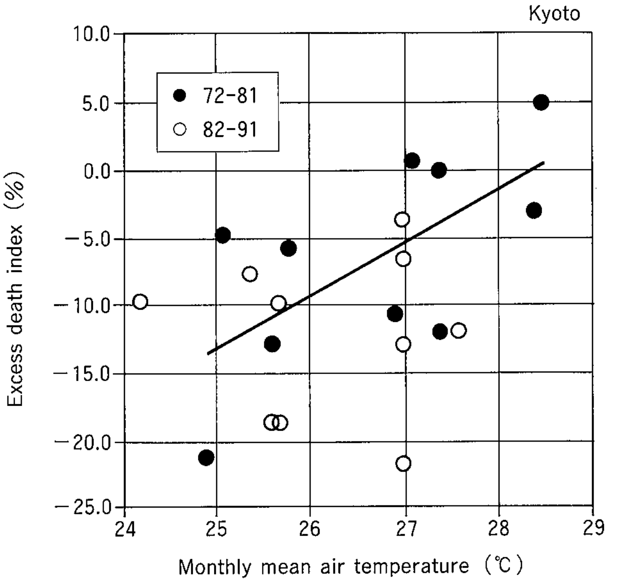

Fig. 9 The relationship between the excess death index of C. V. D. and monthly mean air temperature in Kyoto city in July ; the former period 1972-1981 (●) and the latter period 1982-1991 (○). The solid line is the regression line for the former with statistical significance, but there is no statistical significance for the latter (Yamanaka and Nakamura, 1995).

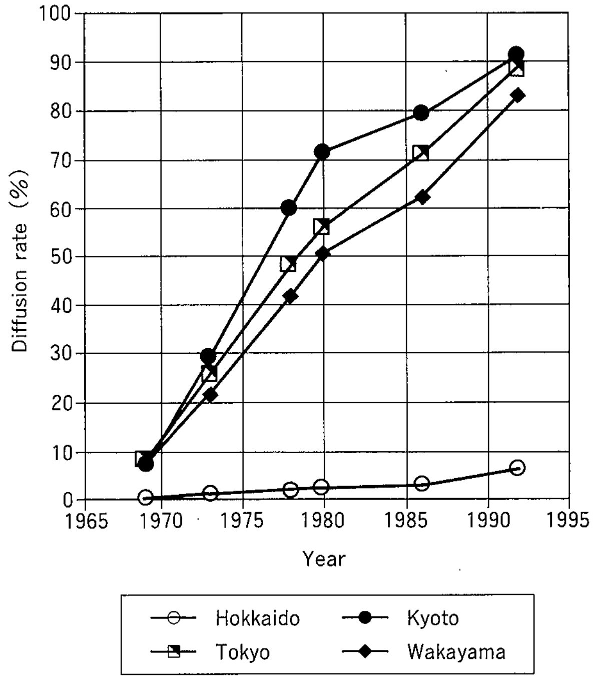

Fig. 10 Diffusion rate of air-conditioners in households in some prefectures in recent about 20 years. Symbols : ○ Hokkaido, □ Tokyo, ● Kyoto pref., ◆ Wakayama pref. (Yamanaka and Nakamura, 1995).

increasing heat begins. The latter, rapidly increasing heat imposes considerable stress on human bodies, so that it might bring about death from C. V. D. Thus, the death index from C. V. D. in July should be related to the increasingly hot climate which is represented by the monthly mean air temperature. However, those who have passed safely through the stress of July would not experience such hard stress from the climate in August, so they can continue their lives. It might imply that there is little relation of the index to the climate, namely monthly mean air temperature.

The same tendency, i. e., that the relation of the index to the hotness of the climate exists in July and vanishes in August, appears in both Wakayama prefecture and Hokkaido but not in Tokyo. Regarding no statistical relation of the index to climate in Tokyo in July, some reasons could be considered. First, the low limit of monthly mean air temperature reaches 22°C which is lower than 24°C in Kyoto city. As shown in Hokkaido, for lower values of monthly mean air temperature there is a possibility of the regression line going negative. Namely, the interval of temperature occupied in July may be on the transition point of the slope of regression line, so that the regression line disappeared. Existence of an extreme in the other regression line in a higher order in Tokyo has been previously shown in Figure 5. Second, the occupational makeup of the population in Tokyo is notably different from that of other prefectures ; agriculture and fishery workers are minimal (0.5% in Tokyo but 7.0% overall in Japan in 1992 according to General Statistics) and there are many office workers (24.6% Tokyo but 19.4% overall). This implies that in Tokyo there are many people who are minimally impacted by the hot climate in summer. Third, the relative numbers of the aged over 65 years in Tokyo are minimal (10.5% Tokyo, 10.7% Kyoto, and 11.0% Wakayama). The aged are known to accept easily the impact of climate.

