Prediction of Heat Disorders in Japan

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Abstract

Recently, the incidence and mortality rates from heat disorders have been increasing in Japan. Long ago, heat disorders previously occurred most often at work, such as in mines. Although the incidence is relatively low, occurrence of heat disorders during sports activities is showing an increase. Heat disorders can be prevented by appropriately controlling exercise, resting, and drinking water with salt, based on a full understanding of environmental conditions. Accordingly, in Japan, criteria based on meteorological conditions during sports activities and at work are being used to prevent heat disorders. The Japan Sports Association proposes "exercise guidelines for preventing heat disorders," while the Japan Society for Occupational Health recommends using "occupational exposure limits for heat stress." Recently, as public interest in heat disorders has surged as global warming increases and urban heat islands become more pronounced, the ability to predict heat disorders occurring in daily life activities is becoming a popular media topic. However, the guidelines and prediction models for heat disorders used now need further development. We anticipate the development of more accurate, user-friendly guidelines and prediction models for heat disorders in daily life activities.

Key words: daily life activities, heat disorders, labor, prediction, sports

1. Introduction

In Japan, public interest in heat disorders has surged in recent years as summer temperatures have tended to increase year by year. In order to prevent the incidence of heat disorders, it is necessary to examine the actual conditions and important to take preventative steps against heat disorders.

Therefore, this report describes the incidence of heat disorders in Japan, and addresses the current status of criteria for preventing heat disorders and predicting its occurrence in three aspects of life: during sports activities (or exercise), at work, and in daily life activities.

2. Incidence of Heat Disorders in Japan

The number of the deaths and mortality rate (per 100,000 citizens) of heat disorders from 1959 to 2003 in Japan is shown in Fig. 1. There were 5,261 deaths from heat disorders (mortality: 117 deaths/year, mortality rate (per 100,000 populations): 0.10 deaths/year). Recently, however, mortalities from heat disorders are increasing (mortality rate in 1999-2003: 0.23 deaths/year). This is attributable to higher summer temperatures as global warming progresses (Watson, 2001) and urban heat islands intensify (Ministry of the Environment, Japan, 2001). The rapid increase in the elderly population and the aging of society is another factor causing this trend (Hoshi & Inaba, 2002a).

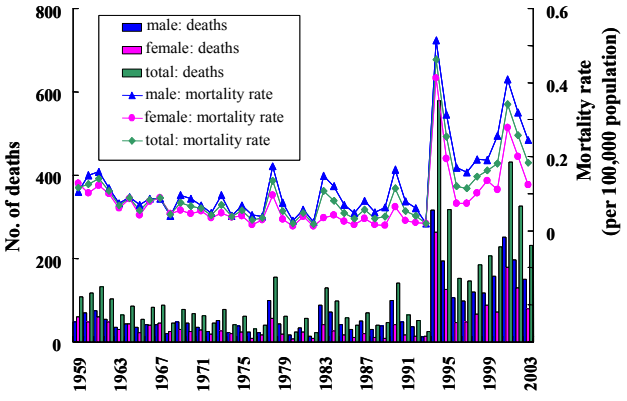

Fig. 1 Numbers of deaths and mortality rates (per 100,000 population) from heat disorders from 1959 to 2003 in Japan.
(Source: Hoshi & Inaba, 2002a)

Long ago in Japan, heat disorders occurred most often in mines, but the incidence has declined as working environments have improved. Recently, most heat disorder cases at work have occurred at construction sites (Ministry of Health, Labor and Welfare, 2003; Miura, 1985). Although the incidence is relatively low, heat disorders during sports activities have tended to increase (Hoshi & Inaba, 2002b). Characteristically, it is common among young people (Hoshi & Inaba, 2002a, 2004a), and occurs even in seasons other than summer (Hoshi & Inaba, 2005). The incidence of heat disorders in daily life activities is much higher than the incidences at work or during sports activities. Specifically, most elderly patients succumb to heat disorders during daily life activities (Hoshi & Inaba, 2004a, 2006).

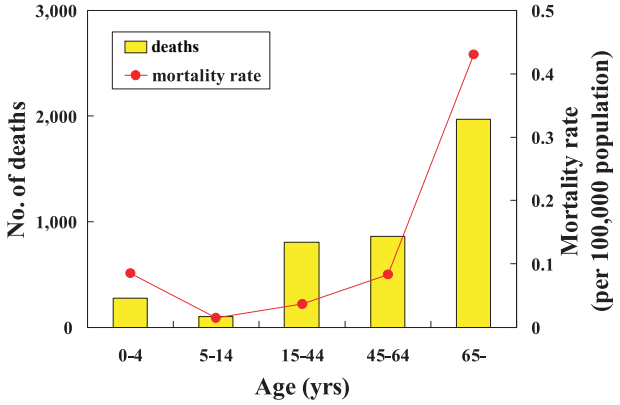

Fig. 2 Numbers of deaths and mortality rates (per 100,000 population) from heat disorders in each age-range group.
(Source: Hoshi & Inaba, 2002a)

