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Heat Disorder in Yamanashi Prefecture during the Summer from 1995 to 2004

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Abstract: The incidence of heat disorders in July and August during 10 yr (1995–2004) reported for the population of Yamanashi prefecture was analyzed, with special consideration of an aging society, in relation to levels and patterns of phases with high daily maximal temperatures. There was an increasing tendency for years with hot summers in comparison to preceding decades. Two climatic characteristics associated with increased incidence of heat disorders have become apparent: first, sustained phases of atmospheric temperatures exceeding ≈32°C, second, rapid onset of phases with high maximal temperature after preceding phases of relatively cool weather. The influence of age expressed itself in a peak of heat disorder incidences among older children and adolescents and in an elevated plateau at ages higher than ≈60 yr. Up to that age, exertional heat disorders prevailed. At higher ages classical, non-exertional heat disorders constituted an increasing fraction. Lethal outcomes among patients suffering from heat disorder was low. Patients older than 70 yr clearly prevailed among the lethal cases. The frequent occurrence of heat disorders among persons of old age puts emphasis on the importance of maintaining social activity to improve well-being in general and physiological resistance against heat in particular, including adequate fluid supply. Because physiological heat defense is limited in an aging population, adequate air conditioning will gain increasing importance in view of the observed tendency for the increasing occurrence of phases with excessively high atmospheric summer temperatures.

Key words: Heat disorder, Local climate, Yamanashi Prefecture, Geriatrics, Preventive measures

Introduction

Temperature recordings during the last century have revealed a distinct trend towards global warming[7]. It is assumed to be the consequence, at least in part, of the “greenhouse effect” caused by rising atmospheric CO_2 concentration[29] and possibly other gaseous air pollutants. Studies of the long-term climatic trend indicate an increase of global temperature proceeding into the future century or even longer[16]. Occurrence of a multitude of extreme weather conditions is anticipated as the consequence of global warming. With special respect to atmospheric temperature, regional differences are assumed to become more pronounced, making predictions difficult. According to different climatic models, average atmospheric temperature is proposed to rise by 2–5°C in the course of the 21th century[13].

Heat stress and heat disorders have been a topic in environmental physiology for a long time. Attention was early focused upon especially two causative factors, first, hot ambient conditions and, second, physical exercise. Both may reinforce each other as causes of failing autonomic defense against overheating, i.e., occurrence of exertional heat stroke[14, 17, 19]. Especially with respect to industrial working conditions, there have been efforts made over decades to develop a general comfort equation and, respectively an universal heat stress index[2, 4]. These parameters take into account operative temperature as the

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given thermal condition and relative humidity and air velocity as variables which may be manipulated to improve heat loss from the body by convection and sweat evaporation. In additionl, from a practical point of view methods were developed to screen laborers for their heat defense capabilities and to set up training regimes for work in hot an humid conditions[20, 30]. With proper consideration of adequate fluid and electrolyte supply, these approaches have been successful in keeping heat disorders at a minimum even in extreme working condition.

Age as a limiting factor in coping with heat stress and, consequently, the necessity to deal with elderly heat disorder victims was first recognized as a consequence of facilitated world-wide traveling by air. The necessity to deal with large numbers of heat disorder victims became most apparent when large numbers of persons not acclimated to heat and being untrained or even physically compromised were transferred in a short time to places with hot desert climate. Pilgrimages to Makkah (Saudi-Arabia) represented a striking example during the years around 1980. Then, heat disorder as a mass phenomenon stimulated large-scale investigations on its pathophysiology and on medical strategies how to deal with high rates of heat disorder occurrence[14].

As reviewed recently, the impression that “heat waves” seem to increase in frequency in otherwise temperate climatic zones has caused concerns because of the resulting large-scale heat disorders in populations not accustomed to such temperature extremes[19]. Improvement of intensive care management and increasing awareness of their occurrence during heat waves in normally temperate climatic zones are considered to have considerably improved the prognosis of heat disorders[15]. For human health, a major medical problem arises from the fact that the consequences of global warming meet an “aging society”. As will be discussed in detail below, the ability to regulate against overheating decreases with increasing age, due to limitations of circulatory performance and sweating capacity and may be compromised further by chronic diseases which become more frequent with advancing age. As the consequence, global warming has become an issue of increasing importance in gerontology, inasmuch as treatment or prevention of heat stress and heat disorders in aged persons at hot ambient conditions is concerned.