The regression line in Hokkaido in July has a negative slope. The interval of monthly mean air temperature in July in Hokkaido is 17 to 23°C, compared with 24 to 29°C in July in Kyoto city. There is no overlap of temperatures between the intervals of these two locations. In the temperature interval in Hokkaido, the influence of heat on the death index from C. V. D. is assumed missing, but the impact of coolness would appear in its place. The aforementioned tendency of Hokkaido in July is coincident to the result indicated in Figure 4.

An advanced analysis has been made for Kyoto city separating the 20 years of data for July into two periods : former, 1972-1981 ; and latter, 1982-1991. Figure 9 shows the results. The solid line is the regression line for the former period with statistical significance, but there was no statistical significance for the latter period. This might imply a change of life style of the people during these 20 years. That is, Figure 10 shows the diffusion rate of air-conditioners in households in some prefectures during a recent period of about 20 years (The Asahi 1970, and others). Averaging for 10 year periods on the figure by proportionally enlarging values, the difusion rate of air-conditioners becomes 50% in the former period and 80 % in the latter period. The rapid increase in the diffusion rate from 24% to 72% is noticeable in the former period, and the diffusion rate reaches 88% in 1991 the end of the latter period. According to development of the gross domestic product in 1970s, air-conditioners hav become common in households in the main parts of Japan except Hokkaido. The spread rate of air-conditioners is supposed to be an index of the change of life style of the people. Needless to say, operation of room cooling equipment in the hot summer eases heat stress on the human body. Currently, this change of life style would account for elimination of the relation of the death rate from C. V. D. to climatic heat.

4. TRANSITION OF IMPACT OF THE HEAT IN SUMMER ON HUMAN DEATHS IN URBAN AREAS

The phenomenon that an attack of a heat wave in summer causes an increase in the number of deaths has been investigated in continental regions, mainly the U. S. A. Clarke (1972) found it was more remarkable in urban areas than in rural. Schuman (1972) mentioned that it was notable in densely built-up districts of New York and St. Louis and that the influence appeared within a week of the heat wave. Ellis (1972) has found it was not singular but occurred repeatedly in the United States. However, Macfarlane (1978) showed it occurred even in London. Not only heat waves but also the heat alone in summer should cause some harm to the human body. In Japan, the

