J Occup Health 2006; 48: 223–229

Journal of Occupational Health

Risk Factors for Heatstroke among Japanese Forestry Workers

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Abstract: Risk Factors for Heatstroke among Japanese Forestry Workers: Takafumi MAEDA, *et al.* Department of Hygiene and Preventive Medicine, Fukushima Medical University School of Medicine—We examined the risk factors for heatstroke among forestry workers in Japan during the summer. We distributed a questionnaire to 124 forestry workers to determine heatstroke symptoms, degree of sweating and hydration, as well as perceived hotness and amount of sunlight at work sites. Forty of the workers (32.3%) reported experiencing heatstroke symptoms. Thirteen and 21 of them reported such symptoms during July and August, respectively. Eleven workers experienced heatstroke at around 14:00; 5 and 4 developed symptoms at around 11:00 and 10:00, respectively. Groups with and without heatstroke symptoms significantly differed in terms of perceived hotness ($p<0.05$), sunlight ($p<0.05$), degree of sweating ($p<0.01$) and frequency of hydration ($p<0.05$) while working. Heatstroke symptoms developed in 60.6% of workers aged up to 50 yr, but in only 22.0% of those over the age of 51 ($p<0.01$). Multiple regression analysis selected the following key variables associated with the development of heatstroke symptoms ($R^2=0.236$ and $p=0.006$): frequency of urination, hotness, BMI and years of forestry work (standard coefficients: +0.229, +0.194, +0.280 and –0.162, respectively). The results of the present study showed that one third of forestry workers developed some symptoms of early heatstroke during summer forestry work. Furthermore, the results indicate that a short duration of forestry service was one of the risk factors contributing to the onset of heatstroke, in addition to heat stress, loss of body water and electrolytes, and obesity.
(J Occup Health 2006; 48: 223–229)

Received Apr 4, 2005; Accepted Mar 8, 2006
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Key words: Age, Years of service, Heat stress, Sweating, Hydration, Obesity, Urination

The incidence of heatstroke is higher during the summer because heat stress increases as a result of higher ambient temperatures and increased solar radiation. Thus, more water and electrolytes are excreted from the body through sweating and urination. Many studies have examined the relationship between air temperature and heat-related mortality as well as the frequency of heatstroke[1–7]. Moreover, muscle activity generates heat during labor and physical exercise in a hot environment and this can induce exertional heatstroke, which is distinct from classic heatstroke[8–10]. Studies on exertional heatstroke have mainly focused upon physical exercise, sport competitions and/or games[11] and military training[12], and various preventive measures have been proposed and implemented for various sports. Japan has thermal guidelines to prevent heatstroke during sports activity[13] and the Japan Society for Occupational Health has published Occupational Exposure Limits for Heat Stress[14]. Moreover, a prediction model of heat disorders using Wet-Bulb Globe Temperature (WBGT) has been developed in Japan[15].

Forestry work such as felling, thinning, carrying, planting, artificial pruning, mowing, as well as the operation of heavy equipment such as timber carts, are performed in unstable positions, often while using heavy oscillating implements such as chainsaws and grass mowers. Therefore, forestry work involves a large physical burden. During the summer, the frequency of mowing bottom grass under direct sunlight increases. Furthermore, workers wear long-sleeved shirts and long trousers, helmets, safety boots and gloves, etc. to protect against physical, animal and insect hazards, and the thermal insulation properties of such clothing is very high. Thus, the thermal load is very large, and might contribute to the high frequency of exertional heatstroke that develops among forestry workers.

Because many people are employed in the service

industry and the influx of new forestry workers is low in Japan, the average age of forestry workers is increasing. Studies of the relationship between heatstroke and aging have indicated that the higher frequency of heatstroke among the elderly is associated with a decline in thermoregulation capabilities[16–22].

