Journal of Global Environment Engineering, Vol. 4, pp. 105–117, 1998

POTENTIAL IMPACT OF GLOBAL WARMING IN JAPAN — IMPACT ASSESSMENT OF WARMING ON HUMAN HEALTH —

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Abstract

Climate change is likely to have mostly adverse direct and indirect impacts on human health. Direct health impacts include an increase in mortality due to an increase in intensity and duration of heat waves. The potential impact of global warming on human mortality in Japan was assessed based on a relationship among ambient temperature, mortality, and an estimated future population in 2050. We focused on elderly people who are identified as sensitive to global warming, and concluded that: 1) assuming a temperature increase of 3°C by 2050, the population at risk will double in comparison with the current population, and about 9% of such a population at risk are due to global warming and the remaining is due to a change in population structure, that is, population aging, 2) global warming is likely to have a favorable impact on mortality in colder seasons as suggested in the IPCC Second Assessment Report, and 3) the potential adverse impact in urban area will be significant in 2050 because of the projected aging and concentration of the population.

KEYWORDS: *Global Warming, Health Impact, Heat Stress, Population Aging*

1. Introduction

The IPCC Second Assessment Report of 1995 identified both direct and indirect impacts of global warming on human health, most of which are negative impacts. The direct impact is an increase in mobility and mortality due to hot weather and increased heat waves. The indirect impact is the expansion of potential infected areas of vector-born diseases such as malaria and dengue fever (IPCC, 1996). However, very few studies on the direct and indirect impacts of global warming on human health have been conducted so far mainly because of the lack of information on the relationships between climate condition and health. To mitigate future negative impacts on human health, it is necessary to establish methods assessing such impacts.

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In this paper, we investigated the potential direct impact of global warming on human health in Japan, in particular the potential impact of an increase in ambient temperature on human mortality. First, a framework for this research to assess the potential impact of a temperature increase on mortality is introduced. A key component of this framework is a relationship between ambient temperature and mortality rate obtained from the analysis between the past 18 years of mortality records of individuals and daily maximum temperature records (Honda *et al.*, 1995). Second, we defined and calculated two indices to evaluate the impact of a temperature increase of 1 to 3°C in 1990 (before warming) and 2050 (after warming). Those are the population at risk and the mortality risk. From the temperature - mortality analysis, it was concluded that elderly people who are 65 years old or more are very sensitive to variations in daily maximum temperature. Therefore, considering the future projected total population and senior population in 2050, we estimated the population at risk and the mortality risk. Finally, based on these calculated indices, we examined the global warming impacts on human health in terms of 1) change in population structure, 2) seasonal variation, 3) regional variation, and 4) gender-specific characteristics.

2. Review of the literatures on global warming Impacts on human health

2.1 Health impacts described in the IPCC Second Assessment Report

The IPCC Working Group II has dealt with the impacts of global warming on various sectors, and reviewed the recent publications on possible impacts and adaptations to various sectors. The potential direct and indirect impacts identified in human health sectors are mostly negative. For example, increases in predominantly cardiorespiratory mortality and illness due to an anticipated increase in intensity and duration of heat waves are projected as a direct impact on human health. On the other hand, increased temperature in colder regions and colder seasons would reduce cold-related deaths (IPCC, 1996).

2.2 Stuides on heat-related impacts on human health

Table 1 summarizes several studies on heat-related impacts on human health. Smith *et al.* analyzed the relation between heat stress and mortality as part of a comprehensive survey of global warming conducted by the US Environmental Protection Agency. As a result of this analysis based on temperature and mortality data in 12 cities such as New York, Los Angeles, and Chicago, it is concluded that temperatures higher than 28°C would increase daily average deaths (Smith *et al.*, 1989). Other studies considered the relationship between temperature and death in nations, regions, and cities, and factors affecting that relationship (Kunst *et al.*, 1993; Rogot *et al.*, 1976; Rogot *et al.*, 1992).