The distribution of heat disorder mortalities by age group from 1959 to 1999 in Japan (Hoshi & Inaba, 2002a) is shown in Fig. 2. The mortality rate from heat disorder is higher among children and the elderly, especially in those aged 65 years or older. This high mortality among the elderly is attributable to their poorer body temperature regulation (Iriki, 1996) and high morbidities from chronic diseases (Harchelroad, 1993) possibly underlying heat disorders in this population. The high mortality among children is caused not only by their immature body temperature regulation but also by care-givers' negligence, leaving them in automobiles in the sun (Takahashi *et al*., 2000). In addition, mortality from heat disorders is much more common in men than in women, and is considered to be greatly affected by gender differences in lifestyles and occupations (Hoshi & Inaba, 2002a).

These results in Japan were similar to those of studies in Europe and the USA. Recently, mortalities from heat disorders during heat waves (prolonged periods of excessive heat and humidity) have been increasing in Europe (Dhainaut *et al*., 2004; Vandentorren *et al*., 2004; Conti *et al*., 2007) and the USA (Naughton *et al*., 2002; Weisskopf *et al*., 2002). Japan lacks a history of heat waves. Therefore, the number of hot days (when the peak temperature of the day is over 30°C), nettaiya (when the lowest temperature of the day is over 25°C), daily maximum temperatures, etc., are used as parameters of the heat environment in Japan (Hoshi & Inaba, 2002a, 2004a, 2005, 2006; Nakai *et al*., 1999).

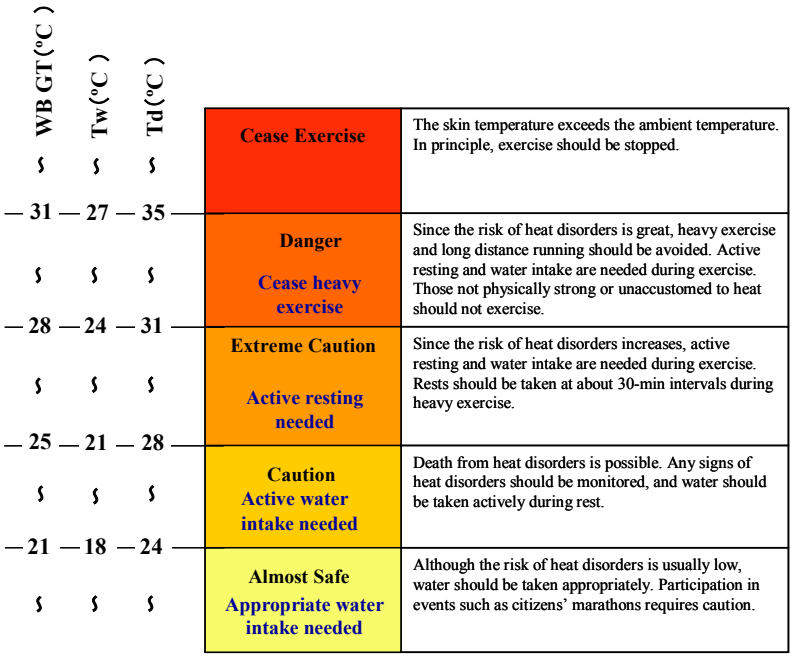

Fig. 3 Exercise guideline for preventing heat disorders proposed by the Japan Sports Association.
WBGT: Wet Bulb Globe Temperature (Source: Kawahara, *et al*., 1994)

3. Prevention of Heat Disorders during Sports Activities (or Exercise)

Heat disorders can be prevented by appropriately controlling exercise, taking rests and drinking water with salt, based on a full understanding of environmental conditions (Kenny, 1985; Frizzell *et al*., 1986; Gisolf & Duchman, 1992; Kawahara *et al*., 1994). Criteria for preventing heat disorders during sports activities and at work have been developed based on the relevant environmental conditions.

WBGT (Wet Bulb Globe Temperature) is known to be useful as an index for environmental heat conditions because it involves not only temperature but also humidity, airflow and radiant heat (Yaglou & Minard, 1957). To prevent heat disorders during sports activities, in 1994 the Japan Sports Association proposed exercise guidelines for preventing heat disorders, using WBGT.

These guidelines proposed by the Japan Sports Association are shown in Fig. 3. The guidelines specify five exercise levels based on WBGT (ºC): discontinuation of exercise at ≥ 31ºC, extreme caution at 28ºC-31ºC (discontinuation of heavy exercise), caution at 25ºC-28ºC (necessity for active resting), attention at 21ºC-25ºC (necessity for active water intake), almost safe at ≤ 21ºC (necessity for appropriate water intake). Methods of performing exercise, taking rests and consuming water and salt are described for each level. WBGT is not measured where sports activities are taking place in many cases. Therefore, the dry bulb temperature (Td) and wet bulb temperature (Tw) equivalent to WBGT are shown.

