Different risk mechanisms of heat disorders during sports activities by season and region in Japan

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Abstract

Objectives: We evaluated seasonal and regional differences in the occurrence of heat disorders during sports activities using cases reported in newspaper articles.

Methods: Cases of heat disorders were collected by search for newspaper articles at a site on the Internet (G-search Data Service; http://db.g-search.or.jp).

Results: Analyzed were 468 reported cases. The environmental temperature on the day of the occurrence of heat disorders was lower in seasons other than summer while the increase in the environmental temperature during the 7-day period until the day of the disorder was more acute in the other seasons. In addition, heat disorders during sports activities occurred at lower environmental temperatures in Hokkaido than in other regions in Japan.

Conclusions: Seasonal and regional differences should be taken into consideration when producing prediction models of heat disorders during sports activities.

Key words: heat disorders, newspaper article, regional difference, seasonal difference, sports activities

Introduction

Recently in Japan, the mortality rate from heat disorders has been increasing (1) due to elevation of temperatures in summer caused by the marked heat island phenomenon (2,3) in urban areas associated with global warming. Also, deaths from heat disorders during sports activities have increased in recent years (4, 5).

Heat disorders occurring during sports activities are considered to be preventable if appropriate measures are taken (6-9). Such preventive measures have been studied (8, 10, 11). Heat disorders, which are caused by high environmental temperatures, mostly occur in summer but also occur in other seasons, although the incidence is low (6). Factors associated with the occurrence of heat disorders such as meteorological conditions may differ between cases occurring in summer and those in the other seasons. Geographically, Japan is a long country extending from south to north and is located in both sub-tropical and sub-arctic zones (12). Therefore, meteorological conditions for the occurrence of heat disorders markedly differ among regions. However, seasonal or regional differences in the occurrence of heat disorders during sports activities have not been studied; thus, these differences were not taken into consideration in the Recommendations for the Prevention of Heat Disorders as a model of the occurrence of heat disorders during sports activities proposed by the Japan Amateur Sports Association (13). It is important in evaluating preventive measures for heat disorders to determine the presence or absence of seasonal and regional differences in the occurrence of such heat disorders.

The incidence of heat disorders can be evaluated in detail based on ambulance transportation data and medical records of medical institutions. Acquisition of such data, especially on a nation-wide basis, is difficult due to the protection of personal information. It can be considered that newspaper articles would be a source of such information, but not all cases are reported in newspapers. These factors make it difficult to evaluate the status of the incidence of heat disorders. Newspaper articles can, however, provide nation-wide data on situations surrounding the occurrence of heat disorders, such as working conditions and meteorological conditions.

We evaluated seasonal and regional differences in the occurrence of heat disorders during sports activities based on cases reported in newspapers.

Methods

Data collection

Cases of heat disorders between 1970 and 2002 were evaluated. Information was collected by searching for information in newspaper articles at a site on the Internet (G-search Data Service; http://db.g-search.or.jp). G-Search allows for a cross-sectional search of databases of 48 newspapers and magazines, including 4 national newspapers and 15 local newspapers.

Information related to heat disorders included age of the sports participant, place of occurrence, date/time of occurrence, and sports activity. Age was classified into 6 categories: 0-5 years, 6-12 years (primary school students), 13-15 years (junior high school students), 16-18 years (senior high school students), 19-64 years (adults), and ≥ 65 years (elderly). The intensity of the sport was classified into 5 categories according to the relative metabolic rate (RMR) estimated according to the sports activity at the time of occurrence of heat disorders: very low intensity sport (RMR: -1.0), low intensity sport (RMR: 1.0-2.5), moderate intensity sport (RMR: 2.5-6.0), high intensity sport (RMR: 6.0-9.0), and very high intensity sport (RMR: 9.0-). For purposes of the study, Japan was divided into 8 regions: Hokkaido, Tohoku, Kanto, Chubu, Kinki, Chugoku, Shikoku, and Kyushu (including Okinawa). The seasons were classified as "summer (July, August)" and "other."