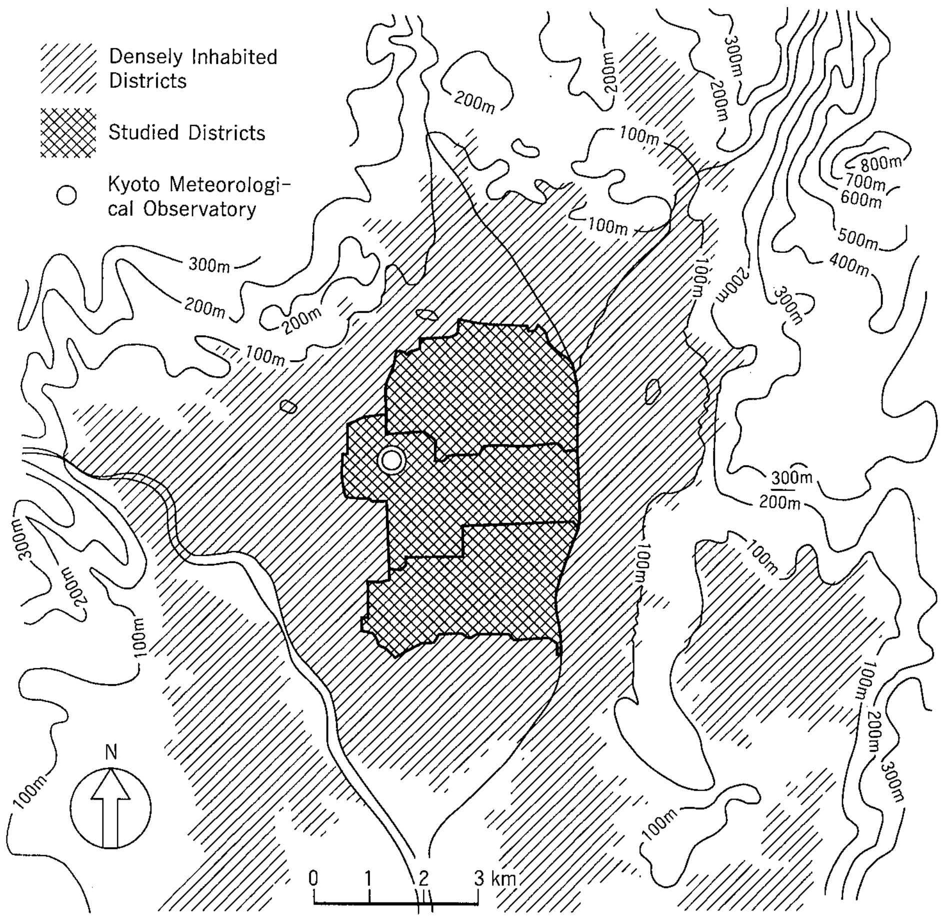

Fig. 11 Map of the central area of Kyoto city where the daily correlation between the climatological observation data in summer and the number of deaths was analyzed. The population of the studied area was 323,872 in the 1975 Census (Nakamura, 1988).

heat in summer reaches considerable strength, and besides, urban areas are densely populated. Thus the relation of the number of deaths to a hot climate needs to be investigated in Japan.

In this section, unlike in previous sections, transition of the impact of the heat in summer on human deaths in an urban area will be discussed from the standpoint of research (Nakamura, 1988). That is, as for urban warming, the following points will be explained : how intensely the heat in summer influenced daily numbers of deaths in an urban area, how different the correlation between hot climate and daily number of deaths was for people at home and those in hospital, and how rapidly the transition of the correlation with the heat appeared.

A central area of Kyoto city was chosen as the urban area to be studied, because it was the hottest district in summer in Japan. Kyoto city is located in a basin at an altitute of 41.4 m above sea level, at a latitude of 35°01'N, bounded by hills except to the south. Heights of the hills around the city are 300 m to 800 m as shown in Figure 11. The mean air temperature is 3.9°C in January and 27.5°C in August. The population of Kyoto city was 1,461,059 according to the 1975 Population Census of Japan. The central area was studied including three wards of the city shown as a crosshatched part of Fig. 11. The population of the studied area was 323,872 and was decreasing by 12.7 % per ten years. The population per square kilometer was 15,451. The number of rooms per ordinary household in residential houses was 4.38. In 1983, 48% of the residential houses had aged 30 years since being built. Single family houses accounted for 57.2% of the total. Almost all of the houses were two-story wooden structures.

Meteorological observation data were obtained at the Kyoto Meteorological Observatory located in the studied area. The data are considered to be applicable to the entire studied area, because the area is located on flat land in a basin. A series of three years, 1971, 1972 and 1973, and three of the subsequent decade, 1981, 1982 and 1983 were selected. Days studied were every day from the 1st of June till the 30th of September each year. Hence the term consists of 122 days including the hottest days in the year.

Regarding the daily number of deaths occurring in the studied area, only deaths by illness were collected, deaths by accident and suicide were excluded. Attention was payed to the place of death, which was sorted by either home or hospital. In general, homes have no clinical apparatus and few cooling systems such as air conditioners, so they seem to be influenced by the outdoor climate. On the other hand, as hospitals have such equipments, they seem not to be easily influenced by the outdoor climate.

The daily mean Discomfort Index (DI) was adopted

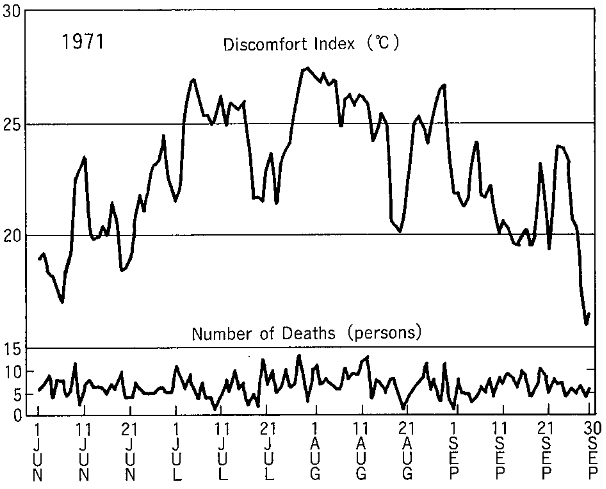

Fig. 12 Variations of the daily mean DI and the daily number of deaths for the total term 122 days from the 1 st of June till the 30 th of September in 1971 (Nakamura, 1988).

