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Deaths from heat-stroke in Japan: 1968–1994

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Abstract Global warming is increasingly recognized as a threat to the survival of human beings, because it could cause a serious increase in the occurrence of diseases due to environmental heat during intermittent hot weather. To assess the direct impact of extremely hot weather on human health, we investigated heat-related deaths in Japan from 1968 through 1994, analyzing the data to determine the distribution of the deaths by age and their correlation to the incidence of hot days in summer. *Vital Statistics of Japan*, published by the Ministry of Health and Welfare of Japan, was the source of the heat-related mortality data employed in this study. Meteorological data were obtained from the District Meteorological Observatories in Tokyo and Osaka, the two largest cities in Japan. Heat-related deaths were most prone to occur on days with a peak daily temperature above 38°C, and the incidence of these deaths showed an exponential dependence on the number of hot days. Thus, even a small rise in atmospheric temperature may lead to a considerable increase in heat-related mortality, indicating the importance of combating global warming. Furthermore, half (50.1%) of the above-noted deaths occurred in children (4 years and under) and the elderly (70 years and over) irrespective of gender, indicating the vulnerability of these specific age groups to heat. Since a warmer climate is predicted in the future, the incidence of heat waves will increase, and more comprehensive measures, both medical and social, should be adopted for children of 4 years and younger the elderly to prevent heat-related deaths in these age groups.

Key words Heat-related deaths · Heat waves · Hot environment · Japan

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Introduction

It is expected that climatic changes associated with global warming will have a serious impact on human beings (Kalkstein and Smoyer 1993; Loevinsohn 1994). Among the potential direct risks that global warming presents to human health is the increase of heat-related deaths during intermittent hot weather, as predicted by WHO (WHO Task Group 1990). An increase in mortality related to heat waves has been reported from various industrialized countries (Schuman et al. 1964; Schuman 1972; Lye and Kamal 1977; Applegate et al. 1981; Smoyer 1998), although most of the people in those countries have ready access to air conditioning and hence are expected to be resistant to climatic stress.

One of the characteristics of the deaths concurrent with heat waves is the specifically higher mortality among the elderly (Lye and Kamal 1977; Applegate et al. 1981; Levine 1969; Zhang and Mao 1990; Morimoto and Nakai 1996). However, previous studies have been conducted regarding individual heat waves, and few long-term studies have investigated the occurrence of hot summers and heat-related mortality. To address this issue, we performed an epidemiological survey of heat-related deaths in Japan in the 27-year period from 1968 through 1994. Data were analyzed with special reference to the distribution of deaths among different age groups and their correlation to the incidence of hot days during the summer.

Methods

The 27 editions of *Vital Statistics of Japan* 1968 to 1994 (Statistics and Information Department 1968–1994) were used as the source of statistical data on heat-related deaths during this period. The causes of death noted in these statistics were based on the *International Classification of Diseases* (ICD); editions 1968–1978 correspond to ICD-8, and editions 1979–1994 to ICD-9. All deaths primarily related to the "effects of heat" were categorized in the N992 (ICD-8) and 992 (ICD-9) codes. In the present study, the subcategories of deaths defined by these codes (i.e., 992.0: heat stroke and sun stroke, to 992.9: unspecified) are comprehensively referred to as death from heat stroke, because this is the

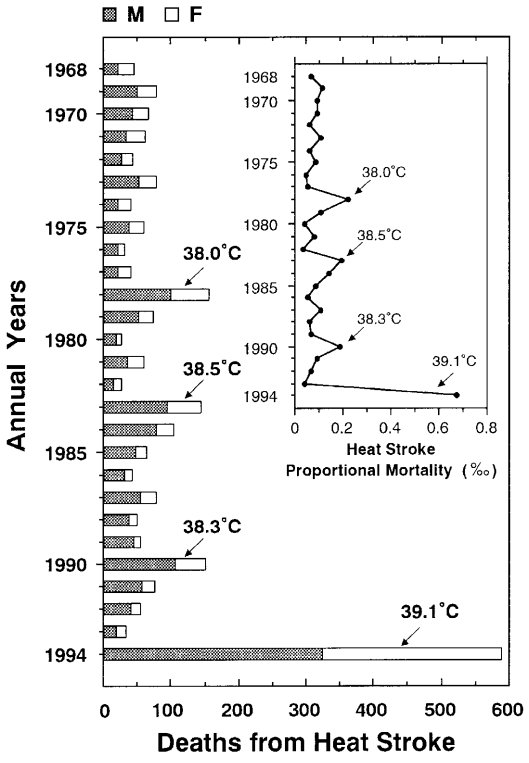

Fig. 1 Heat-stroke mortality in males (*M, filled colums*) and females (*F, open colums*) from 1968 through 1994 in Japan. *Inset* the proportional mortality related to heat-stroke in the same 27-year period. The indicated temperatures denote peak daily temperatures in Osaka when markedly high mortality was recorded