Environmental temperature

As to the meteorological conditions at the time of occurrence of heat disorders, the maximum temperature (°C) (Td) and relative humidity (%) at this temperature at the nearest meteorological observatory were investigated. As a parameter of a hot environment, wet-bulb globe temperature (WBGT, °C) was calculated (14). In the calculation of WBGT, the wet bulb temperature (Tw) was calculated using Sprung's equation (15). WBGT was estimated using a regression equation for the relationship between WBGT and dry and wet bulb temperatures: $WBGT = 1.925 + 1.298\,(0.7\,Td + 0.1\,Tw)$ (16). For indoor cases, none of the newspaper articles described the indoor temperature. Therefore, outdoor environmental conditions were used for indoor cases.

Analytical methods

Age, sport intensity, regional differences, and changes in WBGT at the daily maximum temperature during the 7-day period before the occurrence of heat disorders were analyzed by one-way analysis of variance, followed by pair-wise comparison using Scheffe's method. Sport intensity according to age groups was compared by the $\chi 2$ test. The association between the daily maximum temperature and relative humidity at the daily maximum temperature was analyzed by Pearson's correlation. The correlation coefficient was compared by the test of the difference in the coefficient. As multivariate analysis, the association of meteorological factors with heat disorders occurring in other seasons was analyzed using its occurrence in summer as a control employing a multiple logistic model. In this analysis, each factor was classified as follows: sport intensity, RMR < 6 and RMR ≥ 6; daily maximum temperature, < 33° C and ≥ 33° C; relative humidity at the daily maximum temperature, < 55% and ≥ 55%; WBGT at the daily maximum temperature, < 30°C and ≥ 30°C; diurnal temperature range, < 9°C and ≥ 9°C; mean wind velocity on the day of occurrence, < 3.4 m/s and ≥ 3.4 m/s (causing constant movement of leaves and twigs); mean cloud volume, < 7.5 and ≥ 7.5 (cloudy); difference in the daily maximum temperature between the day of occurrence of heat disorders and the

Table 1 Occurrence of heat disorders in principal sports activities according to age

Activities	Total	PS	JS	SS	AD	EL	UN
Baseball	74(26)	2(1)	21(9)	40(16)	11		
Mountain climbing	38		8	16	12	2	
Marathon or ekiden	35(35)		2(2)	9(9)	19(19)	1(1)	(4)
Golf	33(1)			1	21(1)	6	5
Running	28(28)	3(3)	6(6)	6(6)	12(12)		1(1)
Tennis	27(2)		8(1)	3(1)	12	1	3
Soccer	25(8)	4(1)	7(4)	8(3)	6		
Opening ceremony	24		3	15			6
Cheering as spectator	24		3	12	3	1	5
Rugby	22(2)		5	12(2)	5		
Kendo	17(2)	2	6(1)	7(1)	2		
Basketball	13(3)		5(1)	8(2)			
Softball	10	2	3	1	4		
Others	98(15)	4	25(8)	41(6)	15(1)	9	4
Total	468(122)	17(5)	102(32)	179(46)	122(33)	20(1)	28(5)

PS: Primary school students, JS: Junior high school students, SS: Senior high school students

AD: Adults, EL: Elderly, UN: Unknown ( ) : Number of cases while running

previous day (difference in Tx/-1d), < -1.0°C and ≥ -1.0°C; difference in WBGT at the daily maximum temperature between the day of occurrence of heat disorders and the previous day (difference in WBGT at Tx/-1d), < -0.5°C and ≥-0.5°C; difference between the daily maximum temperature on the day of occurrence of heat disorders and the mean maximum temperature during the previous 7-day period (difference in Tx/-7d), < -2.0°C and ≥ -2.0°C; and difference between WBGT at the daily maximum temperature on the day of occurrence of heat disorders and the mean WBGT at the daily maximum temperature during the previous 7-day period (difference in WBGT at Tx/-7d), < -1.5°C and ≥ -1.5°C. Statistical processing was performed using a statistical package HALBAU, and $p < 0.05$ was considered to be significant.

