Impact of Climate Change on Human Health in Asia and Japan

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Abstract

Recent IPCC (Intergovernmental Panel for Climate Change) reports have recognized health impacts as one of the most important issues.

The health impacts of climate change in Asia are serious: the WHO (World Health Organization) has calculated the disability adjusted life years (=DALYs) due to the climate change in 2000 (compared with a baseline of 1961-1990). Among the regions studied, South-East Asia-D, which includes Bangladesh, Bhutan, India, the Maldives, Myanmar and Nepal, had the highest total DALYs mainly due to diarrheal diseases and malnutrition.

Unlike in the rest of Asia, the health impacts in Japan have been considered to be mainly direct. To evaluate the impact of heat stress, the relationship between daily maximum temperature and mortality rate was examined for different prefectures. The relation was V-shaped, that is, there was shown to be an optimum temperature (OT) at which the mortality rate is lowest, and the mortality rate is higher when the temperature becomes either higher or lower than the OT. The V-shaped pattern was affected by climate: The OT shifted from right to left as the area became warmer. We found that the 85-percentile of the daily maximum temperature best predicted the OT in Japan.

The elderly contributed most to the V-shaped temperature-mortality pattern due to compromised adaptive capacity. As for causes of death, circulatory and respiratory diseases constituted the V-shape.

One of the potentially important issues is mortality displacement, i.e., that the decedents due to heat stress would have died anyway within several days or in a couple of months even if the heat stress had not occurred. This phenomenon is, however, still in debate.

Key words: climate, diarrhea, elderly, heat stress, malnutrition

1. Introduction

Recent IPCC reports have recognized health impacts as one of the most important issues along with problems of dwindling water resources, energy, agriculture and biodiversity (Watson *et al*. eds., 1996; McCarthy *et al*. eds., 2001). It is extremely difficult, however, to conduct health research with regard to climate change, partly because we cannot conduct experiments on possible hazards to humans, and partly because health is related not only to climate, but also to ecological, social, cultural and economical factors. Another difficulty is data collection. Especially in developing countries, it is very hard to collect morbidity and mortality data. Even in developed countries this can be a difficult task. For example, Japan has an official system for collecting these data for some important infectious diseases, but no system as a nation, for collecting data on heat stroke incidence.

Despite the above difficulties, we have accumulated knowledge, owing to the efforts of pioneering researchers. In this article, I will present the status quo of the research and its results, first from new reports and articles with emphasis on Asia and second from our own research in Japan.

2. Health Impacts in General

Global climate change is not a mere shift in average temperatures. It also entails increased climate variability, i.e., more hot days, more frequent and intense floods (Milly *et al.*, 2002). In other words, not only will the mean increase, but so will the degree of variance. We need to take these two changes into account in estimating the impact of global climate change.

Although the data for estimating health impact is not readily available, it is rather easy to collect the numbers of heat stroke patients transported to hospitals by ambulance cars. This type of impact is called a "direct" impact. Other examples of direct impact are injuries and drownings due to floods or typhoons.

Unlike direct impacts, indirect impacts, which affect human health through ecological and/or social disruptions, are very hard to estimate. An example of an indirect impact would be malnutrition due to reduced crop yields under an altered climate. There are only a few reports on this type of impact. Among those is an estimation of the underfed population under certain climate change scenarios (Parry *et al*., 2004).

3. Health Impacts in Asia

Asia has wide range of countries, from the Middle East to the Far East, and from boreal Russia to tropical countries such as Indonesia and Papua New Guinea. Also, its socio-economic status varies from country to country, with Japan being one of the most highly developed countries, with the world's second largest GDP as of 2005, whereas people in many South East Asian countries suffer from poverty. Because of this diversity and lack of data for many developing countries, it is hard to describe in detail or summarize the impact in Asia. Below are a few examples of sketches by the WHO.