Table 1. Several studies on heat-related impacts on human health

Researcher	Study Area	Major findings
Rogot E, 1976	32 Cities, USA	Relationship between mortality rate and daily average temperature was V-shaped. The mortality rate was lowest when the daily average temperature was 15.6 – 26.6°C based on 1962 – 1966 records. Mortality rate increased due to hot weather. Causes of death were heat stroke, circulatory and respiratory diseases.
Smith et al., 1989	12 Cities, USA	Change in mortality rate in global warming was estimated. Adaptability was also considered.
Rogot, E. et al., 1992	USA	Benefit of air conditioners to reduce morbidity risk in hot weather was examined.
Kunst, A.E. et al., 1993	Netherlands	Relationship between daily mortality and daily temperature from 1979 through 1987 was examined. Influenza, air pollution, and seasons were controlled. Wind speed, relative humidity, causes of mortality were taken into consideration. Mortality rate was lowest when ambient temperature was 20 – 25 °C.
Kalkstein, L.S., 1994	New York, Shanghai	Factors such as air conditioners and air pollution were taken into consideration.
Honda, et al., 1995	Kyushu Region, Japan	Relationship between ambient temperature and mortality in Kyushu showed a V-shaped pattern. Mortality is lowest when the daily maximum temperature is 28 – 33°C (65 years of age and older).

3. Framework of human health risk assessment and methodology

3.1 Framework of human health risk assessment

Figure 1 shows the framework of assessing the heat-related health impacts in this study. The data sets and geographical information and models used as well as the procedure of this analysis are shown in this figure (Harasawa *et al.*, 1997). Meteorological data, regional population, and socio-economic data were collected and processed, and then stored in a Geographical Information System (GIS)-based database. The research results on the relationship between ambient temperature and mortality rate conducted by Honda et al. (Honda *et al.*, 1995) and a population projection model were used for this study. In addition, GIS was used for spatial analysis and graphical presentation of the research results of this study. Based on the future projections of population and arbitrary temperature scenarios, potential impacts on human health in several cases were calculated and evaluated.

3.2 Database for health risk assessment and method of analysis

(1) Temperature data

Future climate scenarios show possible future changes in temperature and precipitation. Such scenarios are necessary for impact analysis of global warming. However, available general circulation model (GCM)-based climate scenarios still suffer from coarse spatial resolution. Their typical spatial resolution is about several hundred km, which is not sufficient for a small country such as Japan. Considering this limitation of the current available GCM scenarios,

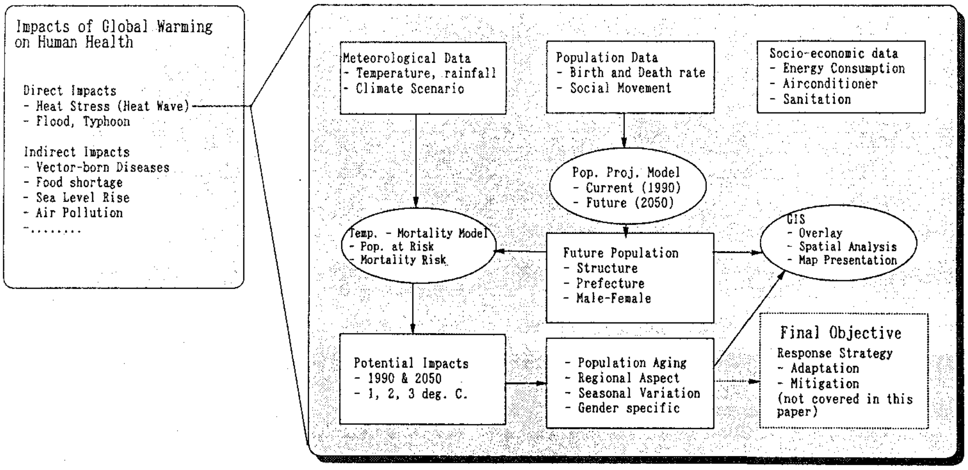

Figure 1. Research framework for assessing the human health impact

we took into consideration an arbitrary temperature scenario (Carter et al., 1994), and used three cases of arbitrary temperature increase such as 1°C, 2°C, and 3°C from the average temperature throughout the past 18 years.

As to meteorological data, 18-year records taken from the AMeDAS (Automated Meteorological Data Acquisition System) data (1976-1986) and DSP data (1987-1993) were used to estimate a long-term average of daily maximum temperature on a monthly basis. The climate variables stored in the latter data set are basically a subset of the former data set, and have enough temporal and spatial accuracy for this work. Both meteorological data sets were provided by the Japan Meteorological Agency. In this study, one measurement site located in the capital city of each prefecture was selected and its meteorological records were used for calculation of long-term statistics because the relationship between ambient temperature and mortality rate was obtained based on the climate records observed in the capital city of each prefecture (Honda *et al.*, 1995). Representative values, which were inputs to the temperature and mortality relationship, were estimated as a long-term average of 18-year daily maximum temperatures on a monthly basis. Figure 2 shows an example of the long-term average, maximum, minimum, and standard deviation of daily maximum temperature records in Tokyo.