Heatstroke at work that was formerly associated with foundry workers and miners has recently been observed among construction workers. Although forestry work is associated with a considerable risk of heatstroke due to a high physical workload, high heat stress, and an aging workforce, heatstroke in forestry workers has not been studied in detail. Heatstroke symptoms have historically been included in statistical databases only when they were sufficiently serious to require hospitalization or cause death. They have never been considered when symptoms were relatively mild, because strategies such as resting in a cool place, hydration, and cooling at the workplace alleviate the symptoms. Accordingly, many more people have probably experienced early symptoms of heatstroke than has been reported. Furthermore, forests are often far from hospitals, which might lead to the death of forestry workers who develop critical symptoms. Thus, early detection and treatment of heatstroke among forestry workers is required, and the risk factors that induce early symptoms must be defined so that heatstroke can be prevented.

We therefore conducted surveys on heatstroke among Japanese forestry workers to identify risk factors from the relationship between heatstroke symptoms and thermal factors, hydration behavior, age, years of forestry service and individual physical features.

Methods

One hundred and twenty-five forestry workers (118 males, mean age ± SD 55.8 ± 13.6 yr; 7 females, 54.1 ± 4.8 yr) who were working in Fukushima prefecture, Japan, provided their written informed consent for participation in the study, which was approved by the Ethics Committee

Table 1. Questionnaire

Age ( ) years Gender (male, female)
Years of forestry service ( ) years and ( ) months
Situation during forestry work in summer
Clothing during work
Subjective hotness at the work site (very hot, slightly hot, neutral, not hot)
Presence of sunlight at the work site
(direct sunlight without shade, direct sunlight with shade, not direct sunlight)
Degree of sweating (much, a little, none)
Response to sweating (change clothes, no response, other)
Main work site
(south slope of mountain, north slope of mountain, mountain path,
town, park, road, other)
Frequency of urination ( ) ~ ( ) times during work
Hydration during summer forestry work
Frequency ( ) times during work
Time (0900, 1000, 1100, 1200, 1300, 1400, 1500, 1600, 1700, 1800, other)
Volume ( ) ml per consumption
Freely available (yes, no)
Type of beverage
during work (water, cold tea, hot tea, sports drink, carbonated drink, other)
during lunch (water, cold tea, hot tea, sports drink, carbonated drink, other)
during break (water, cold tea, hot tea, sports drink, carbonated drink, other)
Heatstroke symptoms
Did you experience any of the following symptoms during summer forestry work:
(Please check box if experienced)
□feeling bad, headache, ||qualm, ||nausea, ||sluggishness,
□lassitude, □muscle ache, □muscle spasm, □feeling disoriented,
||unusually high body temperature, □fainting, palpitation,
□rapid breathing, blackout (anemia)
If so, describe month ( ) ( ) ( )
If so, describe time of onset ( ) ( ) ( )

Table 2. Numbers of respondents reporting heatstroke symptoms during summer forestry work

Heatstroke symptoms	Number of persons (%)
Feeling bad	15 (12.1%)
Headache	5 (4.0%)
Qualm	9 (7.3%)
Nausea	6 (4.8%)
Sluggishness	8 (6.5%)
Lassitude	7 (5.6%)
Muscle ache	12 (9.7%)
Muscle spasm	5 (4.0%)
Feeling disoriented	7 (5.6%)
Unusually high body temperature	6 (4.8%)
Fainting	0 (0.0%)
Palpitation	10 (8.1%)
Rapid breathing	3 (2.4%)
Blackout (Anemia)	4 (3.2%)
Any one of above symptoms	40 (32.3%)

Table 3. Numbers and rates of reporting heatstroke symptoms per month and hour of occurrence

	Number	Rate (%)
Month		
May	1	2.5
June	1	2.5
July	13	32.5
August	21	52.5
September	4	10.0
Hour		
9	1	2.5
10	4	10.0
11	5	12.5
12	1	2.5
13	1	2.5
14	11	27.5
15	2	5.0
16	2	5.0
17	0	0.0