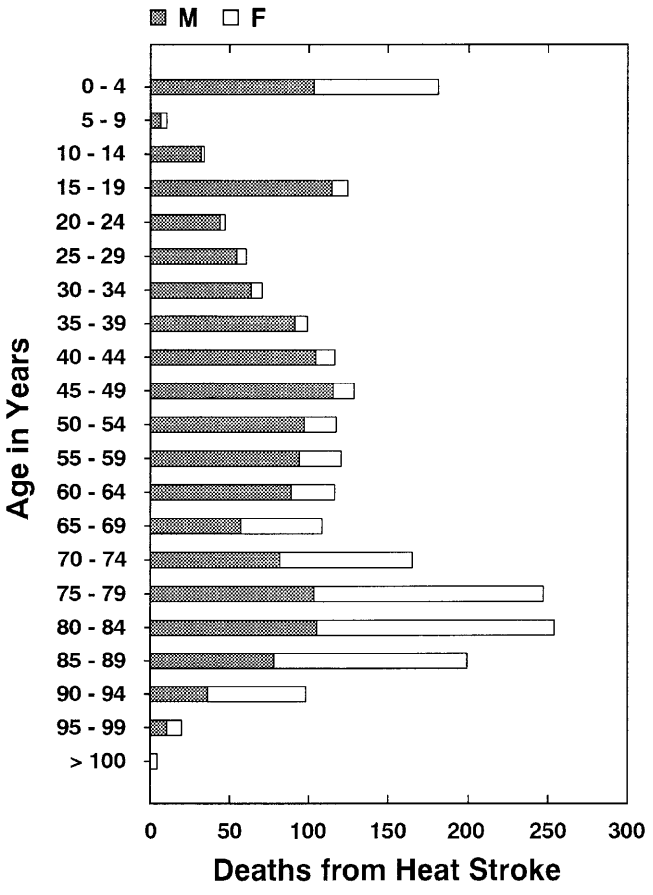

Fig. 2 The distribution of heat-stroke mortality by age group in males (*M, filled colums*) and females (*F, open colums*) from 1968 through 1994 in Japan

most catastrophic (Knochel 1974) of the heat diseases listed. The mortality data after 1994 were excluded from the study, because the categorization of the causes of death changed after 1995 following the current ICD-10 and newer data are consequently insufficient to assess in detail the influence of this update on the vital statistics.

Japan is a long, thin archipelago stretching through the West Pacific for almost 3500 km between 25°N and 45°N, from northern temperate areas to subtropical southern islands. Its total land mass is slightly larger than Great Britain but the population of Japan, approximately 124 million in 1994, is concentrated on only 3% of the land, mostly in the larger cities, because mountains and riverbeds account for more than 80% of the land mass. Tokyo and Osaka are the largest cities in the nation and, together, the Tokyo and Osaka Districts contained 33.8% of the Japanese population in 1994 (Statistics and Information Department 1968-1994). Furthermore, if the Nagoya District (lying halfway between Tokyo and Osaka) is included, 47.8% of the population and 42.0% of the total number of deaths were contained in these three largest Districts in 1994. Thus, while the geographical features of Japan make it difficult to define a "representative temperature" throughout the nation, it is reasonable, from a demographic viewpoint, to use the atmospheric temperature data observed by the District Meteorological Observatories in Tokyo and Osaka (Observation Department 1968–1994) for analysis. These cities, as well as most other larger cities, are located on the main island, Honshu, positioned in the North Temperate Zone, and have a four-season climate with a temperature range similar to that of, for example, the eastern seaboard of the United States.