(2) Relationship between ambient temperature and mortality rate

The relationships between daily maximum temperature and mortality rate by prefecture were used in this study. These show V-shaped patterns (Honda *et al.*, 1995). Figure 3 shows four examples of the daily maximum temperature and mortality relationship in Hokkaido, Tokyo, Fukuoka, and Okinawa prefectures. From the analysis conducted by Honda *et al.*, the V-shaped functional relationship in each prefecture was identified for people who are 65 years or older. The mortality rate is low at a moderate temperature that is defined as an optimum temperature here, and it is higher for either lower or higher temperatures. In the case of Tokyo, the mortality rate has a tendency to increase above the optimum temperature range of 28 to 33°C. Both the functional relationships of Fukuoka and Hokkaido also show

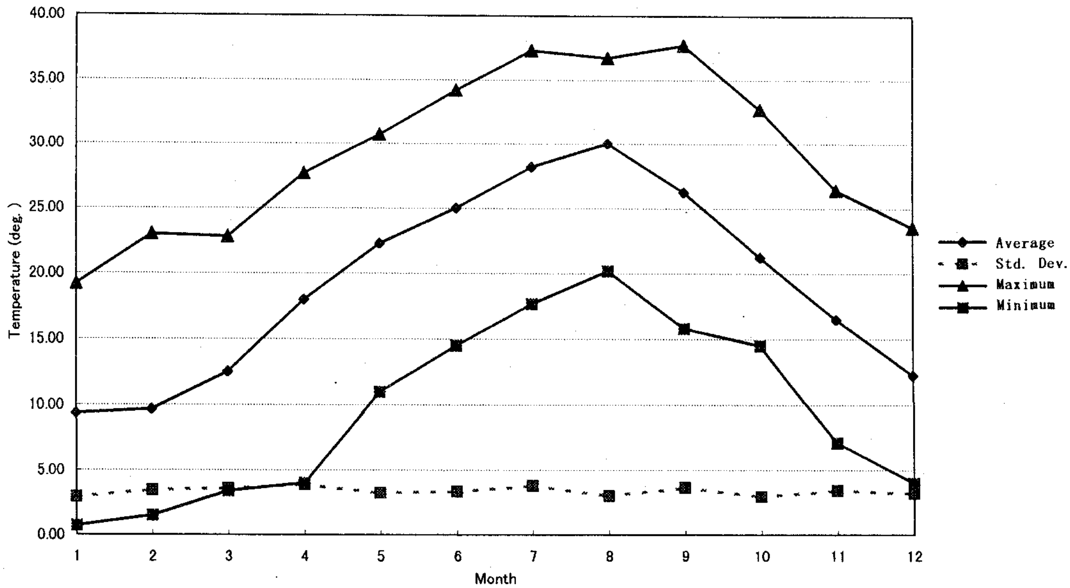

Figure 2. Long-term average, maximum, minimum, and standard deviations in daily maximum temperature in Tokyo

V-shaped patterns of which optimum ranges are 28 to 33°C and 23 to 28°C, respectively. However, Honda *et al.* found that there is no such optimum temperature range obtained in Okinawa (Honda, et al., 1995). Since the Japanese islands stretch from north to south, and climate conditions vary significantly from region to region, we used the prefectural temperature - mortality relationships for this analysis.

(3) Projection of future population

Figure 3 shows that the mortality rate is related to temperature increases due to global warming. To establish and implement countermeasures against the potential impacts of heat stress or hot weather, it is important to estimate how many persons will be affected due to warming. Considering future impacts of global warming, it is more appropriate to predict numbers of affected persons based on a future possible population. A population projection model was originally developed using a cohort factor method by the National Institute of Population and Social Security Research, the Ministry of Welfare and Health (National Institute of Population and Social Security Research, 1994a, 1994b). Assuming fertility rates, death rates, and social movement rates, this model calculates the age structure in each prefecture. The period of population prediction is from 1990 to 2010. In this study, using this model, the age structure of future population up to 2050 was projected. In 2050, the percentage of people who are 65 years or older is projected to be about 30%, which is almost double compared to the 17% in 1990.