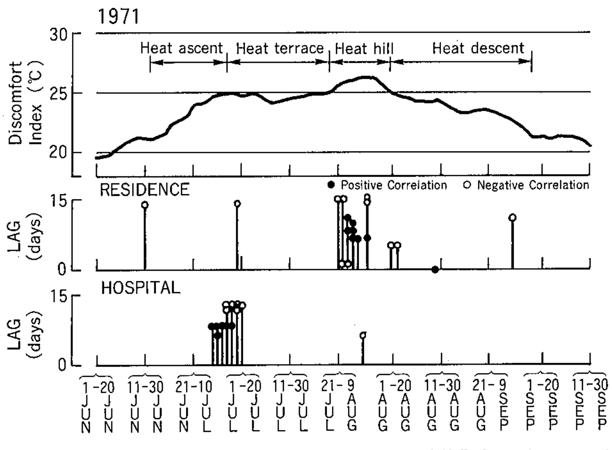

Fig. 13 Twenty-day moving average of DI for the total term in summer of 1971 at the top, appearance of the correlation of DI with the number of deaths at home in the middle, and appearance of the correlation in hospital at the bottom (Nakamura, 1988).

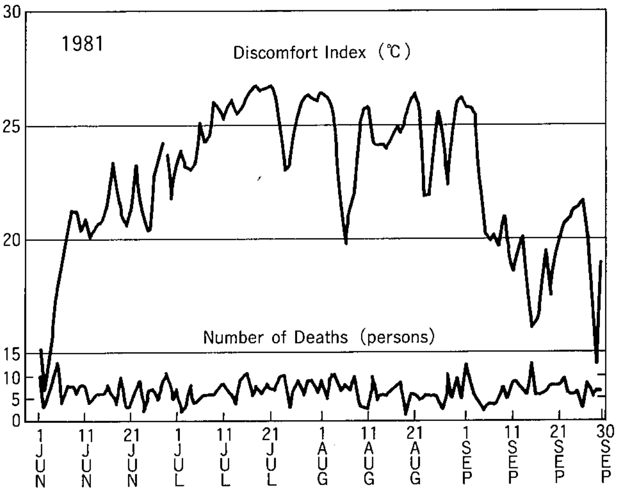

Fig. 14 Variations of the daily mean DI and the daily number of deaths for the total term in summer of 1981 (Nakamura, 1988).

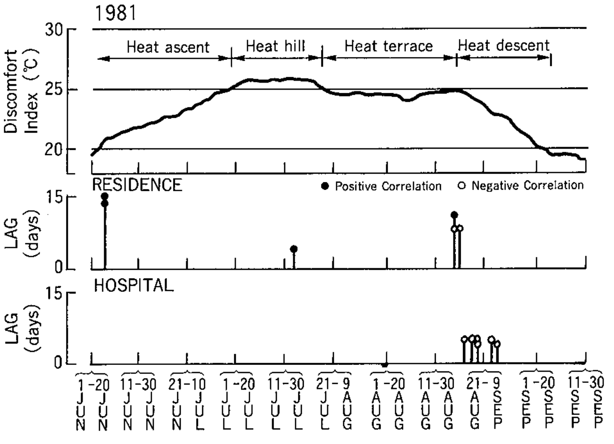

Fig. 15 Twenty-day moving average of DI for the total term and appearance of the correlation of DI with the number of deaths at home and in hospital, in summer of 1981 (Nakamura, 1988).

as a thermal index indicating the hot-humidness of each day. DI is defined as a mean of dry bulb temperature and wet bulb temperature (Sohar *et al.,* 1978). Regarding use of DI, a previous study had made it clear that the correlation of the daily mean DI is superior to that of other indices such as daily mean air temperature, daily maximum temperature, daily minimum temperature, and so on. As the daily mean wet bulb temperature was not observed, it was calculated by Goff-Gratch's equation using daily mean vapor pressure and daily mean air temperature.

Day-to-day fluctuation of DI is not a perfectly random process, so a simple application of an analytical method for stochastic processes would end in a failure. To overcome this fault, a moving cross-correlation method was devised. Features of the method consist of the following four processes : 1) a short term is taken out of the total term, which is from the 1st of June till the 30 th of September, 2) the linear trend of DI is removed out of the variation within the short term, and 3) for the specified short term, the analysis of the cross-correlation between the day-to-day DI and the day-to-day number of deaths is carried out, 4) the short term is moved every day after finishing the analysis. A length of 20 days was chosen as the short term in the real analysis.