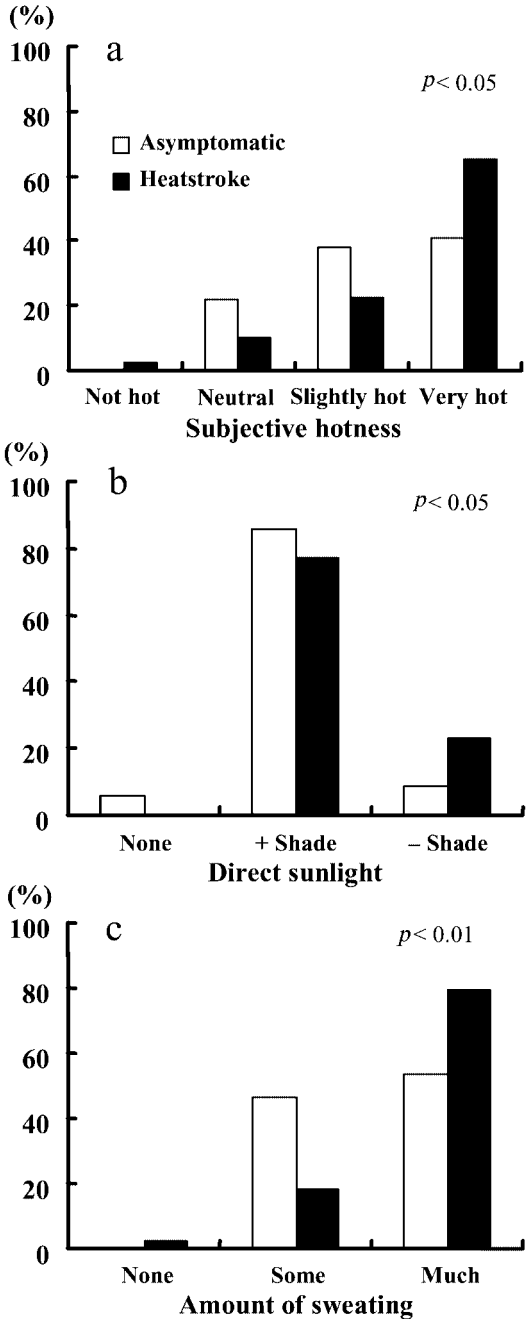

Fig. 1. Subjective hotness (a) and sunlight (b) at work site and sweating (c) in heatstroke and asymptomatic groups. Black and white bars indicate heatstroke and asymptomatic groups, respectively. Significant differences between both groups were analyzed by chi-square test.

of Fukushima Medical University. This survey was conducted in November, 2003. Only one worker failed to complete the questionnaire, resulting in a response rate of 99.2%.

Table 1 shows the questionnaire that was completed by the workers. The working situation was examined through responses to 8 questions that addressed clothing, subjective hotness, presence of sunlight, degree and response to sweating, main location of mountain work site and frequency of urination. Seven questions addressed hydration with respect to frequency, timing, volume and types of beverages consumed during work, freely consumption, and consumption during lunch time and breaks. Heatstroke symptoms were defined as feeling bad, headache, qualm, nausea, sluggishness, lassitude, muscle ache, muscle spasm, feeling disoriented, unusually high body temperature, fainting, palpitation, rapid breathing and blackout (anemia). Other information

Table 4. Age, years of forestry service, physical characteristics and hydration behavior during work in heatstroke and asymptomatic groups

	Heatstroke	Asymptomatic	*p* value
Age (yr)	50.58 ± 14.21	58.20 ± 12.08	0.002
Years of service (yr)	16.38 ± 13.90	21.17 ± 13.59	0.128
Physical characteristics			
Height (cm)	164.13 ± 6.25	162.75 ± 7.10	0.296
Weight (kg)	64.64 ± 8.56	62.20 ± 8.69	0.143
%Fat (%)	24.92 ± 2.84	21.35 ± 5.43	0.179
BMI (kg/m^2)	24.03 ± 3.17	23.45 ± 2.62	0.285
Hydration behavior			
Frequency (times)	5.61 ± 3.36	4.35 ± 1.98	0.013
Volume (ml/time)	2.71 ± 1.54	2.49 ± 1.42	0.453
Total volume (l/d)	2.07 ± 1.23	1.83 ± 0.87	0.232

Values are indicated as means ± S.D. Significant differences between heatstroke and asymptomatic groups were analyzed by t-test. Age and frequency of hydration significantly differ between groups.

requested included age, gender, years of forestry service and anthropometric values such as height, weight, body fat ratio and BMI as well as month and hour at which the symptoms were felt.