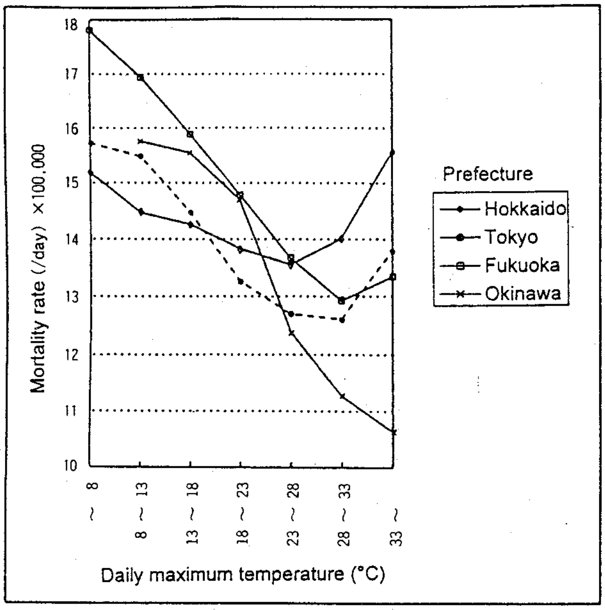

Figure 3. Relationship between daily maximum temperature and mortality for selected prefectures (65+ year old males, 1972-1990)

(4) Population at risk and mortality risk

Two indices for evaluation of the health impact are defined as follows.

Population at risk (P_{risk}) (Unit: persons/day): Absolute number of deaths calculated from the temperature - mortality functional relationship for the population of age 65 and over F_{65+}), an input of which is a long-term average of daily maximum temperatures (T) statistically obtained on a monthly basis. P_{risk} is calculated as follows.

$$P_{risk} = F_{65+}(T) \times P_{65+} \tag{1}$$

Here, P_{65+} is the population of age 65 and over.

Mortality Risk (M_{risk}) (Unit: 1/day): Population at risk (P_{65+}) divided by total prefectural population (P_{total}). This index is introduced to eliminate the population size effect in each prefecture and to compare the health impacts among prefectures. M_{risk} is calculated as follows.

$$M_{risk} = P_{risk}/P_{total} \tag{2}$$

Four cases are taken into consideration here as follows.

Case 1: 1990 (Current condition)

Case 2: 1990 (+1, +2, +3°C increase in ambient temperature)

Case 3: 2050 (No change in temperature and change in population structure)

Case 4: 2050 (+1, +2, +3°C increase in ambient temperature and change in population structure)

Major assumptions in calculation of the above indices are as follows; 1) Our main concern is with people 65 or older; 2) Causes of death will not differ in 2050, and no physical or social

Table 2. Monthly- and increased temperature- specific population at risk and mortality risk

	Population at Risk: P_{risk} (persons/day)								Mortality Risk: M_{risk} (1/day, $\times 10^{-7}$)				
	1990				2050				1990	2050			
Month	+0°C	+1	+2	+3	+0°C	+1	+2	+3	+0°C	+0°C	+1	+2	+3
1	2110	2100	2089	2084	4434	4419	4397	4389	171	396	395	393	392
2	2102	2098	2086	2063	4422	4418	4393	4356	170	395	395	392	389
3	2032	1967	1944	1929	4295	4117	4072	4049	164	384	368	364	362
4	1826	1791	1778	1759	3839	3738	3713	3689	148	343	334	332	330
5	1731	1694	1676	1670	3628	3564	3512	3501	140	324	318	314	313
6	1669	1659	1648	1641	3500	3486	3466	3455	135	313	311	310	309
7	1642	1643	1645	1665	3456	3459	3463	3499	133	309	309	309	313
8	1644	1654	1678	1724	3461	3480	3526	3623	133	309	311	315	324
9	1659	1645	1643	1645	3487	3461	3459	3461	134	312	309	309	309
10	1754	1717	1698	1677	3681	3613	3577	3512	142	329	323	320	314
11	1916	1880	1813	1787	4023	3965	3801	3727	155	359	354	340	333
12	2078	2031	1963	1950	4379	4266	4105	4079	168	391	381	367	364

adaptation to a warmed environment is not considered; 3) Factors such as global warming and population aging affect mortality independently, and 4) Relationship between temperature and mortality is expressed in a step function which gives a certain value for every 5°C range of temperature as shown in Figure 3.

4. Results and discussion

4.1 Calculated population at risk and mortality risk for each month and each temperature range

Month- and temperature-specific population at risk and mortality risk indices are shown in Table 2. Both indices were calculated for the 65-or-over age persons who are sensitive to the increase in temperature in all prefectures. Then those indices were summed up as a national total as shown in Table 2. The estimated population at risk in 1990 ranging from 1642 persons/day in July to 2110 persons/day in January will almost double by 2050 assuming the temperature increase by 3°C, i.e., ranging from 3455 persons/day in June to 4389 persons/day in January. The calculated mortality risk is also demonstrated in Table 2. The mortality risk varies from 133×10^{-7} - 171×10^{-7} 1/day in 1990 to 309×10^{-7} - 392×10^{-7} 1/day in 2050

4.2 Global warming and future change in population structure (population aging)

Here we define '$P_{2050(+3)}$' as the population at risk in 2050 due to a temperature increase of 3°C. The effect of global warming on change in the population at risk can be described as '$P_{2050(+3)} - P_{2050(+0)}$', so that '$P_{2050(+0)} - P_{1990(+0)}$' is identified as the effect of other factors. In this analysis, this item reflects an increase in mortality mainly due to population aging, i.e. an increase in population of age 65 and over.