Results

Principal sports activities

There were 468 cases in which the place and date were clear. Table 1 shows the occurrence of heat disorders during principal sports activities according to age. In all age groups, the number of cases was high for baseball, mountain climbing, and marathon or ekiden (long distance relay races).

According to age, the number of reported cases was highest for soccer in primary school students, baseball in junior and senior high school students, and golf in adults and the elderly. Sports activities differed among the age groups. About 26% of all cases of heat disorders occurred while running.

Sport intensity

WBGT at the daily maximum temperature according to sport intensity is shown in Fig. 1. The WBGT for very high sport intensity was lower than that for other sport intensities ($F = 13.355$, $p < 0.01$), being significantly lower than that for any other sport intensity except for low intensity (very low intensity: $p < 0.05$; moderate intensity and high intensity: $p < 0.01$).

Fig. 2 shows the relationship between the daily maximum temperature and relative humidity at this temperature. At each sport intensity, a significant negative correlation was observed between the maximum temperature and relative humidity ($p < 0.01$).

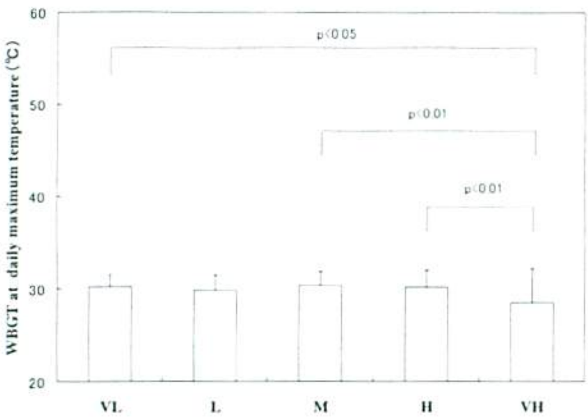

Fig. 1 WBGT at daily maximum temperature according to sport intensity.
VL: Very low intensity sport, L: Low intensity sport, M: Moderate intensity sport, H: High intensity sport, VH: Very high intensity sport, Values are mean ± SD.
WBGT: Wet bulb globe temperature

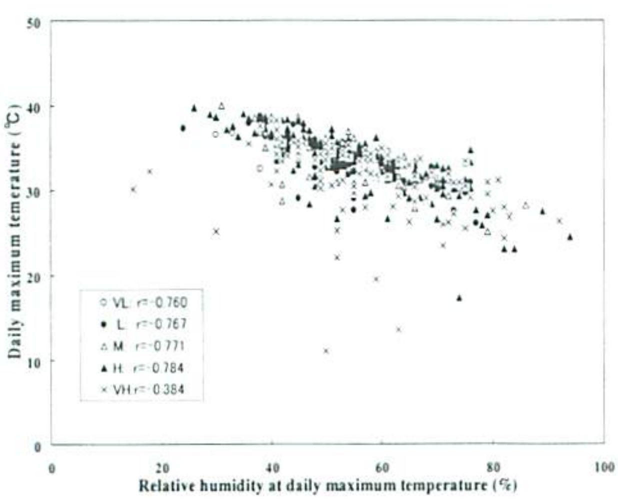

Fig. 2 Relationship between daily maximum temperature and relative humidity at the daily maximum temperature according to sport intensity.
VL: Very low intensity sport, L: Low intensity sport, M: Moderate intensity sport, H: High intensity sport, VH: Very high intensity sport, Values are mean ± SD.

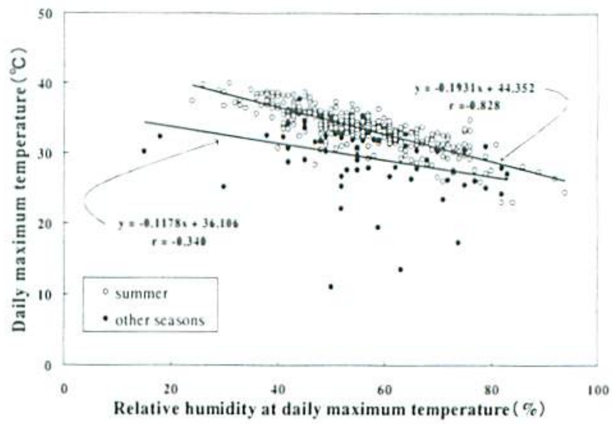

Fig. 3 Relationship between daily maximum temperature and relative humidity at daily maximum temperature in summer and other seasons.

