SEASONAL VARIATIONS OF DAILY MORTALITY IN TOKYO CITY

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ABSTRACT

Daily deaths of all causes in Tokyo residents from 1966 to 1972 were analyzed with relation to environmental conditions. As the analytical methods, daily deviation from 15-day moving average, simple correlation coefficients and stepwise regression procedure between daily deaths and environmental variables were employed. Seasonal variations of daily deaths, high in winter low in summer, and significant association between all causes of death in older age group and environmental variables, temperature and sulfur dioxide were found.

Greater Tokyo is composed of the 23 wards of Tokyo City proper, and the adjacent satellite cities. This paper deals with mortality rate in Tokyo City proper, about 8,500,000 of its population in 1965, approximately 10% of the total population of Japan. The general trend of population composition of Tokyo is toward an influx of young people from rural areas during past two decades.

There have been many intensive studies of daily mortality related to environmental conditions in large cities in the world, dominated are the London study by Martin,1 New York studies by Greenburg,2 Schimmel,3 Hechter,4 Goldsmith,5 Cassell6 and McCarroll,7 and another mathematically oriented work by Lebowitz.8 Furthermore, Hexter,9 and Ellis10 have reported excess deaths related to heat in urban areas in the United States.

Present study discusses a dynamic pattern of mortality in Tokyo City, particularly the seasonal variations of daily mortality associated with environmental conditions such as temperature and air pollution.

METHOD AND RESULTS

To investigate daily variations of deaths from all causes for the residents of
Tokyo, death certificates compiled at the Tokyo City Department of Health, registered in 52 local health centers, were copied for a period of 6 years, 1966 to 1972, as the basic sources of information. (In Japan, when death certificates need to be examined for a special purpose like ours, it is necessary to obtain special permission from the Administrative Management Agency of the Government.) Although some of the causes of death in the certificates may be ambiguous, the reliability of the total number of deaths is considerably high because of the efficient notification system.

Population and total deaths in Tokyo (23 wards) during the part of study period are as follows:

Table: Population of Tokyo City

<table>
<thead>
<tr>
<th>Year</th>
<th>Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>1966</td>
<td>8,623,568</td>
</tr>
<tr>
<td>1967</td>
<td>8,622,063</td>
</tr>
<tr>
<td>1968</td>
<td>8,631,734</td>
</tr>
<tr>
<td>1969</td>
<td>8,663,875</td>
</tr>
</tbody>
</table>

Table: Number of total deaths during 3 year study period

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Deaths</th>
</tr>
</thead>
<tbody>
<tr>
<td>1966 April-1967 March</td>
<td>42,662</td>
</tr>
<tr>
<td>1967 April-1968 March</td>
<td>44,143</td>
</tr>
<tr>
<td>1968 April-1969 March</td>
<td>42,921</td>
</tr>
</tbody>
</table>

Section A of Figure 1 indicates the variation in the numbers of daily deaths for a 3-year period, from 1966 April through 1969 March. Similar to the reports from other large cities in the northern hemisphere, a seasonal cyclic variation with characteristics of high mortality in winter and low mortality in summer is observed in this figure. There is an average of 108 deaths per day from April through September and 123 deaths per day from October through March.

Section B of the same figure shows the variation of daily average temperature having a shape inversely symmetric with that of the mortality cycle in Section A. Section C indicates the daily average levels of sulfur dioxide (SO₂), and Section D shows the daily average values of suspended particulate matter (SPM).

Figure 2 illustrates the monthly mortality rate by age groups for the 3 years. The seasonal variations are most prominently observed for the age group 60 years and over, similar to the tendency in the developed countries of the Western world. In this age group small humps of death rate are noticed during the summer months. According to health statistics issued from Tokyo city, these were not due to epidemics of summer infectious disease. As shown in Figure 3, monthly average daily deaths and causes for age 60 and over, Tokyo 1971, these
Fig. 1 Daily death and atmospheric indices, Tokyo.

Fig. 2 Monthly death by age groups Tokyo.

Fig. 3 Monthly average daily deaths & causes for age 60+ Tokyo, 1971.
humps may be due to cerebrovascular haemorrhage aggravated by heat stress and probably dehydration during summer. However, an analysis similar to those in Ellis’ paper on urban deaths due to heat prostration in America, was not possible because of the lack of statistical data and therefore further investigation is necessary to clarify this phenomenon. There are also some contributions of acute respiratory diseases and accidents to this small summer peak. As to cancer death, no seasonal variation was observed (Fig. 3).