The increased population at risk in August is 1979 persons/day ($= P_{2050(+3)} - P_{1990(+0)}$), which consists of an increment due to population aging, i.e., 1817 ($=P_{2050(+0)} - P_{1990(+0)}$)

and an increment due to warming, i.e., 162 ($P_{2050(+3)} - P_{2050(+0)}$). In other words, when temperature increases 3°C by 2050, the excess deaths will be 1979 persons/day. This excess number of deaths can be divided into two factors, i.e., the excess deaths due to population aging (1817 persons/day) and those due to warming (162 persons/day). The latter value is about 9% of the former value. In January, the total excess deaths due to population aging and to warming are 2279, 2324, and - 45, respectively. This shows the effect of warming as positive or favorable, and that it will reduce the number of deaths in colder seasons.

The difference in the population at risk and the difference in mortality risk between 1990 and 2050 are demonstrated in Figure 4(a) and (b). Since the absolute number of elderly people is larger in the metropolitan regions, the population at risk is larger. However, the mortality risk shows no significant difference among prefectures.

4.3 Seasonal variation in the mortality risk

Figure 5 shows monthly variation in mortality risks in 2050 when the increase in temperature ranges 0 - 3°C. The larger temperature increase, the higher mortality risk. In contrast, the mortality risks in other months tend to decline in general. In particular, the mortality risks in October to December decline as the temperature increases and the positive effect of warming is observed.

4.4 Comparison of population at risk and mortality risk among regions

All 47 prefectures are divided into 13 regions. This regional divisions were originally defined based on those used by the National Institute of Population and Social Security Research (National Institute of Population and Social Security Research, 1994a, 1994b) and the population at risk and the mortality risk of the 65-or-over age group for each region in August 1990 and August 2050 are calculated and summarized in Table 3. In addition, Figure 6 shows regional values of both indices for comparison. The regional population at risk and the mortality risk were plotted in each case as defined above.

When the temperature increases of 3°C by 2050, the mortality risk will change from the present 92.86×10^{-7} - 168.6×10^{-7} 1/day to 276.36×10^{-7} - 373.0×10^{-7}, but there are some remarkable differences in the index among regions. In 1990, the value of the South Kanto region including Tokyo, Chiba, Saitama, and Kanagawa, is the highest, and that of the Kyushu region is the second. In 2050, the estimated population at risk of South Kanto will still be the first, but the Kyushu region will be the 4th. This is explained by the future changes in population structure in both the South Kanto and the Kyushu regions. In the South Kanto region, the population in Tokyo is projected to decline, but the population of the surrounding 3 prefectures will increase. As a result, total population will change from 31.8 million in 1990 to 38.4 million in 2050. As a result of population aging, the population of age 65 and over is projected to be 10.4 million vs. the present 3 million in this region. This change in population structure results in an increase in population at risk of 853 persons/day from the present 320 persons/day. In terms of the mortality risk which is obtained through a division of the population at risk by the total regional population, population aging as well as population concentration in metropolitan areas would increase the population at risk in this region.

In contrast, in the Kyushu Region, the total population of 13.3 million in 1990 (1.9 million of the 65-or-over age group) will fall to an estimated 9.5 million (2.8 million) in 2050. The elderly population in 2050 will be approximately 1.5 times larger than that in 1990. The