Results

During the 27-year period from 1968 through 1994, there were 2326 deaths from heat stroke in Japan (1480 male and 846 female casualities). Annual deaths and the proportional mortality related to heat stroke ranged from 26 cases (0.037‰) in 1982 to 589 cases (0.672‰) in 1994, as shown in Fig. 1 and its inset. The heat-stroke mortality average in this 27-year period was 86 cases/year (0.116‰). A strikingly high (0.672‰) rate of mortality due to heat stroke was recorded in 1994, when Japan was beset by a severe heat wave; record-breaking high temperatures were observed at 61 observatories (42% of all of the observatories in Japan) and, at 8 of these observatories, temperatures exceeded 39°C. High rates of mortality due to heat stroke were also recorded in some years other than 1994: 155 cases in 1978, 144 cases in 1983, and 152 cases in 1990. As indicated in Fig. 1, these years were characterized by markedly hot summers with peak daily temperatures of at least 38.0°C. The distribution of the heat-stroke deaths among different age groups during this 27-year period is shown in Fig. 2. Markedly high mortality was found in the 0 to 4-year-old and over-70-year-old age groups, accounting for

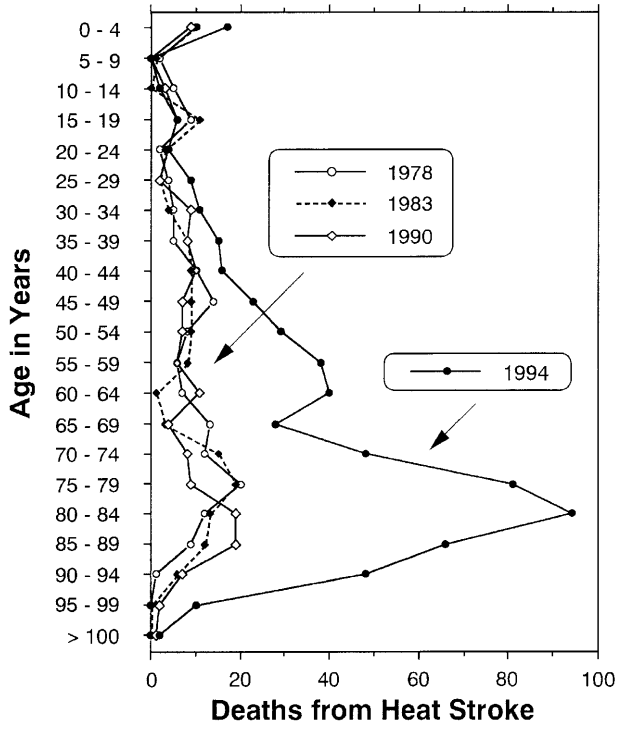

Fig. 3 Heat-stroke mortality in Japan by age group in the years when markedly high temperatures were recorded

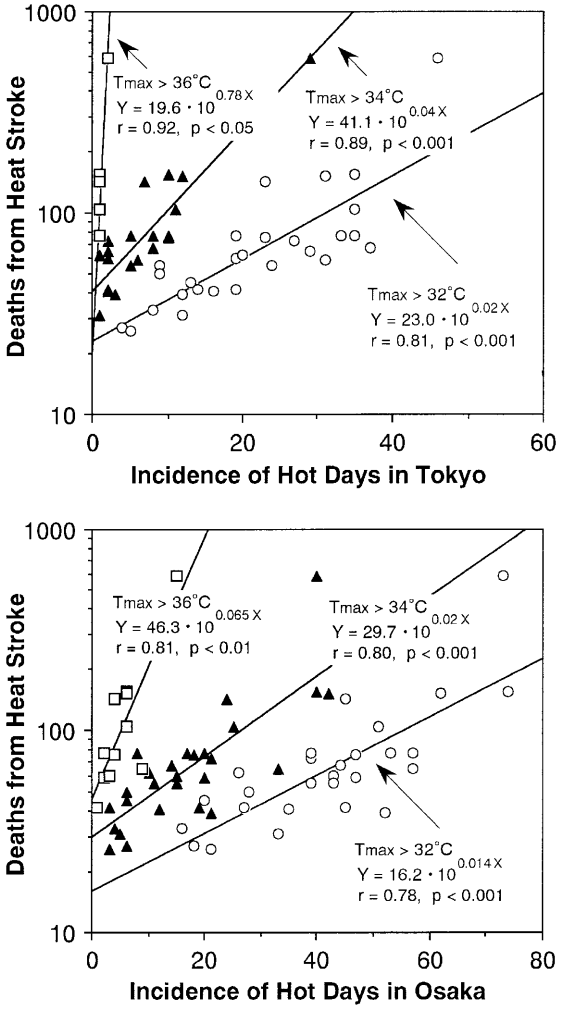

Fig. 4 The relationship between heat-stroke mortality and the occurrence of hot days in Tokyo (*upper panel*) and Osaka (*lower panel*). T_{max} denotes the peak daily temperature

50.1% of all of the heat-stroke deaths that occurred during the period. What is characteristic of these groups was that the incidence of heat-stroke death was almost independent of gender (M:F=1:1.31). High mortality was also found in the 15- to 19-year-old age group with a sharp peak, and in the 35- to 64-year-old age groups with a broader distribution. In these groups, however, the number of male victims was five times greater (M:F=1:0.18), as mentioned later in the Discussion. On the other hand, the gender independence of the mortality in the above-mentioned 0 to 4-year-old and over-70-year-old age groups suggests the specific vulnerability of these groups to heat stress.