The WHO calculated, by WHO region, the disability adjusted life years (DALYs, see box) due to climate change in 2000 (compared with the baseline in 1961-1990). Among the regions, South East Asia-D (SEAR-D, which consists of Bangladesh, Bhutan, Korea, India, the Maldives, Myanmar and Nepal) had the highest total DALYs (Ezzati *et al*. eds., 2004). Diarrheal diseases and malnutrition contributed most strongly to the DALYs in SEAR-D. Partly because of the large population in SEAR-D, the DALYs attributable to the climate change were about twice as large as the DALYs of Africa-E, which had the second largest DALYs. These facts suggests that food security and public health infrastructure are very important in counteracting the health hazards due to climate change, especially in Asia.

The projected casualties due to coastal floods are also the highest in 2030 in SEAR-D (Ezzati *et al*. eds., 2004). Although Japan has a large proportion of its population in coastal areas, the infrastructure of Japan is much better than that of SEAR-D countries, and typhoons of similar scale may cause much smaller numbers of casualties in Japan, compared with in SEAR-D countries.

Other impacts to consider include vector-borne infectious diseases. Among them, malaria and dengue fever have been well studied. However, the epidemic mechanisms of these diseases are complex, the important determinants of which include (i) vector survival and reproduction, (ii) the vector's biting rate, and (iii) the pathogen's incubation rate within the vector organism (Patz *et al*., 2003). Also, there are several malaria risk determinants such as drug resistance, human migration, human immune status, control programs, and local land-use change (Patz *et al*., 2005). Partly due to these complicated mechanisms, there has been controversy over whether climate change would increase the number of patients with these diseases. Hay *et al*. (2002) for example, concluded that there was no significant warming trend despite the malaria incidence elevation, but recently, Pascual *et al*. (2006) updated Hay and his coworkers' data, reanalyzed them, and concluded that a warming trend existed. More interdisciplinary research is necessary for obtaining an uncontroversial conclusion.

Box: Disability adjusted life years (DALYs)
(See http://www.who.int/healthinfo/boddaly/en/index.html for a more detailed explanation)

DALY is the sum of:
- years of life lost due to premature death (YLL)
- years of life lived with disabilities (YLD).

YLL takes into account the age at death. YLD takes into account disease duration, age at onset, and a disability weight reflecting the severity of the disease.

4. Health Impacts in Japan

Unlike the above-mentioned WHO estimates, it is unlikely that the most important health impact of the global warming in Japan will be diarrheal diseases or malnutrition. In calculating DALYs, the WHO assumed that the increase in risk in diarrheal diseases falls to zero when the per capita GDP exceeds 6,000 US dollars per year (Ezzati *et al*. eds., 2004). This is why our efforts have been mainly focused on the direct effects. Below, I will present some results of our analysis. However, although the effect level is small compared with the above mentioned SEAR-D countries, even in developed countries, diarrheal diseases or food poisoning may be associated with higher temperatures. Sakuma *et al*. (2006) demonstrated that the number of cases of verocytotoxin-producing *Escherichia coli* was associated with temperature, and Bentham and Langford (2001), Kovats *et al*. (2004), and D'Souza *et al*. (2004) demonstrated the relationship between food poisoning and high temperatures. Sakuma *et al*. (2006) also pointed out that children (aged less than 15 years) and elderly (aged 65 years or older) were at risk. Considering this, we should be careful about infectious diarrheal diseases during very hot days, even in developed countries.

In the following analyses, we used the mortality data provided by the Ministry of Health and Welfare of Japan with special permission. The data included date of birth, date of death, sex, cause of death and address of the decedents. The corresponding meteorological data were obtained from the Japan Meteorological Agency. Population data were obtained from the office of the Prime Minister. Some of the analyses are old and only categorized temperature was used, but in some newer analyses, we used a smoothing spline in evaluating the relationship between temperature and mortality. This nonparametric regression method allowed us to finely evaluate the relationship.

As shown in Fig. 1, the relationship between daily maximum temperature and the all-causes mortality rate is V-shaped, that is, there is an optimum temperature (OT) at which the mortality rate is lowest and the mortality rate is higher when the temperature becomes either higher or lower than the OT. Figure 1 also shows that males and females exhibit similar patterns, with the OT for females located lower. This V-shaped pattern can be found anywhere in the world, at least in mid-latitude countries (Bull & Morton, 1978; Saez *et al.*, 1995; Curriero *et al.*, 2002), including Lebanon (El-Zein *et al.*, 2004). This pattern is mainly attributed to circulatory diseases and respiratory diseases (Honda *et al.*, 1995). Figure 2 is the visualization of another example.