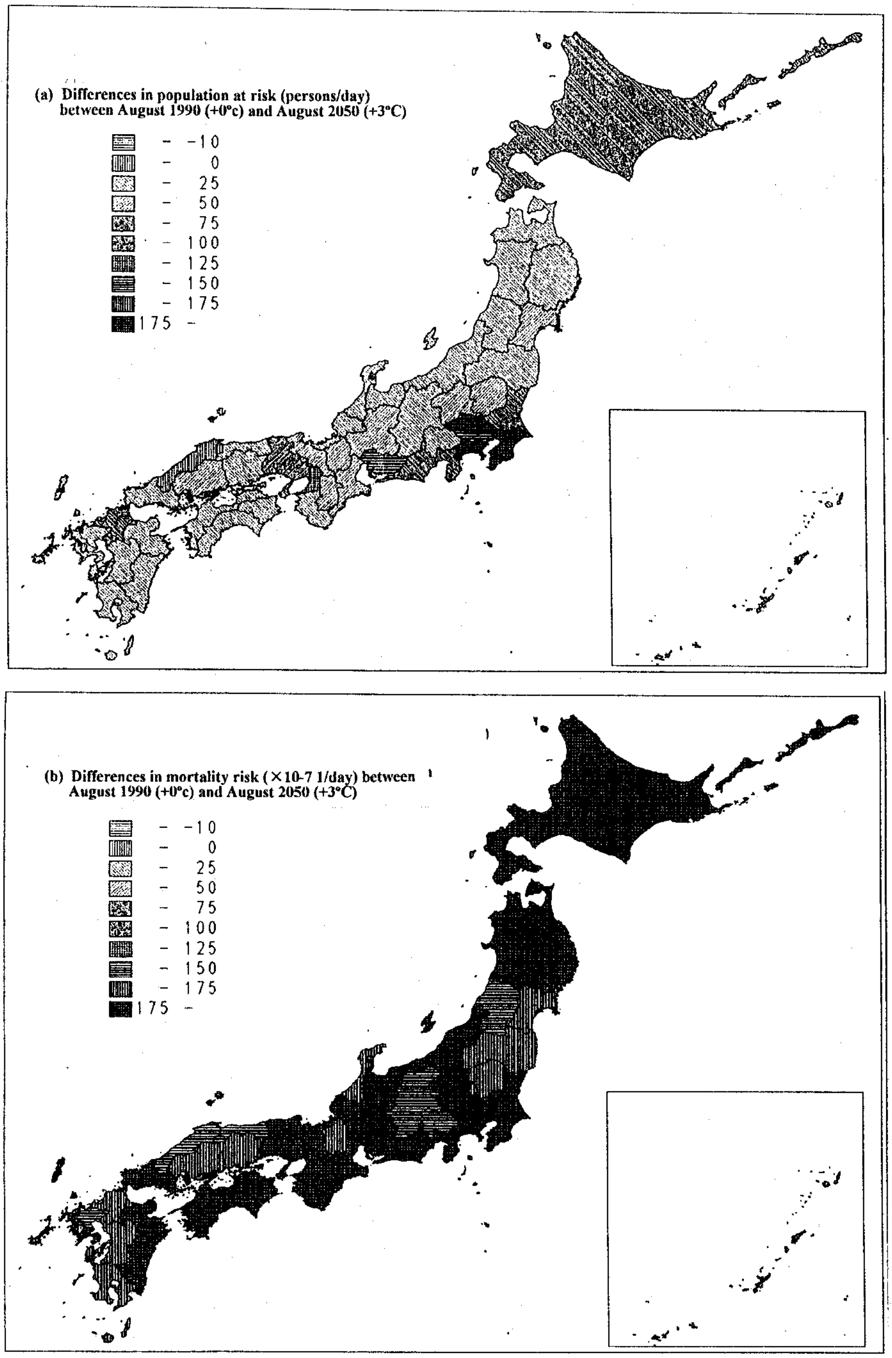

Figure 4. Estimation of change in risk indices with a 3°C increase in temperature and population aging