The guidelines have been compiled as a guidebook and are used in education to prevent heat disorders during sports activities in Japan (Kawahara *et al*., 1994).

4. Prevention of Heat Disorders at Work

The Japan Society for Occupational Health (JSOH) has recommended adopting "occupational exposure limit for heat stress" since 1983 (Table 1) (JSOH, 1983, 2001). The conditions applied are as follows. Subjects: healthy young men (usual summer clothes) acclimatized to hot environments and skilled in the relevant work. Work period: continuously for 1 hour or intermittently for 2 hours of work. Work conditions: water and salt taken appropriately.

The intensity of work is indicated by five RMR (Relative Metabolic Rate) levels and metabolic energy (kcal/h), and the acceptable temperature limit is specified for each level: 32.5ºC (WBGT) for very light work (RMR: ≤ 1, kcal/h: ≤ 130), 30.5ºC for light work (RMR: 1-2, kcal/h: 130-190), 29.0ºC for Moderate work (RMR: 2-3, kcal/h: 190-250), 27.5ºC for moderate work (RMR: 3-4, kcal/h: 250-310), and 26.5ºC for heavy work (RMR: 4-5, kcal/h: 310-370). RMR is an index for evaluating work load intensity. This index has been used in Japan for a long time. It is calculated by METS (Metabolic Equivalents) = RMR/1.2 + 1. The relationship between the work load intensity and acceptable level of WBGT is similar to the result of ISO7243 (2003).

5. Prediction of Heat Disorders Occurring in Daily Life Activities

In Japan, public interest has surged in heat disorders in recent years as summer temperatures have tended to increase year by year. Accordingly, prediction of the incidence of heat disorders is becoming popular in the media, *e.g*., during weather forecasts on TV and the radio, on web pages with information for preventing heat disorders, such as that of the Japan Weather Association (http://www.n-tenki.jp/

Table 1 Occupational exposure limits for heat stress proposed by the Japan Society for Occupational Health.
(Source: JSOH, 1983, 2001)

Work load intensity	Metabolic energy (kcal/h)	Acceptable level WBGT(°C)
RMR -1 (Very light)	-130	32.5
RMR 1-2 (Light)	130-190	30.5
RMR 2-3 (Moderate)	190-250	29.0
RMR 3-4 (Moderate)	250-310	27.5
RMR 4-5 (Heavy)	310-370	26.5

WBGT: Wet Bulb Globe Temperature
Workload intensity
RMR -1; Finger work such as on a word processor or key punch
RMR 1-2; Lathe operation, automobile operation, etc.
RMR 2-3; Concrete polishing, work involving fast walking, etc.
RMR 3-4; Light to moderate carpenter work, bicycle operation, etc.
RMR 4-5; Work using the whole body, such as agricultural work, clamping of rivets, etc
*RMR=(Working metabolism - Resting metabolism)/Basal metabolism

Heat_Disorder/), and in publications, such as the health guidance manual for heat disorders by the Environment Agency (http://www.env.go.jp/health/Heat Stroke/index.html/). However, these media channels predict the incidence of heat disorders based on the criteria of the exercise guidelines for preventing heat disorders proposed by the Japan Sports Association (Kawahara *et al*., 1994). Actually, heat disorders occur less frequently during exercise (Hoshi & Inaba, 2002b). Besides, the exercise guidelines are intended to prevent heat disorders at the site of exercise by evaluating environmental conditions there, and are not designed to predict the occurrence of heat disorders. Therefore, the guidelines should not be applied to heat disorders occurring during activities other than exercise. Based on this recognition, Hoshi and Inaba developed a predictive model for heat disorders occurring in all activities (Hoshi & Inaba, 2004b) (Fig. 4). In the new prediction model, the regression line was calculated from the correlation with daily maximum temperature and relative humidity at daily maximum temperature in the day of occurrence of heat disorders. This regression line was in agreement with the WBGT value. The +1SD of this regression line was approximated to 32ºC, and -1SD was 27ºC, -2SD was 24ºC.

This prediction model represents the risk of heat disorders at four levels based on WBGT. Extreme danger, at ≥ 32ºC, may occur even for people staying still. Preventive measures should be actively taken, such as avoiding going outdoors. Danger, at 27ºC-32ºC, occurs for the largest number of people. Adequate preventive steps should be taken. Extreme caution, at 24ºC-27ºC, applies more often at work or in usual activities. Sufficient caution should be exercised. Caution, at ≤ 24ºC, may be needed during heavy exercise such as marathons. Caution should not be neglected.