Other meteorological factors such as humidity may also be of interest. However, as far as Japanese data are concerned, relative humidity did not confound the temperature-mortality relationship (Honda *et al.*, 2000), and other factors were only sporadically examined in related reports. Hence, I will restrict my focus to temperature as the only variable for describing weather and climate.

The V-shaped pattern was affected by climate (Curriero *et al.*, 2002; Honda *et al.*, 1998) as well: The OT shifts from right to left as the area becomes warmer (Honda *et al.*, 1998) as shown in Fig. 3. However, the long-term average temperature may not be a good predictor of the location of the OT; Okinawa, the southernmost prefecture of Japan, has a very high long-term average temperature, and became an outlier when the relation between OT and long-term average temperature was examined. Instead, we found that the 85 percentile of the daily maximum temperature best predicted the OT in Japan (Honda *et al.*, submitted) (Fig. 4).

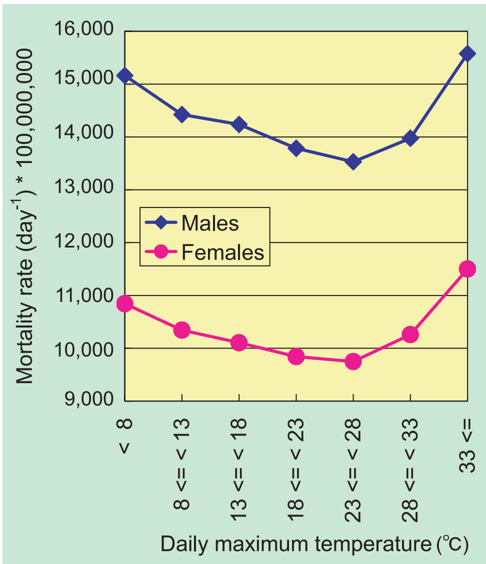

Fig. 1 Temperature and mortality in Hokkaido, Japan.

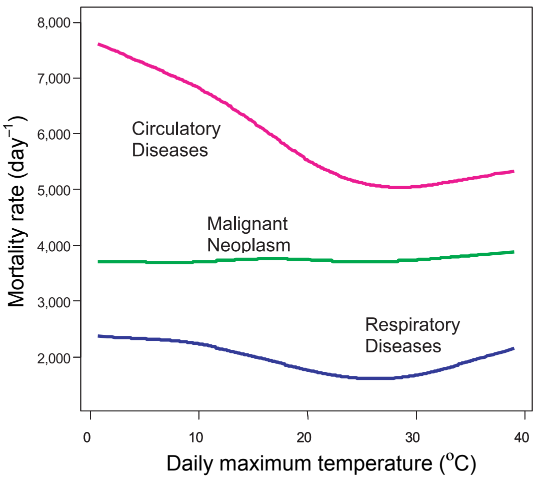

Fig. 2 Relationship between daily maximum temperature (°C) and cause-specific mortality rate, Tokyo, Japan, 65+ years old males, 1972- 1994.
Smoothing spline curves with degree of freedom = 6. Mortality rate multiplied by 100,000,000.

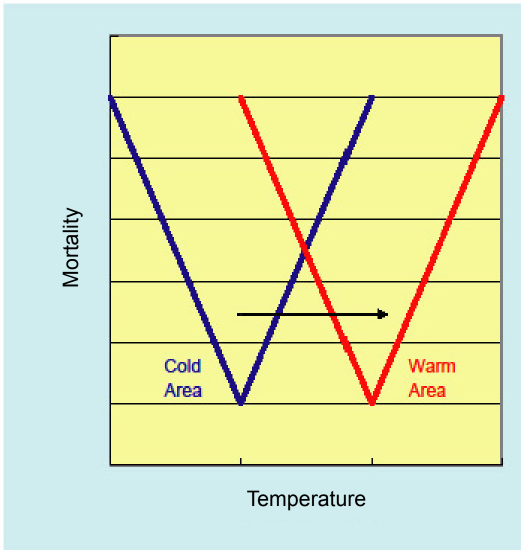

Fig. 3 Schematic presentation of the climate effect on the temperature-mortality relationship.