However, the correlation coefficient for very high sport intensity was lower than that for any other sport intensity (low sport intensity: $p < 0.05$; moderate and high sport intensities: $p < 0.01$).

Comparison among seasons

The number of reported cases of heat disorders was 235 in July and 163 in August, which accounted for about 85% of all cases. However, there was 1 case in February, 3 in April, 5 in May, 25 in June, 27 in September, 6 in October, and 3 in November.

Fig. 3 shows the relationship between the daily maximum temperature and relative humidity at this temperature in summer and in the other seasons. Both in summer and in the other seasons, a significant negative correlation was observed ($p < 0.01$). However, the correlation coefficient for the other seasons was significantly lower than that in summer ($p < 0.01$).

Fig. 4 shows changes in WBGT at the daily maximum temperature from 7 days before to the day of occurrence of heat disorders. The WBGT at the daily maximum temperature 7 days before the occurrence of heat disorders in summer was 28.5°C but gradually increased, reaching 30.3°C (1.8°C increase) on the day of occurrence of disorders ($p < 0.01$). In the other seasons, the WBGT increased from 23.6 °C to 26.7 °C (3.1 °C

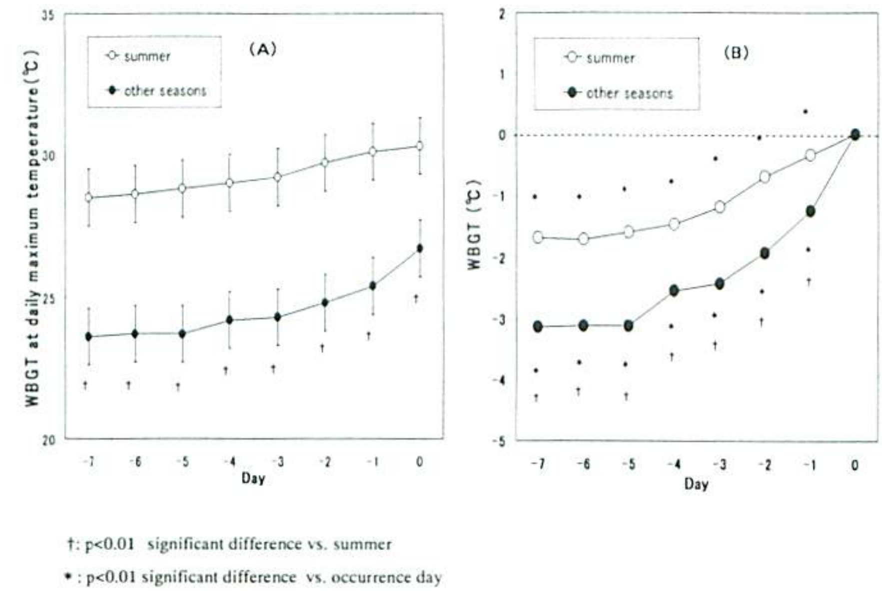

Fig. 4 Changes in WBGT at the daily maximum temperature from 7 days before to the day of occurrence of heat disorders.
Values are mean ± SD.
WBGT: Wet bulb globe temperature

Table 2 Odds ratio between risk factors from heat disorders in seasons other than summer using multiple logistic model (WBGT: Wet bulb globe temperature)