The chi-square test comparatively analyzed heatstroke occurrence with respect to subjective hotness, direct sunlight at work, sweating status and type of consumed beverage. A t-test comparative analysis of heatstroke occurrence with respect to frequency and volume of hydration, age, years of forestry service and physical features was performed. The chi-square test was used to compare the rates of heatstroke categorized by age and years of forestry service. Multiple linear regression analysis assessed the independent contributions of age, years of forestry service, other questionnaire items and physical features to the development and number of heatstroke symptoms. Age and years of forestry service were fixed as independent variables and the questionnaire items and physical characteristics were selected as independent variables by a stepwise procedure. P values below 0.05 were regarded as statistically significant.

Results

Forty of the 124 (32.3%) forestry workers reported experiencing heatstroke symptoms during the summer.

Table 2 shows the respective numbers of workers who indicated experiencing each symptom of heatstroke while working in the summer. "Feeling bad" was experienced by 15 workers, "muscle ache" by 12, "palpitation" by 10, "qualm" by 9, "sluggishness" by 8, "lassitude" and "feeling disoriented" by 7, "nausea" and "unusually high body temperature" by 6, "headache" and "muscle spasm" by 5, "blackout (anemia)" by 4, and "rapid breathing" by 3 persons.

Table 3 shows the number of workers who reported heatstroke symptoms per month and the hour at which they occurred. One developed heatstroke symptoms in May, 1 in June, 13 in July, 21 in August, and 4 in September. Eleven workers reported heatstroke symptoms at 14:00, 5 at 11:00, and 4 at 10:00. Symptoms also developed during the morning.

Figure 1 compares the rates relative to subjective hotness (Fig. 1a) and sunlight (Fig. 1b) at the work site, and degree of sweating (Fig. 1c) in the symptomatic and asymptomatic groups. Figure 1 shows that the two groups significantly differed in terms of subjective hotness (very hot: heatstroke, n=26 (65.0%); asymptomatic, n=30 (40.5%); $p<0.05$), presence of sunlight (direct with no shade: heatstroke, n=9 (23.1%); asymptomatic, n=6 (8.7%); $p<0.05$) and degree of sweating (much sweating: heatstroke, n=31 (79.5%); asymptomatic, n=40 (53.3%); $p<0.01$).

Table 4 shows age, years of forestry service, physical characteristics, and hydration behavior while working in the heatstroke and asymptomatic groups. The two groups significantly differed in terms of hydration frequency (means ± SD; 5.61 ± 3.36 vs. 4.35 ± 1.98 times, respectively; $p<0.05$). However, beverage volume consumed per time and daily total volume did not significantly differ between the groups.

Neither group significantly differed in terms of whether they consumed water, cold tea, hot tea or carbonated drinks. However the consumption of isotonic beverages significantly differed between the two groups (heatstroke, n=17 (42.5%) vs. asymptomatic, n=18 (21.4%); $p<0.05$). Furthermore, 10 (33.3%) respondents of the group that reported one or two symptoms of heatstroke and 7 (63.6%) of the group that reported three or more