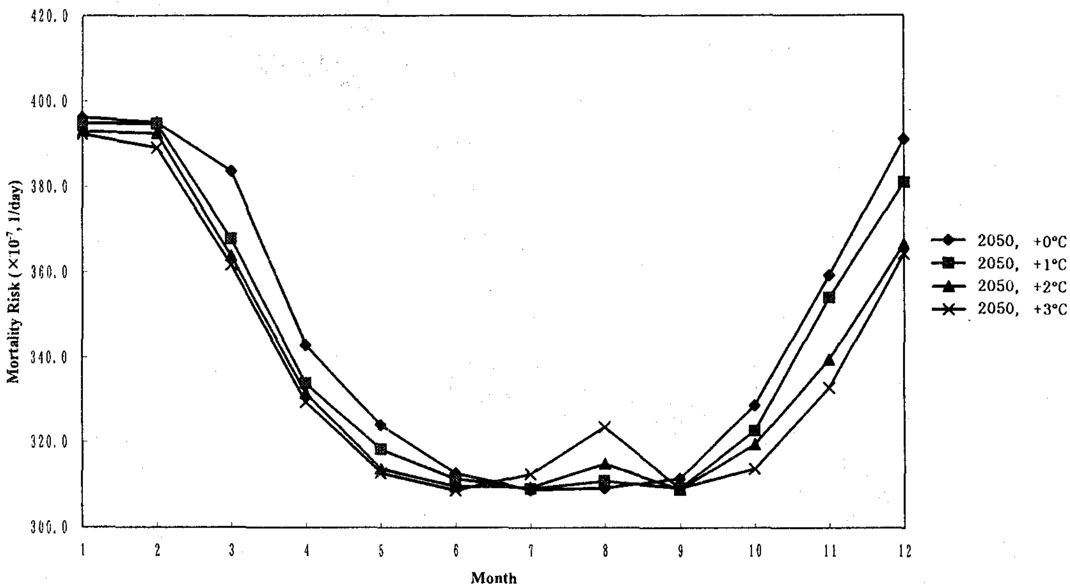

Figure 5. Seasonal variation in mortality risk

Table 3. Population at risk and mortality risk in August 1990 and August 2050

Region	1990			2050				Mortality Risk		
	Population x 10000	Age>65 x 10000	Pop. at Risk (+0°C) Per./day	Pop. Estimated x 10000	Age >65 x 10000	Pop. at Risk (+0°C) Per./day	Pop. at Risk (+3°C) Per./day	1990 (+0°C) x 10^{-7} 1/day	2050 (+0°C) x 10^{-7} 1/day	2050 (+3°C) x 10^{-7} 1/day
1 Hokkaido	564	68	77	354	109	122	127	136	344	359
2 Tohoku	974	136	154	669	197	221	226	158	331	337
3 North Kanto	675	83	96	705	191	223	229	142	316	324
4 South Kanto	3180	300	320	3838	1037	1122	1173	101	292	306
5 Hokuriku	558	83	94	397	117	133	143	168	336	361
6 Tozan	301	47	51	261	73	79	80	169	302	305
7 Tokai	1422	161	177	1322	375	417	446	124	316	337
8 East Kinki	367	47	54	404	106	123	130	148	304	323
9 West Kinki	1674	182	204	1351	372	420	447	122	311	331
10 Chugoku	775	116	126	557	163	177	181	163	318	326
11 Shikoku	420	66	74	258	82	92	96	176	357	373
12 Kyushu	1330	190	207	952	275	299	309	156	313	325
13 Okinawa	122	12	11	126	36	34	35	93	266	276
Total	12239	1493	1644	11194	3132	3461	3623			

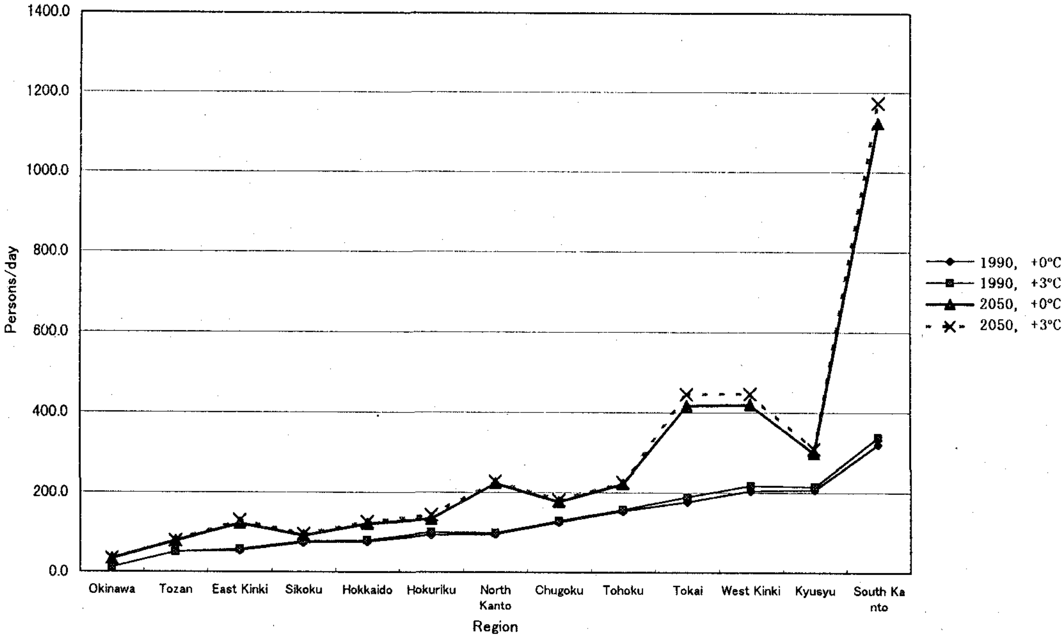

Figure 6. Comparison of regional population at risk in August

population at risk will rise to 309 persons/day from 207 persons/day, reflecting the increased elderly population.