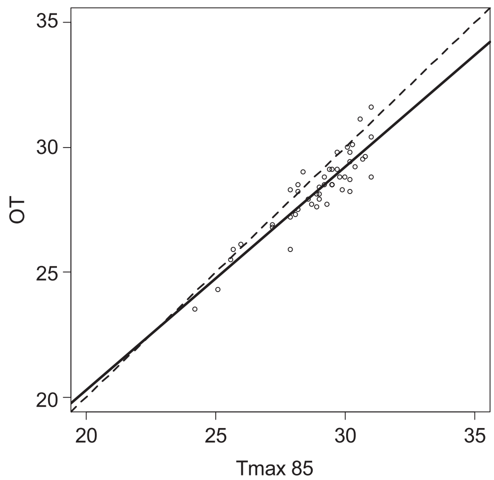

Fig. 4 Relationship between 85 percentile value of daily maximum temperature (Tmax 85) and optimum temperature (OT).
The solid line shows the regression line, and the dotted line shows the situation OT = Tmax 85.

As for the magnitude of the mortality rate, elderly people contributed to the V-shaped temperature-mortality pattern. Still, the children's mortality rate showed a relationship with temperature (Honda *et al.*, 1995). Unlike the situation among the elderly, our further analysis showed that the higher mortality rate among children was attributable to accidents, as shown in Fig. 5. The higher mortality on weekends than weekdays in this figure suggests that the pattern is attributable to "risk shift," that is, for example, children going swimming, where the risk is much higher than that in their usual life around home. Even during weekends, the mortality rate was higher for higher temperatures. Thus, it is possible that heat stress affected children's physiological strength or ability to react to danger.

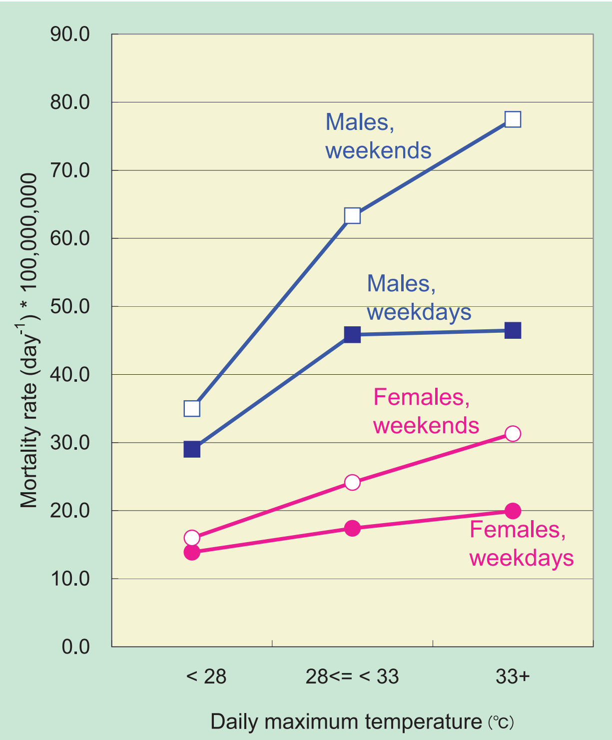

Fig. 5 Relationship between daily maximum temperature and mortalities of all external causes, Japan, 1980-1994.