This study investigates the annual incidence of heat disorders in relation to atmospheric temperature during the period from July to August for ten years—from 1995 to 2004. The accumulated data served as the basis for predicting the incidence of heat disorders due to the rise of atmospheric temperature. As the main aspect of this study, special attention was focused on heat disorder occurrence and outcome in relation to the age of the patients.

In the past, studies on heat stress and heat disorders were carried out mainly from the viewpoint of industrial hygiene in order to define the safety conditions to be observed for laborers working in hot environments. The investigations concerning improved working capacity in the heat were carried out mainly in young, healthy persons. Apart from measures to prevent heat illness in general, such as heat stroke or heat exhaustion, precautions to avoid special disturbances, such a heat cramps, are playing important roles in improving the labor conditions in the heat. Not least, the individual state of physical training and acclimation to the environmental conditions has turned out to be of great importance. The fact that physiological performance is relevant in coping with heat stress also requires its consideration in aged persons when dealing with preventive measures against heat stress and heat disorders.

For this reason, the second aspect considered in the present study is the physiological ability of the aged to cope with heat stress. In general, participation in social activities, which is positively correlated with physiological and psychological functions[5] has been confirmed to be of great importance for the well-being of the aged in the society[6]. To estimate the relevance of physical well-being with special respect to resistance against heat disorders, knowledge is required about the age-dependent characteristics of regulation against over-heating and how these functions can be maintained or improved. This knowledge provides the basis for preventive measures against heat disorders at each age and helps to predict the danger of heat disorder for an aged person as the function of the general environmental and the individual physiological conditions.

Methods

In Yamanashi Prefecture the incidence of heat disorders during July and August was followed up for 10 yr, from 1995 to 2004. The population of Yamanashi prefecture located adjacent to Tokyo amounts to about 900,000. Figure 1 presents the demographic state of the population determined for the year 2004. It may be assumed that there was not much change during the decade investigated in this study. Therefore, this diagram presents adequate information to judge on the relative frequencies of heat disorder incidences when their relation to age will be discussed.

The cases of heat disorders due to hot environment evaluated in the study included heat syncope, heat exhaustion, heat cramp and heat stroke and were taken from two data sources. The first data base were patients transported by

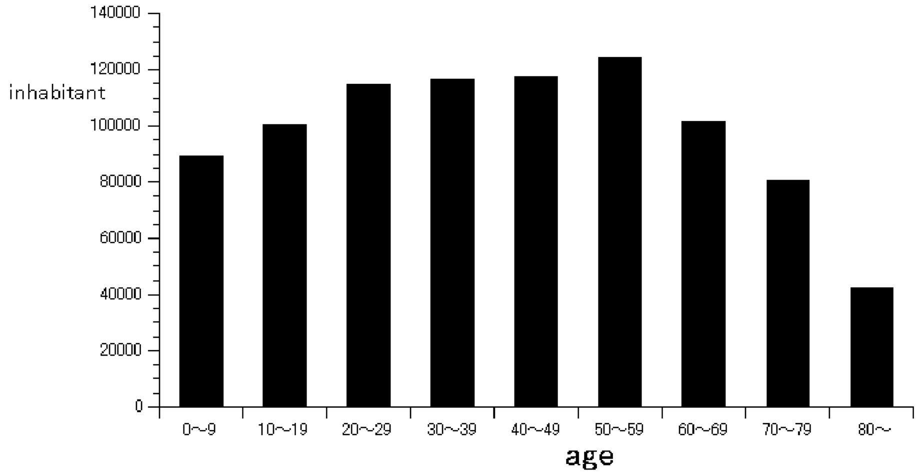

Fig. 1. Population of Yamanashi prefecture in 2004 classified according to decades of age.
Number of inhabitants (ordinate) within the decades of age (abscissa) are presented for each age class by black columns with exact number indicated above.

ambulance, the second database was obtained by questionnaires sent to about 450 members of the Japanese Medical Association in Yamanashi. The number of cases during 1995–2004 obtained by ambulance information and by answers to the questionnaires are summarized in Table 1. Cases reported by ambulance were 484, those reported by the questionnaires were 106, and 11 cases were reported by both, resulting in altogether 579 cases of heat disorder. Table 2, presents the average maximal and minimal daily temperatures during July and August of the years 1995 to 2004 which were measured in the KOFU meteorological observatory located in the center of Yamanashi Prefecture. The temperature data are listed together with the number of heat disorder cases during the respective two-months periods.

Table 1.