Heat disorder forecasts via certain media channels (TERUMO Health Forecast; http://kenkotenki.jp/contents) are classified into sports activities and daily life

Relative humidity at daily maximum temperature (%)

Daily maximum temperature (°C)	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
40	30	30	31	32	33	34	35	36	37	38	39	40	41	41	42	43	44
38	28	29	30	31	32	32	33	34	35	36	37	38	39	39	40	41	42
36	27	27	28	29	30	31	32	32	33	34	35	36	37	37	38	39	40
34	25	26	27	27	28	29	30	31	31	32	33	34	35	35	36	37	38
32	24	24	25	26	27	27	28	29	30	30	31	32	33	33	34	35	36
30	22	23	23	24	25	26	26	27	28	29	29	30	31	31	32	33	34
28	20	21	22	23	23	24	25	25	26	27	27	28	29	29	30	31	32
26	19	20	20	21	22	22	23	24	24	25	25	26	27	27	28	29	29
24	17	18	19	19	20	21	21	22	22	23	24	24	25	25	26	27	27
22	16	16	17	18	18	19	19	20	21	21	22	22	23	23	24	25	25
20	14	15	15	16	17	17	18	18	19	19	20	20	21	21	22	23	23
18	13	13	14	14	15	15	16	16	17	17	18	18	19	19	20	20	21
16	11	12	12	13	13	14	14	15	15	16	16	17	17	17	18	18	19
14	10	10	11	11	12	12	12	13	13	14	14	15	15	15	16	16	17
12	8	9	9	9	10	10	11	11	11	12	12	13	13	13	14	14	15

Extreme Danger (32°C -)	May occur even among people staying still. Preventive measures should be taken actively, such as avoiding going out.
Danger (27 - 32°C)	Occurs in the largest number of people. Preventive measures should be taken adequately.
Extreme Caution (24 - 27°C)	Occurs more often at work or in daily activities. Sufficient caution should be exercised.
Caution (- 24°C)	May occur during heavy exercise such as marathons. Caution should not be neglected.

In automobiles in the sun, heat disorders may occur irrespective of the season. Specifically, temperatures in automobiles surge on sunny days. Do not leave young children in a car even for a few minutes.

During sports activities, heat disorders may occur even on cool days in seasons other than summer. In particular, caution should be exercised if the WBGT increases by at least 3ºC within one week. Take water and salt adequately.

Fig. 4 Prediction model of heat disorders using WBGT in Japan.
WBGT: Wet Bulb Globe Temperature (Source: Hoshi & Inaba, 2004b)

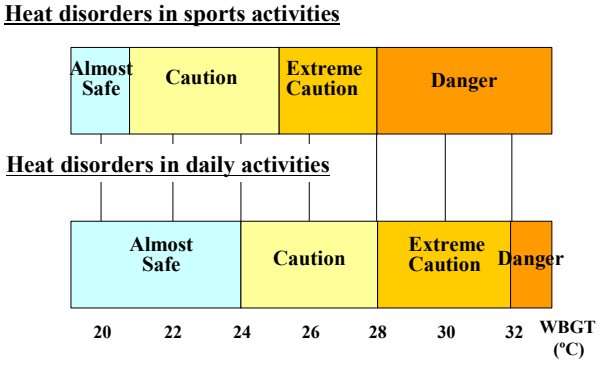

Fig. 5 Prediction of heat disorders according to the TERUMO health forecast.
(Source: TERUMO Health Forecast)

activities (Fig. 5). Exercise guidelines for preventing heat disorders proposed by the Japan Sports Association are used at sports activities, and a new prediction model of heat disorders is being used for daily life activities. For sports activities, exercise discontinuation and danger levels were unified into one danger level. For daily life activities, the extreme caution level was modified to 28ºC-32ºC from 27ºC-32ºC.

The Japanese Society of Biometeorology launched the Research Council for Heat Disorder Prevention in 2006, which began research on predicting the incidence of heat disorders and development of prediction models. It is expected that they will develop more accurate, more user-friendly prediction models for heat disorders in daily life activities.

6. Conclusion

In Japan, public interest in heat disorders has surged in recent years as summer temperatures have tended to increase year by year. Heat disorders can be prevented by appropriately controlling exercise, taking rests, and drinking water with salt based on a full understanding of environmental conditions. Accordingly, in Japan, criteria based on meteorological conditions during sports activities and at work are being used to prevent heat disorders.

For sports activities, exercise guidelines for preventing heat disorders were proposed by the Japan Sports Association in 1994. For labor, occupational exposure limits for heat stress were proposed by the JSOH in 1983 and 2001. For daily life activities, a predictive model for heat disorders was proposed by Hoshi and Inaba in 2004. The prediction models in use, however, still need to be improved.

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(Received 10 November 2006, Accepted 29 January 2007)