
Tomohiko Ihara

Estimation of DALY loss due to heat stroke and sleep disturbance caused by air temperature rise in Tokyo, Japan

Tomohiko Ihara[1], Yuya Takane[2], Yutaka Genchi[3]

[1] *The University of Tokyo, 5-1-5 Kashiwanoha, Kashiwa, Chiba, Japan, ihara-t@k.u-tokyo.ac.jp*

[2] National Institute of Advanced Industrial Science and Technology (AIST), 16-1 Onogawa, Tsukuba, Ibaraki, Japan, takane.yuya@aist.go.jp

[3] National Institute of Advanced Industrial Science and Technology (AIST), 16-1 Onogawa, Tsukuba, Ibaraki, Japan, y.genchi@aist.go.jp

dated : 1 July 2015

1. Introduction

Residents in urban areas are now confronting two kinds of warming which are global warming and urban heat island. The former is caused by an increase in concentration of greenhouse effect gases and the latter is caused by urbanization. The air temperature rise effect of urban heat island is not small compared to global warming. The world 11-year average air temperature has increased by 0.90 degrees during the last 100 years. The Japanese 11-year average air temperature has increased by 1.38 degrees. However, the 11-year average air temperature rise of Tokyo during the same period leads to 3.03 degrees.

Such high air temperature rise has posed various environmental problems in the society. Human health is one of the problems. High daytime air temperature considered to lead to heat stroke while high night air temperature can pose sleep problems. However, only health damage due to heat stroke has been remarked and some countermeasures including an alerting service have been installed in Japan. The reason is considered as follows. Damage of heat stroke can be quantified by using public statistics of deaths or the number of patients transported by ambulance. These statistics are made every year by Japanese or local governments. Meanwhile, there is no statistics related to sleep in Japan. Many previous studies have assessed damage on sleep by nighttime air temperature rise. However, their assessed values could not be compared with damage of heat stroke and ignored in the society.

This study aimed at developing damage functions of heat stroke and sleep disturbance at the same measure and estimating the current damages caused by air temperature rise.

2. Methodology

2.1 Disability-adjusted life year (DALY)

We adopted the disability-adjusted life year (DALY) as the measure for heat stroke and sleep disturbance in this study. DALY was developed by World Health Organization (WHO, 2015). It is the sum of the years of life lost (YLL) and the years lost due to disability (YLD).

$$\mathrm{DALY} = \mathrm{YLL} + \mathrm{YLD}$$

YLL is calculated to multiply the number of deaths (N) by the standard life expectancy at age of death in years (L).

$$\mathrm{YLL} = \mathrm{N} \times \mathrm{L}$$

YLD is calculated to multiply the number of incident cases (I) by the disability weight (DW) and the average duration of the case until remission or death (L).

$$\mathrm{YLD} = \mathrm{I} \times \mathrm{DW} \times \mathrm{L}$$

2.2 Heat stroke

For heat stroke, we estimate only YLL because YLD due to heat stroke is considered to be relatively small compared to YLL.

It is well known that heat stroke is related to wet-bulb globe temperature (WBGT) (Yaglou and Minard, 1957; ISO, 1989), which is a heat index considering the effects of air temperature, air humidity, wind velocity, and radiation on humans. WBGT is represented as the below equation.

$$\mathrm{WBGT} = 0.7T_w + 0.2T_g + 0.1T$$

Here, T_w, T_g, and T represent wet-bulb temperature [°C], globe temperature [°C], and air temperature [°C].

A damage function of heat stroke, whose explanatory variable is WBGT, is made based on a relationship between the number of daily patients transported by ambulance due to heat stroke (MOE, 2014) and daily maximum WBGT observed by the Ministry of the Environment of Japan (2014), the ratio of the total number of death due to heat stroke and the total number of transported patients, and daytime population (MIC, 2000; 2005;

2010). Daytime populations in years, where population census was not conducted, were interpolated from that in 2000, 2005, and 2010 using yearly estimated population by Tokyo Metropolitan Government (2015). Statistics of heat stroke in the central of Tokyo since 2010 is used because the numbers of transported patients and deaths increased since 2010 in Japan.