	No of cases reported by questionnaires	No of cases transported by ambulance	Common to both data	Total No of cases
1995	27	34	5	56
1996	3	25	0	28
1997	12	29	1	40
1998	12	37	3	46
1999	8	27	0	35
2000	10	37	0	47
2001	13	69	1	81
2002	11	59	0	70
2003	3	52	1	54
2004	7	115	0	122
Total	106	484	11	579

Results and Discussions

The change of incidence of heat disorders during 10 years, from 1995 to 2004

Figure 2 presents the numbers of heat disorder cases on a given day and maximal and minimal daily temperatures during July and August for each year from 1995 to 2004. Visual inspection indicates that the incidence of heat disorders is associated more closely with maximal daily temperature, but the daily temperature minimum has been included in the diagrams as a reference. Variable patterns of distribution and daily numbers of heat disorder cases were found during the 10 yr of observation.

In 1995, it became hot suddenly at the end of July and the heat continued till the end of August. The incidence of heat disorders increased significantly, when the atmospheric temperature rose suddenly to levels around 38°C. Subsequently the incidence decreased gradually day by day, although high levels of environmental temperature were maintained. This particular pattern was not found during the subsequent years.

During the following 5 yr (1996–2000), maximal atmospheric temperature levels of similar degrees as in 1995 occurred only on a few days and were not maintained. The incidence of heat disorders was more irregularly distributed over the period of observation with greater occurrence during July in some years and during August in others. There was no fixed pattern of heat disorder incidence but the distribution of cases suggests for these years an increase in occurrence if there is a sudden rise in maximal daily temperature.

Among the subsequent 4 yr, 2003 was an exception,

Table 2.

AD	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Nr of cases	56	28	40	46	35	47	81	70	54	122
July										
Maximal daily temperature°C	30.3	31.2	30.9	31.3	30.9	32.2	34.6	32.6	27	34.6
Minimal daily temperature°C	22.5	22.2	21.5	22.0	22.1	22.0	23.3	23.3	20.2	22.8
August										
Maximal daily temperature°C	35.7	31.7	33.0	32.6	31.9	33.3	32.3	33.3	31.2	31.8
Minimal daily temperature°C	24.3	22.7	23.0	23.5	23.6	31.7	22.8	22.9	22.3	22.2

because the summer was quite cool during July and parts of August, However, there were two spells of short lasting atmospheric temperature peaks in early and late August. These periods were associated with a relatively high incidence of heat disorders. The remaining years were particularly hot. In the years 2001 and 2004 the incidence of heat disorders was clearly associated with the intense temperature peaks which occurred during July. In 2002 a rather high temperature plateau existed from the end of July to the middle of August and was associated with a distinct increase in the numbers of heat disorder cases.

Ambient temperature and incidence of heat disorders

Although the distribution patterns of heat disorder incidence are greatly variable from year to year, two factors relevant as causes for heat disorder seem to emerge from the diagrams of Fig. 2. First, the incidence of heat disorders increases distinctly, when atmospheric temperature increases rapidly after a period of relatively cool temperature, as it is seen most distinctly in 1995. Second, during prolonged periods of very high atmospheric temperatures, there is a tendency for the incidence of heat disorders to increase with the level of maximal atmospheric temperature, as it is suggested by the observations made in 2004.

In Fig. 3, the number of heat disorder cases listed in Table 2 together with the daily minimum and maximum temperatures, are graphically presented for each year together with average daily maximal temperature during July and August. Although—with the exception of 2003—the average daily maximal temperatures only deviate from each other by less than 3°C, there is a clear tendency that the 4 highest levels of heat disorder incidence (1995, 2001, 2002, 2004) are associated with the 4 highest average maximal temperatures. Less clear is the relationship between incidence of heat disorders and the two lowest average maximal daily temperatures during the observation period (1996 and 2003). In 1996, the incidence of heat disorders was lowest. In 2003 as the year of the lowest average daily maximal temperature, the incidence of heat disorders was nearly as high as in 1995, although lower than during the preceding and following years. The corresponding diagram in Fig. 2 suggests that this observation seems to reflect the influence of sudden heat peaks after relatively cool preceding atmospheric temperatures.

The highest incidence of heat disorder cases was observed in 2004. As shown by the corresponding diagram of Fig. 2, there was a combination of high average maximal atmospheric temperature with superimposed even higher transient temperature peaks occurring in July and extending into August. Not shown here—but incorporated into Fig. 6 (see below)—is the information that the incidence of heat disorders was also relatively high in June (16 cases) and September (12 cases), i.e., the months of the summer season in which usually few cases of heat disorder are observed.