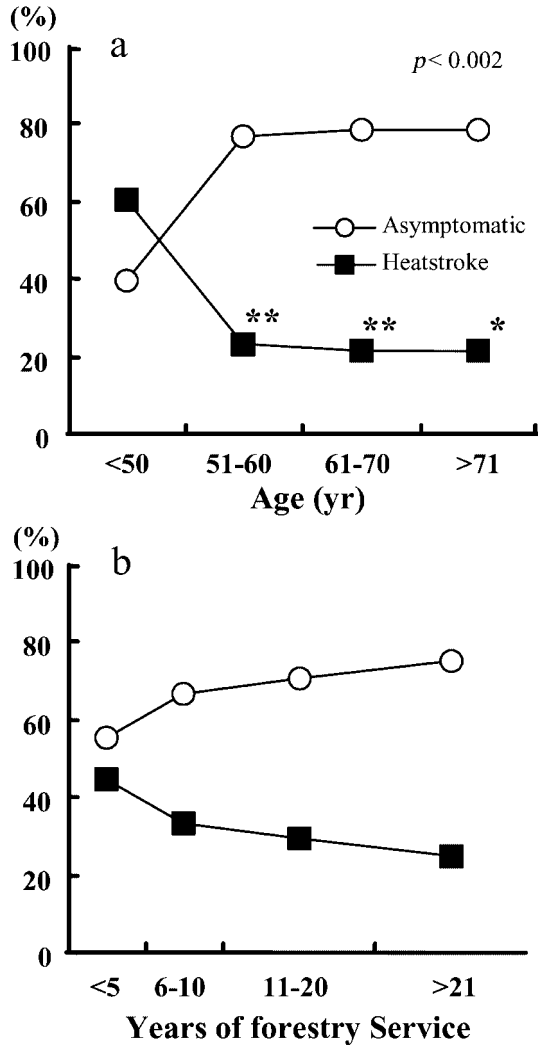

Fig. 2. Rates of reporting heatstroke symptoms for each age group (a) and after various years of forestry service (b). Black and white circles indicate heatstroke and asymptomatic groups, respectively. Significant differences in distribution of data between both groups were determined by the chi-square test. **, $p<0.01$; *, $p<0.05$ vs. workers aged 50 yr and below.

symptoms consumed isotonic beverages, compared with 18 (21.4%) of the asymptomatic group ($p<0.05$).

Age differed significantly between groups (means ± SD, heatstroke vs. asymptomatic, 50.58 ± 14.21 vs. 58.20 ± 12.08 years; $p<0.01$). Figure 2 shows the rates of heatstroke and absence of symptoms categorized by age (Fig. 2a) and years of service (Fig. 2b). Heatstroke symptoms developed in 60.6% of respondents aged 50 years or less, in 23.1% of those aged 51–60, 21.6% of those aged 61–70 and in 21.4% of those aged 71 years and above (Fig. 2a). Thus, younger respondents tended to develop heatstroke symptoms ($p<0.01$). Although the relationship between years of forestry service and heatstroke symptoms was not statistically significant, more workers with fewer years of service reported heatstroke symptoms.

The stepwise multiple regression analysis used heatstroke symptoms as a dependent variable, and the independent variables were age, years of forestry service, subjective feeling of hotness, presence of sunlight, degree of sweating, frequency of urination, frequency of hydration, volume of hydration (ml/time and l/day), freely consumption, height, weight, BMI, and %Fat. Four variables associated with heatstroke symptoms were selected in the model with $R^2=0.162$ and $p=0.052$: frequency of urination, subjective hotness, years of forestry service, and age (standard coefficients: +0.315, +0.190, +0.021 and –0.181, respectively). A similar regression analysis using the number of heatstroke symptoms as a dependent variable selected five variables with $R^2=0.378$ and $p=0.006$: frequency of urination, hydration volume (l/day), %Fat, years of forestry service and age (standard coefficients: +0.436, +0.174, +0.208, –0.078 and –0.194, respectively).

Discussion

This study showed that one third of the workers experienced symptoms of heatstroke during summer forestry work, and that heatstroke tended to occur in those aged 50 and below. To clarify factors contributing to heatstroke under these conditions, we investigated thermal factors, balance between hydration and sweating, types of consumed beverages, age, years of forestry service and physical features.

Workers in the heatstroke group felt hotter and tended to work more frequently in direct sunlight compared with asymptomatic colleagues. Thus, thermal factors such as high ambient temperature and radiation from direct sunlight induce heatstroke symptoms. The main function of workers in the forestry industry during summer is mowing grass under trees. Since bottom grass grows especially in sunny places, sunlight is usually direct at mowing sites. The results of our questionnaire indicated that many reported heatstroke events were caused by the physical load of mowing grass under direct sunlight.

Secondly, although the heatstroke group consumed beverages more frequently than the asymptomatic group, the volume per time and the total volume of beverages consumed during work did not significantly differ between groups.

The heatstroke group reported much sweating, suggesting that water and electrolyte loss through this process is involved in the onset of heatstroke symptoms during forestry work. Generally, considerable sweating was induced by the high temperature and/or high workload associated with the job. Workers in the heatstroke group who reported much sweating might have

a higher workload in a hotter environment than those in the asymptomatic group. Furthermore the balance between hydration and sweating suggested that heatstroke during forestry work might be prevented by consuming an optimal volume of water and electrolytes from appropriate beverages.