The damage function made in this study is shown as Fig. 1. The smooth spline was used for regression analysis.

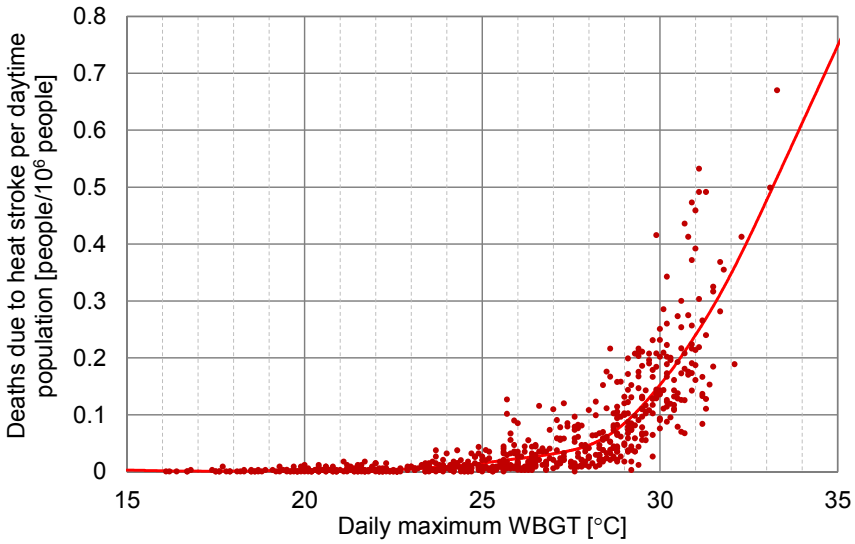

Fig. 1 Relationship between WBGT and heat stroke.

Average life expectancy of people died is also needed. Heat stroke is developed in healthy subjects. Therefore, average life expectancy was calculated by multiplying the ratio of ages at death due to heat stroke in the central of Tokyo (Tokyo Metropolitan Government, 2010; 2011; 2012; 2014), and life expectancy of each age in the central of Tokyo (MIC, 2010b). The calculated value is 18.10 years.

DALY lost by heat stroke is assessed by multiplying the death due to heat stroke and average life expectancy of people died due to heat stroke.

2.3 Sleep disturbance

For sleep disturbance, we estimate only YLD because sleep disturbance does not develop to death directly.

The number of sleep disturbance is considered to be related to nighttime air temperature. We already have quantified a relationship between air temperature at 0000 LST and prevalence of sleep disturbance based on our previous epidemiological studies conducted in Tokyo, 2006 and 2007. The result (Ihara et al, 2014) is shown as Fig. 2.

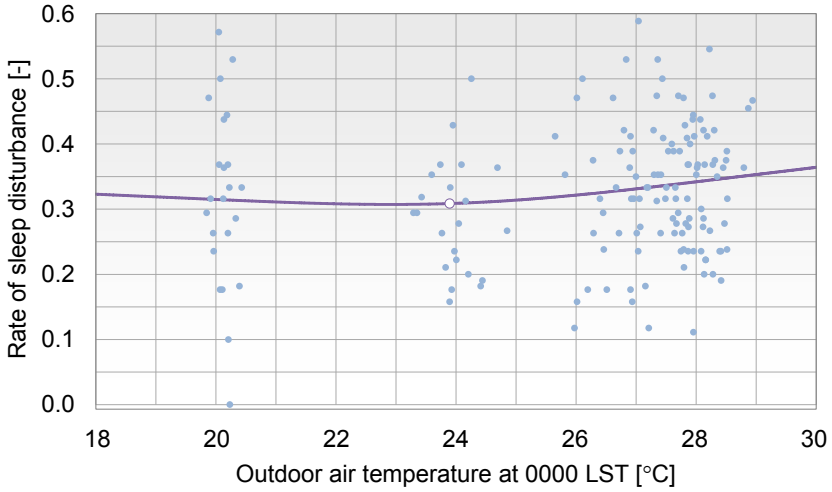

Fig. 2 Relationship between nighttime air temperature and sleep disturbance.

Fukuda et al (2013) developed disability weight of sleep disturbance based on interview to experts. They reported that its value is 0.1.