Appearance of correlation between DI and the number of deaths was judged on a level of statistical significance of 1%. Both positive correlation and negative correlation can occur as significant correlations. Positive correlation includes both cases in which the number of deaths increases when DI increases and in which the number of deaths decreases when DI decreases ; and negative correlation includes both cases in which the number of deaths increases when DI decreases and in which the number of deaths decreases when DI increases.

In the study, attention was payed to the daily increase in the number of deaths. During the time of increasingly hot days, in other words, when the twenty-day average of DI was increasing only positive correlations were considered. To the contrary, when days were becoming cooler only negative correlations were taken into account. As hot days were continuing both correlations were considered.

Figure 12 shows variations of the daily mean DI and the daily number of deaths for the total term of 122 days from the 1st of June till the 30th of September in 1971. Figure 13 shows the twenty-day average of DI for the total term at the top, appearance of the correlation of DI with the number of deaths at home in the middle, and appearance of the correlation in hospital at the bottom, respectively, in summer of 1971. The lag on the ordinate in the middle and at the bottom indicates the days that the correlation has appeared late since DI loading. The value 25°C of the twenty-day average of DI could be supposed to be a standard sorting out of the influence of heat based on the relationship between appearance of the correlation and the twenty days average of DI through the total analysis. To understand the influence of heat, based on this standard, it is convenient to separate the total term into four periods following the illustrated variations ; heat ascent, heat terrace, heat hill and heat descent.

Figure 13 indicates that during the heat hill period there was intense correlation at home but not in hospital, and that during the heat ascent period, to the contrary, there was intense correlation in hospital but not at home. Residential houses seem to have been influenced by the severe heat outdoors. In addition, the appearance of the correlation in hospital during the heat ascent period occurred from June 25 to July 20. This coincides with the previous description that, as shown in Figure 8, rapid increasing heat would impose considerable stress on human bodies, although not always death from C. V. D. alone.

Figure 14 shows variations of the daily mean DI and the daily number of deaths for the total term in summer in 1981, which is synoptically the same as 10 years before, as can be seen in comparison with Figure 12. Figure 15 shows the twenty-day average of DI for the total term and appearance of the correlation of DI with the number of deaths at home and in hospital, in summer 1981. Figure 15 shows that although the heat was not as weak in summer as compared with Figure 13, both residential houses and hospitals show little correlation. A correlation appeared only during the heat descent period. This would suggest existence of reasons other than hot climate.

The research has extracted some features of the changing impact of heat in summer on numbers of deaths in an urban area, which are as following three points :

(1) As for residential houses and hospitals where deaths had happened, the ratio of number of deaths at home to that in hospital changed from 1 to 1 in the 1970s to 1 to 4 in the 1980s. During these ten years, the way of thinking of people regarding medical care is assumed to have been altered. This would be one of the changes in life style of the people.

(2) The correlation with the number of deaths at home appeared frequently in the heat hill period in 1971, 1972, 1973 and 1983, while that in hospital appeared frequently in the heat ascent period in 1971, 1972, 1973, 1982 and 1983. Some reasons can be considered for these findings. One is a physiological reason that serious patients in hospitals can not make it over the heat hill period because of their lack of tolerance and they die before reaching the heat hill period. Another is a human behavioral reason that air-conditioners in hospitals were not yet fully operating in the heat ascent period because the heat was not yet intense, so that the influence of the outdoor climate could appear. But in the heat hill period, air-conditioners were working enough to remove the influence.

(3) Appearance of the correlation became less in the 1980s than in the 1970s both at home and in hospital. In the previous section (Fig. 10), the rapid increase of the diffusion rate of air-conditioners in households year-by-year was used to infer that the relationship of the death rate from C. V. D. in Kyoto city to outdoor temperatures in the 1970s had vanished in the 1980 s. The same explanation would be applicable to this point. Not only deaths from C. V. D. but also total deaths have declined in the relation to heat since the 1980s in Kyoto city, which is considered to be caused by the change of life style of the people. This tendency extends to other districts in Japan, except Hokkaido.

In conclusion, at present when urban warming is advancing more rapidly than global warming, invalid and aged persons should be protected against heat in summer by using air cinditioners in the greater part of Japan. On the other hand, healthy and young persons should stand the heat in summer to get acclimatized to it, which would help keep their healthy state as they age.

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