The relationship between average daily maximal atmospheric temperature during July and August and the incidence of heat disorders is more distinctly revealed by Fig. 4 in which the two parameters are plotted against each other for the entire period of 10 years of observation. When average daily maximal temperatures of 31–32°C are exceeded, the incidence of heat disorders increases steeply with further rising temperature. The data suggest that above an atmospheric temperature of ≈32°C even small further increases of average daily maximal temperature become critical.

On the other hand, the year 2003 seems to be an exception. Figure 4 shows that average daily maximal temperature is below 30°C in this unusually cool summer, but the incidence of heat disorders is as high as at average ambient daily temperatures of about 33°C. As emphasized before, there were several bouts of short periods of high atmospheric temperatures in the beginning and end of August, during which the incidence of heat disorders increased steeply.

As a summary, two factors seem to emerge by which the incidence of heat disorders is influenced during the hottest summer months. First, as illustrated clearly by Fig. 4, the

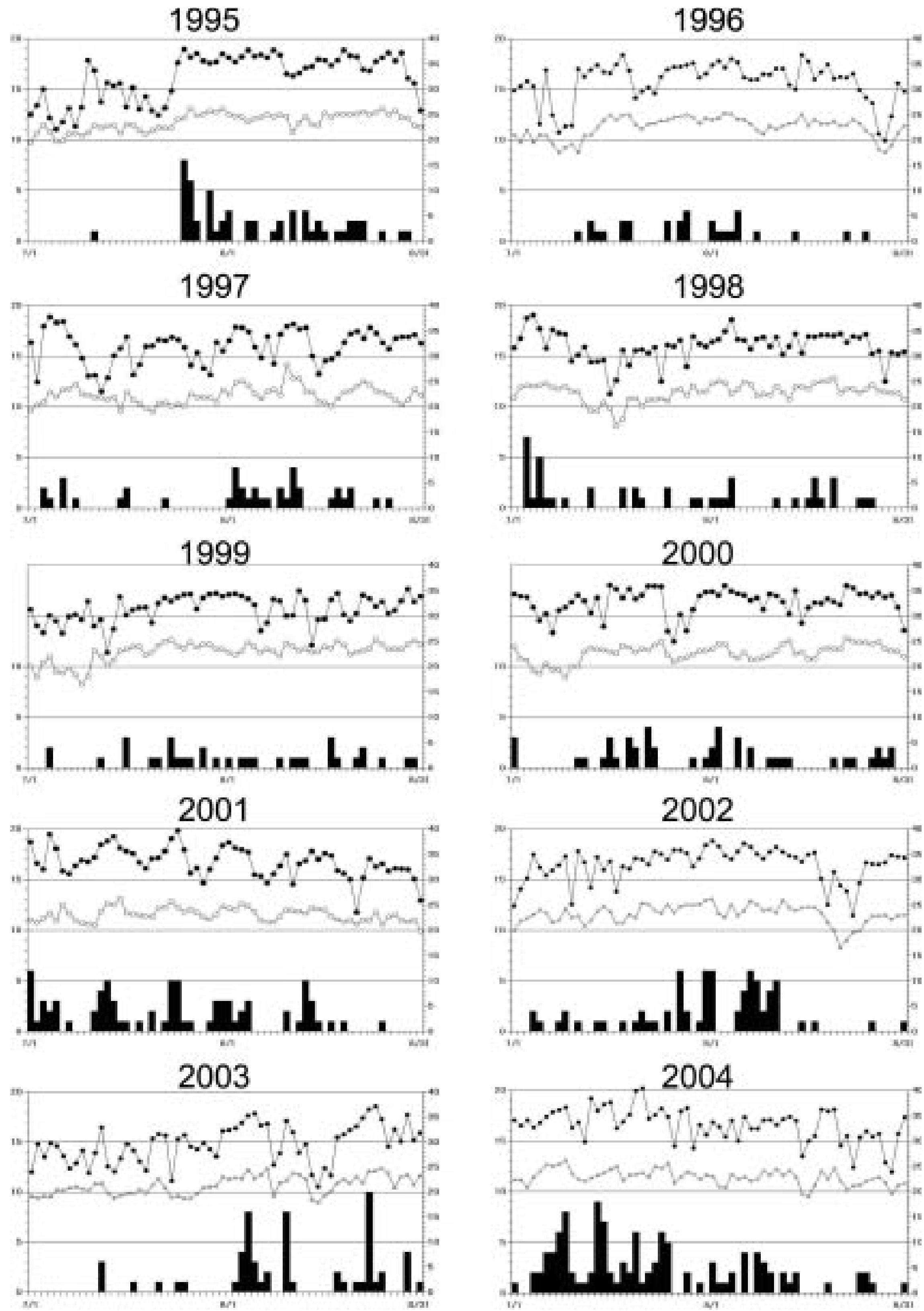

Fig. 2. Ten diagrams showing maximal and minimal daily air temperatures (upper and lower line and scatter plots and right hand ordinate) and daily numbers of heat disorder cases(black columns and left hand ordinate) reported in Yamanashi prefecture on each day during July and August for the years 1995 to 2004.