Factor	Category	Odds ratio	95%CI
Intensity of exercise	<RMR6	1.000	
	≥RMR6	0.843	0.381-1.864
Daily maximum temperature	<33°C	1.000	
	≥33°C	0.066	0.019-0.229
Relative humidity at daily maximum temperature	<55%	1.000	
	≥55%	0.522	0.154-1.769
WBGT at daily maximum temperature	<30°C	1.000	
	≥30°C	0.168	0.058-0.484
Diurnal temperature range	<9°C	1.000	
	≥9°C	2.246	0.731-6.895
Mean cloud volume on day of occurrence	<7.5	1.000	
	≥7.5	2.026	0.847-4.845
Mean wind velocity on day of occurrence	<3.4	1.000	
	≥3.4	0.933	0.369-2.360
Difference in Tx/-1d	<-1.0°C	1.000	
	≥-1.0°C	0.800	0.326-1.964
Difference in WBGT at Tx/-1d	<-0.5°C	1.000	
	≥-0.5°C	1.853	0.744-4.616
Difference in Tx/-7d	<-2.0°C	1.000	
	≥-2.0°C	0.863	0.288-2.588
Difference in WBGT at Tx/-7d	<-1.5°C	1.000	
	≥-1.5°C	6.119	2.180-17.179

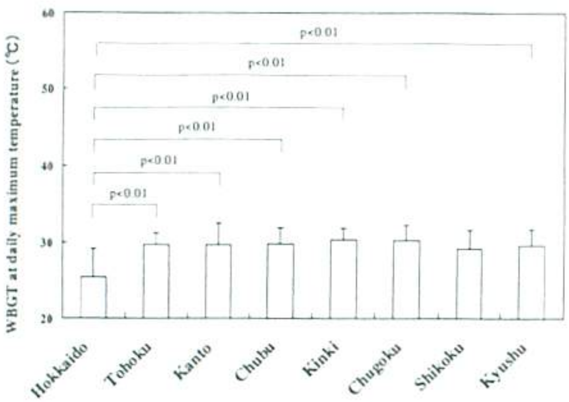

Fig. 5 WBGT at daily maximum temperature of heat disorders among regions.
Values are mean ± SD.
WBGT: Wet bulb globe temperature

increase) ($p < 0.01$). The WBGT at the daily maximum temperature on the day of occurrence of disorders in the other seasons was 3.6°C lower than that in summer ($p < 0.01$), but the increase in WBGT compared with the value 7 days earlier was significantly more marked in the other seasons than in summer ($p < 0.01$). The cases in summer were distributed in the range of WBGT at the daily maximum temperature of 24-34°C, but those in the other seasons were distributed in the range of 10-32°C. Thus, heat disorders occurred in the other seasons at a lower environmental temperature than in summer.

Table 2 shows the association of each factor with heat disorders that occurred in the other seasons with summer as a control using a multiple logistic model. Using the daily maximum temperature of < 33°C as a criterion, the odds ratio at ≥ 33°C was 0.066 (95% confidence interval: 0.019-0.229), showing a significantly lower risk of death than that at < 33°C. For WBGT at the daily maximum temperature, the odds ratio at ≥ 30°C was 0.168 (95% confidence interval: 0.058-0.484), showing a significantly lower risk of death than that at < 30.0°C. Concerning the "difference in WBGT at Tx/-7d" of occurrence of heat disorders, the death risk was significantly higher for a difference of ≥ −1.5°C than for a difference of < -1.5°C (odds ratio: 6.119, 95% confidence interval: 2.180-17.179). The other meteorological factors had no influence.

Regional differences

Fig. 5 compares WBGT at the daily maximum temperature on the day of heat disorders among regions. The WBGT at the daily maximum temperature in

Hokkaido was lower than that in the other regions ($F = 6.092$, $p < 0.01$) and significantly lower than that in all regions excluding Shikoku ($p < 0.01$).

Discussion

Among sports activities, the number of reported cases was the highest for soccer in primary school students, baseball in junior high and senior high school students, and golf in adults and the elderly. Although not shown in the results, sport intensity did not differ among age groups except for the elderly. The elderly group had a higher incidence of heat disorders at low sport intensity and a lower incidence at very high sport intensity than the other groups ($\chi2 = 44.169$, $p < 0.01$). Thus, sports activities at the time of occurrence of heat disorders markedly differed among age groups because of differences in the type of sports among the age groups.