Among the causes of deaths in Tokyo city, like the whole of Japan, cerebrovascular lesions are ranked the first place followed by cancer, ischemic heart diseases, and bronchitis and pneumonia, and accidents in that order. Tuberculosis, which had occupied the top position until 20 years ago, has now dropped down to 10th in rank.

In our initial examination of the relationships between daily death and temperature, we calculated the deviation of the number of daily deaths from the 15-day moving average of deaths. And simple correlation coefficients between the deviation and daily average temperature were calculated. The frequency distributions of these correlation coefficients by months grouped according to season for 3 years are shown in Figure 4 by illustrating the same day relation and the one day lag. Significant positive correlations on same day are observed in summer.

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Fig. 4 Frequency distribution of correlation coefficient, daily mortality (15-moving ave.) vs. daily mean temperature by month.
months. In other words, the effect of temperature on mortality may be almost immediate. Figure 5 and Figure 6 show the correlation coefficients between mortality index (deviation from 15-day moving average) and daily level of SO$_2$ and SPM, respectively, by month grouped according to the seasons. There are a few months in winter which have significant correlations with two pollutants. The 15-day moving average was utilized in this study to obtain a smooth curve and to use the curve as a daily mortality index to measure daily deviations. As Ipsen$^{12}$ has pointed out, there seems to be no special advantage in using the 15-day moving average and our correlation analysis of daily death supports his view.

One of our coworkers, Adachi$^{13}$, applied a stepwise regression procedure on data to 170,000 residents of Tokyo who died between January 1969 and March 1972. The analysis was made to investigate the relationships between the number of daily deaths by age groups and by cause of death as the dependent variables, and environmental factors, such as temperature, relative humidity, SO$_2$, NO$_2$, oxidants, hydrocarbons, carbon monoxide and SPM as the independent variables. The environmental factors were measured at 11 monitoring stations of the Tokyo City Environmental Pollution Control Bureau.

Table 1 shows the frequency of entrance of the environmental variables in

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**Fig. 5** Frequency distribution of correlation coefficient, daily mortality (15-moving ave.) vs. daily means SO$_2$ by month.
Daily Mortality

1966 (May) – 1969 (Feb.)

Fig. 6 Frequency distribution of correlation coefficient, daily mortality (15-moving ave.) vs. daily mean SPM* by month.

Table 1 Frequency of environmental variable entered in monthly regression analysis of daily deaths

36 Months, 8 Areas, 1969 April–1972 March
(Positive Coefficient Only) (%)

<table>
<thead>
<tr>
<th>Cause of Death</th>
<th>Variables</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>R.H.</td>
</tr>
<tr>
<td>All Causes</td>
<td>3.4</td>
</tr>
<tr>
<td>Over 60 Years</td>
<td>3.4</td>
</tr>
<tr>
<td>Ischemic Heart Diseases</td>
<td>3.4</td>
</tr>
<tr>
<td>Cerebro-Vascular Accidents</td>
<td>6.8</td>
</tr>
</tbody>
</table>

monthly multiple regression analysis of daily deaths for 36 months and 8 areas in Tokyo. The regression analysis, with missing data removed, showed that temperature and SO₂ variables contributed significantly to all causes of deaths and to death in the age group of 60 years and over.
Eliminating the seasonal variation, temperature has been found to associate with the incidence of respiratory diseases (W.W. Holland, et al) and of poliomyelitis (C.C. Spicer) by a multiple regression analysis. Association between the daily mortality and temperature is not same from month to month or place to place. Of the eligible computations, however, 10.2% has positive regression coefficient, which is not probable to be entered by chance alone. The facts that positive coefficient is found not only summer months but in winter months and that negative coefficient is rather a few case lead us to a further elaboration.

The results obtained from these two analyses of daily deaths during 1966 to 1972 demonstrate that among environmental factors, temperature appeared to be the predominant contributor to both seasonal variation and daily deaths in Tokyo.

CONCLUSIONS

In conclusion, correlation analysis and multiple regression analysis that the daily death rate in Tokyo, particularly for those over 60 years of age, has shown significant associations with environmental factors such as temperature. The disease most strongly influenced was cerebral vascular diseases. The mortality of cancer showed no seasonal variation.

This study was made as a part of the US-Japan Cooperative Science Program in 1969 and partly reported at the joint meeting in East West Center of Hawaii in 1970. The final report was read at the regional meeting of International Epidemiological Association in Sydney, 1973. A special statistical analysis of this study was made by Lebowitz, M.D. et al, published in Environmental Research Vol. 6, P. 327, 1973.

REFERENCES