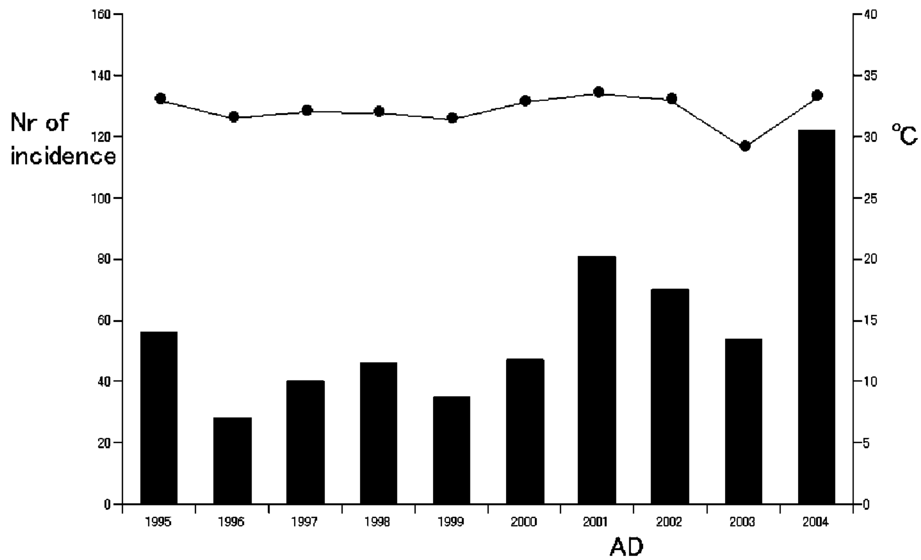

Fig. 3. Black columns and left hand ordinate indicate the number of heat disorder cases reported in Yamanashi prefecture from 1995 to 2004 (abscissa).
Line and scatter plot and right hand ordinate indicate daily maximal temperatures averaged for the months July and August.

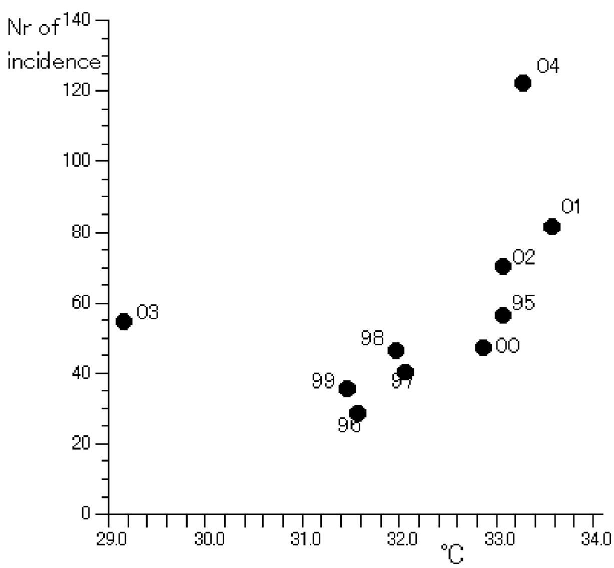

Fig. 4. Heat disorder cases during July and August (ordinate) reported in Yamanashi prefecture for the years 1995 to 2004 presented as scatter plot in relation to the averaged daily maximal temperatures during July and August of the respective years (abscissa).

incidence increases when average daily maximal temperature exceeds 33°C. Above this level, even slight further increases cause a steep increase in the incidence of heat disorders. Second, as shown most clearly in the annual recordings of Fig. 2, the rapid onset of periods of high atmospheric temperature, when preceded by a relatively cool period, clearly increases the incidence of heat disorders. Such a condition would explain why the summer of 2003 appears as an exception in Fig. 4.