Fig.2 represents daily sleep disturbance. Therefore, when applying the relationship shown as Fig.2 for daily nighttime air temperature, it can be considered that average duration of sleep disturbance is 1 day.

DALY lost by sleep disturbance is assessed by multiplying the number of sleep disturbance, its disability weight

and average duration of sleep disturbance.

3. Conclusion

We estimated the current health damage about heat stroke and sleep disturbance in Tokyo using the above DALY loss functions and the meteorological data. The society tends to deem heat stroke as the most important damage caused by urban air temperature rise. However, our result showed that the current DALY loss by sleep disturbance in Tokyo is also important and should not be ignored.

Acknowledgment

This study is supported by the Environment Research and Technology Development Fund (ERTDF) [S-14-4(3): Urban Health Impact Assessment and Cost Benefit Analysis of Mitigation and Local Adaptation] by Ministry of the Environment, Japan.

References

Fukuda S., Ihara T., Genchi Y., Narumi D., 2013: Japanese sleep disturbance and fatigue disability weights in evaluating the effects of increasing temperatures on health by a life cycle approach. *International Journal of Life Cycle Assessment*, **8** (5), 1089–1097.

Ihara T., Takane Y., Genchi Y., 2014. Quantification of sleep disturbance by nighttime temperature rise for assessment by DALY. Proceedings of 14th EMS Annual Meeting & 10th European Conference on Applied Climatology (ECAC), (USB Memory).
http://meetingorganizer.copernicus.org/EMS2014/EMS2014-321.pdf

International Organization for Standardization (ISO), 1989: ISO 7242:1989 Hot environments -- Estimation of the heat stress on working man, based on the WBGT-index (wet bulb globe temperature).

Ministry of the Environment of Japan (MOE), 2014. Information Site for Heat Stroke Prevention. (in Japanese)
http://www.wbgt.env.go.jp

Ministry of Internal Affairs and Communications of Japan (MIC), 2000: Population Census in 2000. (in Japanese)
http://www.stat.go.jp/data/kokusei/2000/

Ministry of Internal Affairs and Communications of Japan (MIC), 2005: Population Census in 2005. (in Japanese)
http://www.stat.go.jp/data/kokusei/2005/

Ministry of Internal Affairs and Communications of Japan (MIC), 2010: Population Census in 2010. (in Japanese)
http://www.stat.go.jp/data/kokusei/2010/

Tokyo Metropolitan Government, Bureau of Social Welfare and Public Health, 2010. Status of Deaths due to Heat Stroke in the summer of 2010. Tokyo. (in Japanese)
http://www.fukushihoken.metro.tokyo.jp/kansatsu/oshirase/necchusyou.html

Tokyo Metropolitan Government, Bureau of Social Welfare and Public Health, 2011. Status of Deaths due to Heat Stroke in the summer of 2011. Tokyo. (in Japanese)
http://www.fukushihoken.metro.tokyo.jp/kansatsu/oshirase/23necchusyou.html

Tokyo Metropolitan Government, Bureau of Social Welfare and Public Health, 2012. Status of Deaths due to Heat Stroke in the summer of 2012. Tokyo. (in Japanese)
http://www.fukushihoken.metro.tokyo.jp/kansatsu/oshirase/24necchusyou.html

Tokyo Metropolitan Government, Bureau of Social Welfare and Public Health, 2014. Status of Deaths due to Heat Stroke in the summer of 2014. Tokyo. (in Japanese)
http://www.fukushihoken.metro.tokyo.jp/kansatsu/oshirase/25natu-necchuushou.html

Tokyo Metropolitan Government, Bureau of General Affairs, 2015. Monthly Estimated Population in Tokyo Metropolitan. (in Japanese)
http://www.toukei.metro.tokyo.jp/jsuikei/js-index.htm

World Health Organization (WHO), 2015: Disability-Adjusted Life Year (DALY).
http://www.who.int/healthinfo/global_burden_disease/metrics_daly/en/

Yaglou C.P., Minard D., 1957: Control of heat casualties at military training centers. *A.M.A. Archives of Industrial Health*, **16** (4), 302–316.