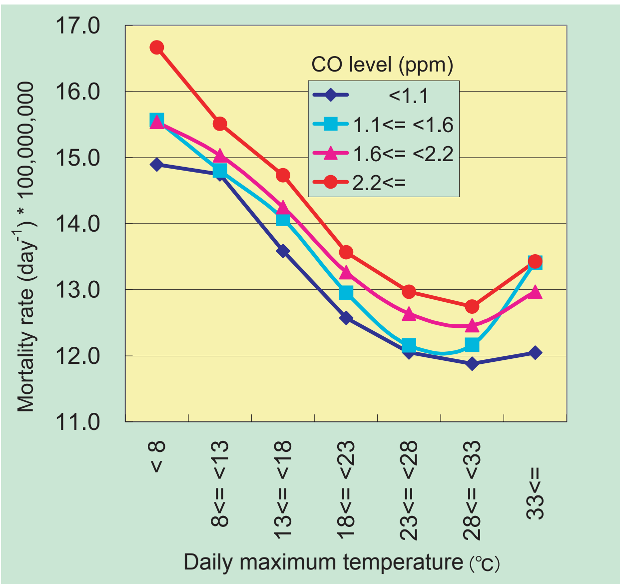

Fig. 6 Relationship between daily maximum temperature and mortality rate by carbon monoxide level, Tokyo, 65+ year old males, 1976-1990.

Another issue is the so-called "multiple stresses." As shown in Fig. 6, the effect of air-pollution can compound the heat-stress effect (Honda *et al.*, 2003). This example is of carbon monoxide, and may not be related to global warming, but the ambient ozone level and number of days with high ozone levels would rise as global warming proceeds, and the mortality rate would increase accordingly.

One of the potentially important issues I have not addressed here is mortality displacement. This phenomenon refers to the situation in which the decedents who had succumbed to heat-stress would have died anyway within several days or in a couple of months even if the heat-stress had not occurred. This phenomenon is, however, still under debate. Hajat *et al.* (2005) reported that the situation varies among countries, and recently, Fouillet *et al.* (2006) reported that no mortality displacement was observed in the 2003 Paris heat wave disaster.

Based on Japanese data and the 85 percentile hypothesis, we projected the possible health consequence of global warming (Takahashi *et al.*, 2007). In

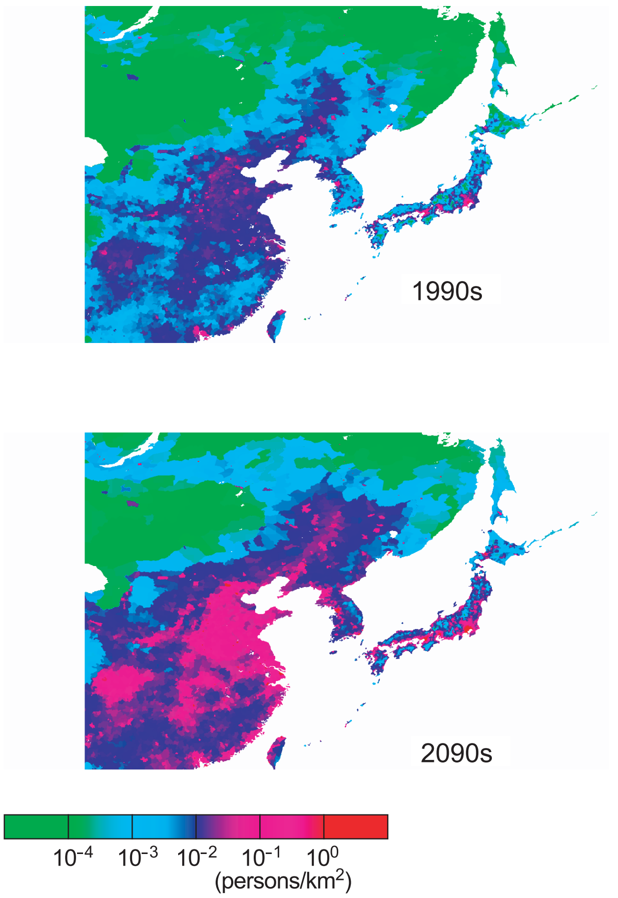

Fig. 7 Estimated excess mortality density.

this simulation we used the Atmosphere-Ocean General Circulation Model with the world's highest spatial resolution at the time of the study and only examined the impact of heat stress (i.e., an offset due to decreased winter deaths was not considered). Other assumptions included the following: population densities not altered in the future; no adaptation or acclimation taking place. Figure 7 shows the results for Japan and some surrounding areas. According to this projection, the impact due to heat stress will be large in Japanese metropolitan areas and the central and coastal areas of China.