On the other hand, if a period of hot atmospheric temperature starts, there is a tendency for the initially high incidence of heat disorders to decrease, although temperature remains high, as shown by the diagram for 1995 in Fig. 2. But again there is an exception from this tendency in 2002. In that year a high temperature level from the end of July to the middle of August is associated with a fluctuating but generally high incidence of heat disorders. Only speculative explanations can be offered for these variations. It may be hypothesized that after the onset of a long-lasting heat wave, the individuals tend to adjust behaviorally by avoiding heat exposure and by reducing their physical activity. Consequently, the incidence of heat disorders should decrease although atmospheric temperature remains high. On the other hand, the efficiency of these behavioral adjustments may depend on other climatic factors. For instance, if a persistently high atmospheric temperature is associated with high air humidity, reducing physical activity may become less effective because sufficient evaporation of heat will be the main problem causing a persisting high incidence of heat disorders.

Age effects on heat disorders

A. Relationship between incidence of heat disorders and age in males and females

Figure 5 indicates the incidence of heat disorders in each

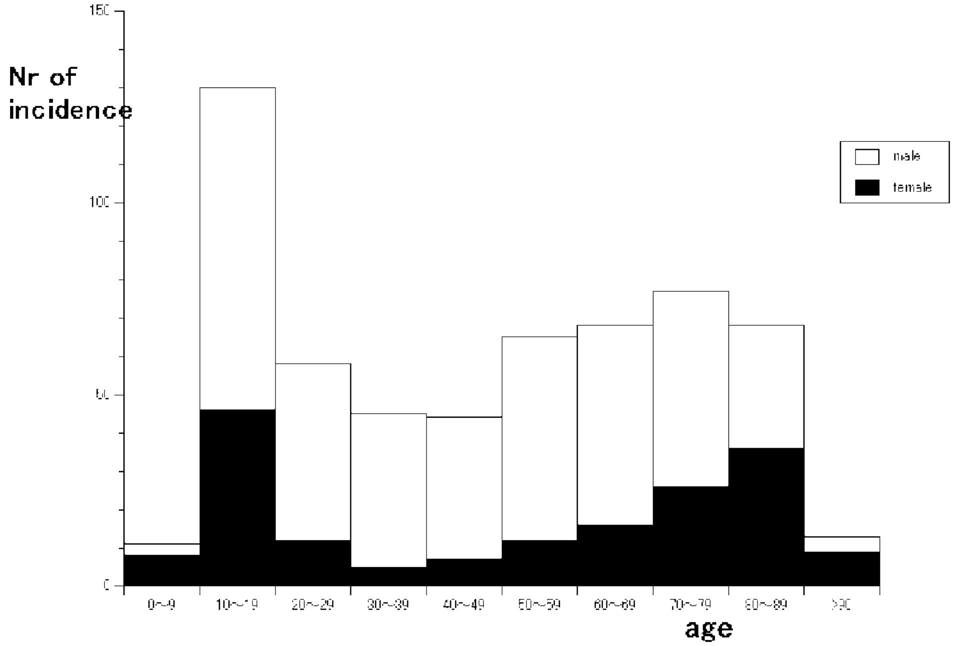

Fig. 5. Incidence of heat disorders reported in Yamanashi prefecture during July and August (ordinate) classified according to age for the 10-year period from 1995 to 2005.
Incidence related to gender is shown for females (black columns) and males (white columns).

decade of life for the sample of cases collected during 10 yr in Yamanashi prefecture. The most significant characteristics of this figure are the high level of incidence at young and old age. There is a distinct peak among older children and young adolescents (young group), and a high level of incidences in the 5th to 8th decade of life (old group). The causes are probably different. Individuals of the young group are very active even in hot weather, but their fluid reserves for evaporative heat dissipation may become exhausted earlier than in adults. On the other hand, the physiological capacity of aged persons to dissipate heat is generally reduced. Most resistant against heat disorders are adults of young to middle ages which represent the physically active part of the population with the highest average fitness.

Figure 5 further shows that generally males prevail over females among persons suffering from heat disorder. This difference is particularly pronounced in the age groups from young adults up to the age of 70. One explanation may be that the fraction of males doing intense physical work, even in the heat, is larger than that of the females in these age groups. At older ages, when the fraction of physically working males declines, the fractions of males and females suffering from heat disorder become progressively similar.

Figure 6 presents with the left hand ordinate and the columns the relation between age and incidence of heat disorders specifically for the year 2004. Age distribution closely resembles that of Fig. 5. Based on the demographic information contained in Figure 1, the filled circles and the right hand ordinate presents the number of cases per 10,000 inhabitants. Since the demographic state probably did not change much during the period from 1995 to 2004, this finding can be generalized for the data obtained for the entire decade. The curve confirms that the incidence of heat disorders has a distinct peak among older children and young adolescents. It then declines and reaches a second smaller peak during the 6th decade when people are still active but no longer as fit as younger adults. The low incidence in the 7th decade reflects the early retirement phase with reduced activity, but subsequently the incidence of heat disorders rises steeply with advancing age.