4.5 Comparison of gender-specific mortality risks

Figure 7 shows the seasonal variation in the mortality risks of males and females in 1990 and 2050 (increased temperature by +0°C and +3°C). In 1990, the monthly values of mortality risk of females are a little higher than those of males. However, in 2050, although the seasonal pattern of variation is almost the same as that in 1990, the difference in mortality risks between females and males is apparent, with the mortality risk of males tending to be higher than that of females. Since the mortality risk is defined as the population at risk divided by the total population, this change might be caused by a change in population structure of both females and males.

5. Concluding remarks

Assuming the future population structure and the potential temperature increase associated with global warming, we examined warming impacts on human health in Japan using the two indices such as population at risk and mortality risk. The age 65-or-over who are identified very vulnerable to hot weather and increased temperature are of our major concern. The research findings are summarized as follows.

(1) In considering the impacts of global warming on human health and our response strategy, the future structural change in population, especially in the aging population as well as the increased temperature are important factors.

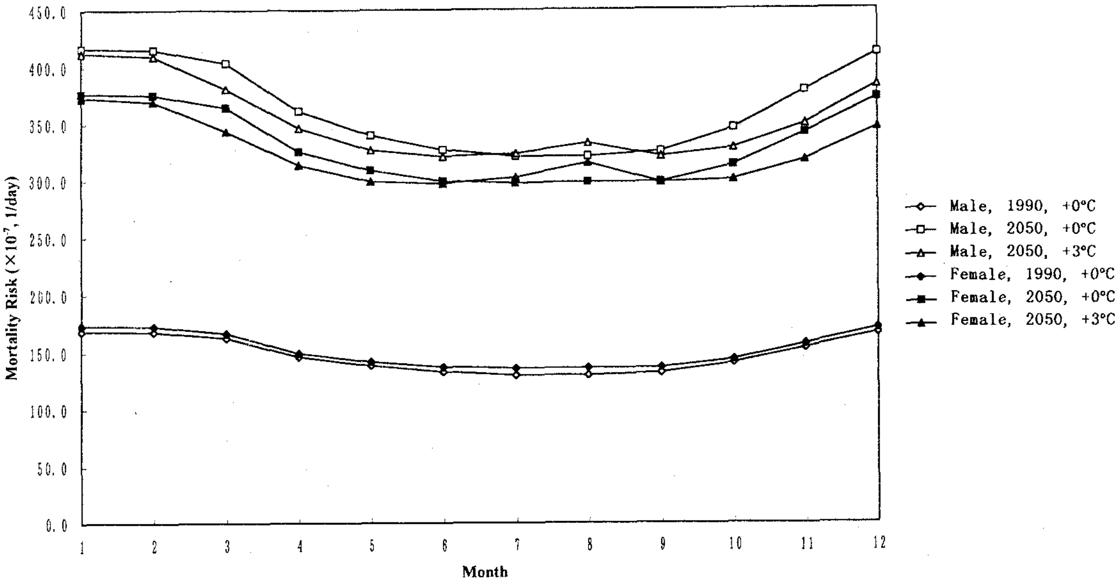

Figure 7. Comparison of gender-specific mortality risk

(2) In the summer (July and August) of 2050, the increase in temperature due to global warming will have adverse effects on human mortality, and will increase the number of deaths in the 65-or-over age group. The additional deaths due to warming are about 9% of the total additional deaths due to population aging.

(3) In other seasons, temperature increase due to global warming assumes a downward trend. This supports the finding reported in the IPCC Second Assessment Report, namely, that global warming causes fewer deaths in winter or in colder regions.

(4) The population at risk will increase in some metropolitan regions mainly because of the concentration of population as well as future population aging. This suggests that large urban areas will be of greatest concern in considering countermeasures.

(5) From the comparison of population at risk between females and males, their seasonal patterns are almost similar, but their absolute number of deaths shows some slight difference reflecting the difference of age distribution between both sexes.

In this analysis, we only considered the relationship among ambient temperature, mortality rate and future population. Further a study will be needed to consider other factors (e.g., acclimatization and social adaptation of people to a warmer climate) for a better understanding of human health impacts due to global warming and for planning and implementing a response strategy. Finally, we would like to acknowledge that this research was supported financially by the Japan Environment Agency's Research Fund.

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