Isotonic drinks are recommended as an efficient source of water and electrolytes during physical exercise. However, the present study found that 17 of 35 workers who consumed isotonic drinks during work developed heatstroke. Furthermore, the ingestion rate of isotonic drinks was higher among workers who developed more symptoms. These findings indicate that water and electrolyte intake cannot prevent heatstroke but are associated with occurrence of heatstroke symptoms. However, metabolic acidosis occurs during heatstroke[21, 23], indicating that a source of electrolytes should be supplied before and/or during work[9, 24], and that hydration status such as timing, volume and type of beverage should be investigated in detail and optimized.

The thermoregulatory function in humans is influenced by various factors[25], especially age and physical fitness. Thermoregulation declines with age[16–20], improves with physical training[26, 27] and is influenced by lifestyle[28]. In addition, obesity, medication and an anamnesis of heatstroke are known risk factors for heatstroke[29].

Generally, elderly people with an age-related decreased ability to thermoregulate[16–20] are greatly influenced by environmental temperature and easily develop heatstroke symptoms[21, 22]. However, we found here that heatstroke predominantly developed in workers aged 50 yr and below, which contradicts previous findings. Although the difference in the rate of heatstroke among groups with various years of service was not statistically significant, the results of multiple regression analysis showed that this parameter negatively correlated with the occurrence and number of heatstroke symptoms. These results indicate that heatstroke developed most frequently in workers with a relatively short duration of forestry service. On the other hand, multiple regression analysis also showed that age contributed more to the number of heatstroke symptoms than years of service. The reasons might be because younger persons have not yet adapted to forestry work and its environment and that the physical fitness levels of workers who had worked for a relatively long time in the forestry industry were relatively higher due to prolonged exposure to the associated physical workload. Moreover, work intensity might be lower in elderly workers, which might explain why the rate of heatstroke was lower in this age group. However, further study is required to clarify this notion. Nonetheless, many early symptoms of heatstroke developed in relatively younger workers, indicating that preventative measures are required at all ages.

Other investigators have reported that lifestyle affects thermoregulation ability[28] and the onset of heatstroke[29]. The present study found that the lifestyle of younger workers, including short sleep duration, as well as sub-optimal dietary and exercise habits, might be associated with the development of heatstroke. The results of multiple regression analysis revealed significantly positive correlations between the number of heatstroke symptoms and degree of obesity, represented as %Fat. That is, individuals with stored body fat due to bad eating habits and/or inadequate exercise, have a higher risk of developing heatstroke during summer work.

Identification and treatment at the early stages of heatstroke are important[9, 30], as is the prevention of heatstroke. To avoid heatstroke in younger forestry workers or those with a short service duration, appropriate hydration before and during work, rest in the shade, sufficient sleep, appropriate nutrition, physical fitness, as well as temperance in smoking and alcohol consumption, will all help to improve heat tolerance[11, 29].

In conclusion, the present study clarified that one third of forestry workers develop some early symptoms of heatstroke during the summer. Contributing factors appear to be short service duration in the forestry industry, heat stress induced by a high environmental temperature and solar radiation, loss of body water and electrolytes through sweating and urination, and obesity.

Acknowledgments: We thank Akiko Sugawara, Hiroko Anbai, Hiroko Yokoyama, and Yumiko Watanabe for excellent technical assistance. This study was supported by a Grant-in-Aid for Occupational Health Research from the Fukushima Labor Health Center, Japan.