B. The role of outdoor activity

Figure 7 illustrates the relationship between exertional tand classical (non-exertional) heat disorder as a function of age. The diagram clearly shows that physical activity in the heat is an important, but age-related, causative factor in the occurrence of heat disorders. Up to an age of about 70 yr, the fraction of persons suffering from heat disorders, while being indoors, is much smaller than that occurring in persons being active outdoors. For this age range exertional

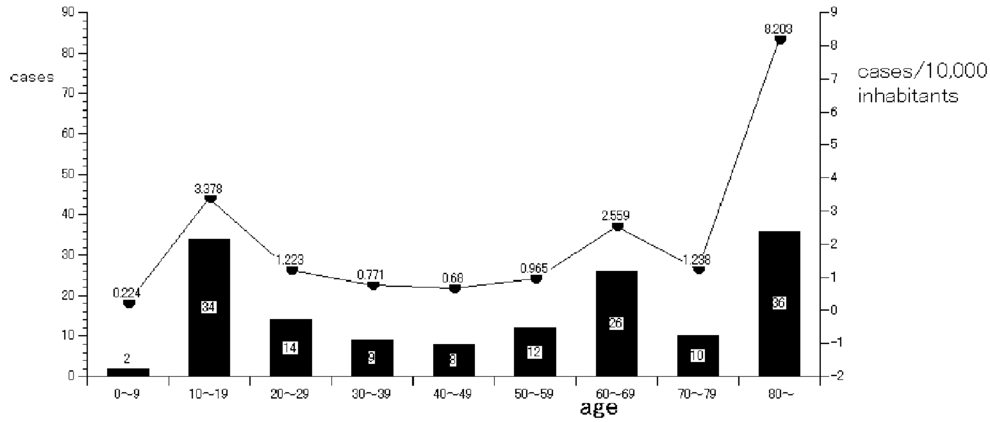

Fig. 6. Incidence of heat disorders (females and males) reported in Yamanashi prefecture during July to September 2004 (150 cases) classified according to age (left hand ordinate and black columns) and incidence of heat disorder cases in each age group per 10,000 inhabitants of each age group (right hand ordinate and line and scatter plot) with numerical presentation of the corresponding fractions.

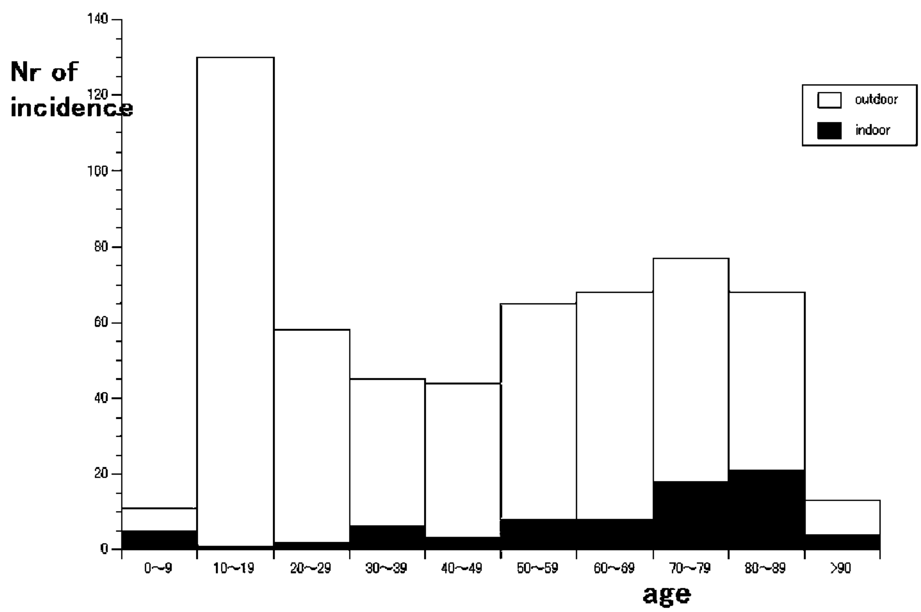

Fig. 7. Incidence of heat disorders (females and males) reported in Yamanashi prefecture during July and August (ordinate) classified according to age for the 10-yr period from 1995 to 2005. Incidence is further classified according to whether heat disorder occurred in indoor conditions (black columns) or outdoor conditions (white columns).

heat disorders are obviously prevalent: The following characteristics were indicated. Among older children and youngsters most cases occurred during exercise such as work, gymnasium (sports) and outdoor playing in the heat. This means high endogenous heat generation and a high loss of fluid, enhancing the susceptibility to heat disorders. Insolation and uptake of radiant ambient heat may add to the risk of heat disorders when exercising outdoors.