5. Useful Information for Weather Forecasting Practice

It has been shown that physiological and behavioral adaptations (McGeehin & Mirabelli, 2001) and changes in public health preparedness (Weisskopf *et al.*, 2002) can reduce heat wave morbidity and mortality. Hence, along with governmental or individual measures to prepare air-conditioned shelters or houses, it should be useful to advise people how they can avoid heat stress and who are vulnerable.

As I showed above, heat stress may cause higher mortalities among children and the elderly. Also, those who already have circulatory and/or respiratory diseases are vulnerable to heat stress. So, in weather forecasts when the temperature becomes high during summer, it will be advisable to warn children, the elderly and those with circulatory and respiratory diseases to be more careful than other people. Also, heat strokes are better predicted by Wet Bulb Globe Temperature (WBGT) than by mere maximum temperature (Committee for investigating environmental effect due to heat island phenomenon, 2004). This implies that hot days with weak wind speeds and strong sunshine should be regarded as more dangerous than similarly hot days with less sunshine or stronger wind. The Japanese Society of Biometeorology is now preparing guidelines for preventing heat stroke, and they will be available probably in 2008. In brief, as the WBGT or maximum temperature becomes higher, the guidelines recommend lighter exercise or no exercise.

Another piece of useful information is that people living in prefectures with a lower 85 percentile value of the daily maximum temperature are more vulnerable to the same level of heat stress, and extra caution is necessary for them.

6. Adaptation and Mitigation

To lessen the impact of climate change, the IPCC has classified two measures, i.e., adaptation and mitigation. Briefly, adaptation refers to efforts to reduce the adverse responses to a certain level of global warming, whereas mitigation refers to efforts to reduce greenhouse gases.

Adaptation may occur naturally. For example, even when the ambient temperature is 18°C in Japan, we feel cool in autumn and warm in spring, due to physiological changes in our bodies during winter. Adaptation may also be achieved through technology. For example, most of the excess deaths during the 2003 European heat wave could have been prevented if they had been in air-conditioned houses (of course, using air-conditioners exacerbates carbon dioxide emissions, but sometimes in some places, it may be necessary). As Kabuto *et al*. (2005) reported, during summer, some residents live at warmer than adequate temperatures even when they are in air-conditioned rooms, so it is advisable for them to use thermometers in controlling room temperature, instead of relying on the controller of the air-conditioner.

Unlike adaptation, which can be region-specific, the effect of mitigation is collective: even when certain countries reduce greenhouse gases substantially, their efforts can be overwhelmed by other countries which increase greenhouse gases. This is why we need international collaboration for mitigating the effects of climate change.

The effects of mitigation are, however, ubiquitous, i.e., all the countries benefit from the effects (although there are some regional variations). Also, if mitigation is completely effective, we need not adapt to global warming. This is analogous to prevention and treatment: if you prevent a disease, you need not suffer from the disease. Unfortunately, the IPCC Working Group I recently reported (2007) that the warming trend will continue even if we stabilize the CO_2 concentration at the year 2000 level, and we may have to take some adaptive actions.

7. Conclusion

We will experience heat-stress, regardless of the occurrence of global warming, because in any case, we will have some hot summers in the future. In this sense, we need to be careful about heat-stress and try to avoid the adverse health consequences due to heat-stress. However, global warming may exacerbate the effect of heat-stress and may raise the all-causes mortality rate and increase the disease burden.

We need to take actions immediately to prevent the hazards caused by global warming, because, as described above, we are already experiencing the adverse effects and the warming trend will inevitably continue for several decades. What kind of actions would be appropriate? Of course, mitigation is important, because the poor regions are unable to take adaptive measures except for physiological ones, which may be weakened further by poor nutritional status. Along with mitigation, adaptation with energy-efficient measures is also important so as not to reduce the mitigation effect. To find the "best mix" of mitigation and adaptation, we need to make a comprehensive evaluation of the effects of global warming.

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