WBGT is a parameter involving temperature, humidity, and radiant heat and is considered to be useful as a scale for a hot environment (14). In Japan, the Japan Amateur Sports Association also proposed Recommendations for the Prevention of Heat Disorders using WBGT (13). In this study, the WBGT at the daily maximum temperature on the day of occurrence of heat disorders in summer ranged from 24°C to 34°C, which was similar to the range reported by a previous study (13). However, in the other seasons, the WBGT at the daily maximum temperature on the day of occurrence of heat disorders ranged from 10° to 32°C, and heat disorders also occurred at temperatures of ≤ 21°C, which was included in the safety range according to the recommendations for the prevention of heat disorders (13). This may have caused the significantly low correlation coefficient between the daily maximum temperature and relative humidity at this temperature in seasons other than summer ($p < 0.01$).

The occurrence of heat disorders has been suggested to be associated not only with the high environmental temperature on the day of occurrence but also with acute changes in temperature (17). Therefore, changes in WBGT at the daily maximum temperature during the

7-day period until the day of occurrence of heat disorders were evaluated. In both summer and the other seasons, WBGT at the daily maximum temperature significantly increased during this period ($p < 0.01$). In addition, the degree of change was significantly more marked in seasons other than summer ($p < 0.01$). Analysis using a multiple logistic model showed a lower death risk in the other seasons at a maximum temperature on the day of occurrence ≥ 33°C than at < 33°C ($p < 0.05$) and at a WBGT at the daily maximum temperature of ≥ 30°C than at < 30°C ($p < 0.05$). In addition, the death risk was significantly higher when the "difference in WBGT at Tx/-7d" of occurrence of heat disorders was ≥ 1.5°C than when it was < 1.5°C ($p < 0.05$). These results suggest that heat disorders in the other seasons were associated with an acute increase in the environmental temperature during the 7-day period until the occurrence of heat disorders despite the low environmental temperature.

WBGT for very high sport intensity was significantly lower than that for other sport intensities because heat disorders during very high sport intensity frequently occurred at a lower temperature. This was also suggested by the significantly lower correlation coefficient between the daily maximum temperature and relative humidity at this temperature for very high sport intensity than for sports of lesser intensities. Running was generally the highest intensity sport. About 50% of cases in the other seasons occurred while running; this percentage was twice that in summer. This higher incidence of heat disorders while running in the other seasons may be associated with the following factors. Running is a high intensity sport and is performed as a training method (18). People attend marathon races or ekiden without acclimating themselves to a hot environment, and excessive heat generation and inadequate water intake due to a higher pace than expected may be associated with heat disorders (19).

In the Recommendations for the Prevention of Heat Disorders as a model of the occurrence of heat disorders during sport in Japan proposed by the Japan Amateur Sports Association, regional differences were not taken into consideration (13). Therefore, we classified Japan into 8 regions from Hokkaido to Kyushu (Hokkaido, 10 cases; Tohoku, 34 cases; Kanto, 181 cases; Chubu, 75 cases; Kinki, 80 cases; Chugoku, 41 cases, Shikoku, 8 cases; and Kyushu, 39 cases) and evaluated regional differences in WBGT at the daily maximum temperature of the occurrence of heat disorders. As a result, WBGT at the daily maximum temperature in Hokkaido was significantly lower than that in the other regions, excluding Shikoku ($p < 0.01$), showing that heat disorders during sport occurs at a lower temperature in Hokkaido than in the other areas. Hokkaido is classified as a sub-arctic zone, and it is colder in Hokkaido than in Honshu, Kyushu and Sikoku, which are classified as temperate zones (12). The threshold of the environmental temperature for the occurrence of heat disorders may be lower in cold regions such as Hokkaido than in warm regions such as Honshu and others. In this study, detailed evaluation was impossible because of the low number of cases in Hokkaido. In the future, detailed evaluation of a higher number of cases in Hokkaido is necessary. When new prediction models of heat disorders during sport are produced, a model for Hokkaido should be produced separately.

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