References

1) WR Keatinge, GC Donaldson, E Cordioli, M Martinelli, AE Kunst, JP Mackenbach, S Nayha and I Vuori: Heat related mortality in warm and cold regions of Europe: observational study. BMJ 321, 670–673 (2000)
2) S Nakai: Number of deaths from heat stroke and meteorological condition: a survey of the last 21 years in Japan. Jpn J Biometeor 30, 169–177 (1993)
3) S Nakai: The connection between heatstroke and environmental temperature. Jpn J Biometeor 41, 51–54 (2004)
4) M Iriki: Heat disorder in Yamanashi Prefecture during the summer from 1995 to 1999. Jpn J Biometeor 37, 63–72 (2000)
5) A Hoshi and Y Inaba: Risk factors of incidence of heat disorders using newspaper reports. Jpn J Biometeor 40, 273–283 (2004)
6) K Tamura, M Ono, M Ando and M Murakami: Relationship between atmospheric temperature and heatstroke by the emergency transportation record. Jpn J Biometeor 32, 111–114 (1995)
7) NJ Shanks and G Papworth: Environmental factors and

heatstroke. Occup Med (Lond) 51, 45–49 (2001)
8) M Weinmann: Hot on the inside. Emerg Med Serv 32, 34 (2003)
9) TP Yeo: Heat stroke: a comprehensive review. AACN Clin Issues 15, 280–293 (2004)
10) H Simon: Hyperthermia and heatstroke. Hosp Pract 15, 65–80 (1994)
11) RJ Murphy: Heat illness in the athlete. Am J Sports Med 12, 258–261 (1984)
12) Y Epstein, DS Moran, Y Shapiro, E Sohar and J Shemer: Exertional heat stroke: a case series. Med Sci Sports Exerc 31, 224–228 (1999)
13) T Kawahara: Heat stroke in sports. J Clin Sports Med 14, 735–740 (1997)
14) The Japan Society for Occupational Health: Recommendation of occupational exposure limits (2004–2005). J Occup Health 46, 329–344 (2004)
15) A Hoshi and Y Inaba: Prediction models of the heat disorders. Jpn J Biometeor 41, 31–38 (2004)
16) Y Inoue, M Shibasaki, K Hirata and T Araki: Relationship between skin blood flow and sweating rate, and age related regional differences. Eur J Appl Physiol Occup Physiol 79, 17–23 (1998)
17) Y Inoue: Prevention of heat illness in children and the elderly. Jpn J Biometeor 41, 61–66 (2004)
18) GS Anderson, GS Meneilly and IB Mekjavic: Passive temperature lability in the elderly. Eur J Appl Physiol Occup Physiol 73, 278–286 (1996)
19) S Sagawa, K Shiraki, MK Yousef and K Miki: Sweating and cardiovascular responses of aged men to heat exposure. J Gerontol 43, M1–M8 (1988)
20) WL Kenney and JL Hodgson: Heat tolerance, thermoregulation and ageing. Sports Med 4, 446–456 (1987)
21) M Ando, S Yamamoto and S Asanuma: Global warming and heatstroke. Jpn J Biometeor 41, 45–49 (2004)
22) JB Worfolk: Heat waves: their impact on the health of elders. Geriatr Nurs 21, 70–77 (2000)
23) A Bouchama and EB De Vol: Acid-base alterations in heatstroke. Intensive Care Med 27, 680–685 (2001)
24) A Takamata: Prevention of heat stroke by ingesting fluid: its physiological mechanisms. Jpn J Biometeor 41, 55–59 (2004)
25) T Maeda: Perspectives on environmental adaptability and physiological polymorphism in thermoregulation. J Physiol Anthropol Appl Human Sci 24, 237–240 (2005)
26) WH Martin 3rd, T Ogawa, WM Kohrt, MT Malley, E Korte, PS Kieffer and KB Schechtman: Effects of aging, gender, and physical training on peripheral vascular function. Circulation 84, 654–664 (1991)
27) CW Ho, JL Beard, PA Farrell, CT Minson and WL Kenney: Age, fitness, and regional blood flow during exercise in the heat. J Appl Physiol 82, 1126–1135 (1997)
28) T Maeda, A Sugawara, T Fukushima, S Higuchi and K Ishibashi: Effects of lifestyle, body composition, and physical fitness on cold tolerance in humans. J Physiol Anthropol Appl Human Sci 24, 439–443 (2005)
29) H Grogan and PM Hopkins: Heat stroke: implications for critical care and anaesthesia. Br J Anaesth 88, 700–707 (2002)
30) Y Heled, M Rav-Acha, Y Shani, Y Epstein and DS Moran: The “golden hour” for heatstroke treatment. Mil Med 169, 184–186 (2004)