The vulnerability of the elderly to heat is graphically presented in Fig. 3, in which the distribution of heat-stroke deaths is shown by age for the years 1978, 1983, 1990, and 1994, when high temperatures of 38.0°C and higher were recorded in Japan. Although the trend towards higher mortality in the above age groups is similar to that shown in Fig. 2 for 1978, 1983 and 1990, the majority (64.0%) of heat-stroke deaths occurred among those aged more than 65 years in 1994, when an extremely hot summer hit Japan.

As suggested in Fig. 3, heat-stroke mortality is dependent not only on age but also on the incidence of hot weather. Figure 4 shows the relationship between heat-stroke deaths and hot days in Japan; the number of days (D) when the peak daily temperature (T_{max}) exceeded 32°C, 34°C, and 36°C was counted for every year and, if such days occurred (D>0), the incidence of heat-stroke death in the corresponding year was plotted against D. From these plots it is clear that the incidence of heat-stroke increases in an exponential manner with respect to D.

Discussion

This long-term study clearly showed that mortality due to heat stroke increases markedly during hot summers. Conversely, the number of heat-stroke deaths was exceptionally low in 1980 (27 cases) and 1982 (26 cases), in accordance with the lower number of hot days (T_{max}>30°C) in these years: 21 days and 24 days, respectively in Tokyo, (Fig. 1). The exponential dependence of the incidence of heat death on the occurrence of hot days (Fig. 4) should provide some insights into the possible influence of global warming on human health, because the associated small rises in temperature may lead to a considerable increase in heat-stroke mortality.

The manner in which global warming influences climatic changes still remains unclear. Some climatologists, however, expect a rise in temperature of 2–3°C in the tropics by 2025–2050, unless the increase of greenhouse gases is terminated (Kalkstein and Smoyer 1993; Mitchell et al. 1990). Thus, if we extrapolate our results to the global scale directly and assume no mitigating factors such as the popularization of air conditioning, it seems certain that heat-related mortality will increase worldwide as a consequence of even a slightly warmer climate.

In the warmer climate predicted in the future, it has been considered that precipitation and humidity will also increase (Loevinsohn 1994), although there would be a geographical and temporal heterogeneity in the occurrence of those changes. In the present study, the influence of humidity on the incidence of heat stroke was not assessed as a variable for analysis, simply because sufficient humidity data, e.g., maximum and/or minimum humidity values, were not available in the meteorological source used. However, because the summers in Japan are extremely humid, it is possible that the heat-stroke casualty in Japan is amplified to some extent by the high humidity throughout this particular season, which should be assessed in depth in future studies.

Another finding of interest in this study is the higher mortality due to heat stroke in specific age groups (Fig. 2). Specifically higher mortality rates among the elderly have been repeatedly reported during single, individual heat waves (Lye and Kamal 1977; Applegate et al. 1981; Levine 1969; Zhang and Mao 1990; Morimoto and Nakai 1996). Our data indicate that such higher mortality rates due to heat stroke among the elderly are not characteristic of heat-wave episodes but are rather common even during ordinary summers, although mortality incidence may vary. Also, the data indicated that attention should be paid to heat-stroke deaths in children younger than 4 years of age. In both these younger and elderly groups, the heat-stroke deaths occurred irrespective of gender (M:F=1:1.31), which suggests the existence of some physical or sociological vulnerability of these specific groups to heat stress.

In contrast, the heat-stroke deaths among those aged between 5 and 64 years largely occurred in males (M:F=1:0.18), suggesting that the majority of these deaths were attributable to exertion-induced heat strokes (Knochel 1974) related to outdoor sports or occupational hazards. Because such deaths are preventable, adequate educational programs should be designed to alert schools, companies, and the public to the dangers involved.

In summary, more comprehensive preventive measures in both the medical and social fields should be implemented for children (≤4 years in particular) and the elderly in the event of extremely hot weather. In the warmer climate predicted in the future, when the incidence of heat waves will increase, greater cooperation to prevent heat-stroke deaths in those groups of people will be required among medical, meteorological, and financial authorities and related organizations throughout the world.

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