For the population beyond the active age Fig. 7 shows that classical, non-exertional heat disorders constitute an increasing fraction. As possible explanations, cardiovascular dysfunction and problems of adequate hydration become more frequent with advancing age. Therefore, in the old group heat disorders may occur already during moderate routine outdoor activities such as weeding, gardening, light farmwork, walking and shopping. On the other hand, the risk for heat disorders, while being indoors, also increases in old people, if room temperature control does not exist or if it breaks down on hot days, because of their reduced physiological capacity for heat defense. In aged persons the risk of heat disorders is further increase increased, if they are suffering from chronic diseases or are dependent on certain types of medication.

In summary, the two periods of high incidence of heat disorders in relation to age, namely, a peak among the juvenile fraction of the population (young group) and an elevated plateau for the fifth to eighth decade of life (old group), reflect different proportions of exertional and classical cases of heat disorder. The former cause prevails in the young group and among the adults in their most active period of life. At ages beyond 50 yr, when the second higher plateau of heat disorder incidence is developing, exertional heat disorder is first prevailing, but with advancing age the fraction of classical, non-exertional heat disorders becomes progressively substantial. The aged persons do not differ from middle-aged persons with respect to the atmospheric temperature at which heat disorders are occurring. Consequently, keeping indoor temperature relatively low for very old people would be helpful as a preventive measure to avoid non-exertional heat disorders.

Deaths related to heat disorders and dependence on age

Table 3 lists the 8 lethal cases associated with the ambulance reports and questionnaires on heat disorders during the period of 1995 to 2004. Considering the 579 cases of heat disorders recorded during July and August of 10 yr in Yamanashi prefecture, this is a very low fraction. There is one exceptional case of a 15 yr old boy who was forced to exercise in hot, fine weather in a state of unrecognized sickness. A 53 yr old male suffered from heat disorder during outdoor exercise at a particularly high environmental temperature of 37.5°C in which he became strongly hyperthermic with a core temperature of 41°C. The remaining 6 lethal cases occurred in the age range between 72 and 91 yr, 3 while staying indoors and 3 while doing age-related, i.e., presumably moderate, outdoor work. One 75-yr old male listed in Table 3 was suffering from MSRA pneumonia which has no relationship to heat disorder. In this case the relatively low environmental temperature of 32.6°C and the only moderately elevated core temperature of 38.2°C suggest that heat disorder as such was not the cause of death. Among the remaining 5 patients, environmental temperatures were between 33.5°C and 38.1°C which suggest that heat disorder contributed to the lethal outcome. This assumption is confirmed for those two cases in which core temperatures were recorded (40°C and 42°C). For the remaining 3 cases core temperature recordings are not available. Three patients had a history of preceding events indicative of vascular disease.

In summary, when relating the number of reported heat disorders to the cases with lethal outcome, treatment must be considered to have been highly effective. Among the 7 deaths which are attributable to heat disorder as the primary cause, 5 occurred in persons at an age of 72 or higher. Thus, advanced age is a substantial risk factor in the incidence of heat disorders.

The physiological background of reduced heat defense in aged persons

The prevalence of aged persons among those heat disorder cases with lethal outcome points to age-related limitations of heat defense, irrespective of the additional risks resulting from multi-morbidity which is frequent among aged persons. All endogenous functions relevant for effective temperature regulation undergo age-related changes. Most of them are disadvantageous for heat defense.

A. Age-related changes in thermoregulatory performance

1. *Skin blood flow*, by which endogenous heat is transported from the body core to the periphery, generally decreases with advancing age. Skin blood flow is, however, not reduced to a degree that it might compromise heat transfer from the body core to the skin in an old person being at rest or doing moderate exercise, but only if exercise intensity is inadequately high. Then, heat-induced increase in skin blood flow may be limited at the expense of enhanced muscle blood flow. The causes for reduced skin vessel vasodilatation in the heat are multifactorial. Vasodilator response of the skin with rising esophageal temperature is less in older than younger persons[12]. In general, reflex sensitivity of skin blood vessels is less in older than younger persons, as tested by cold exposure[11]. Age-dependent decreases in skin blood flow are more distinct on the trunk[10], i.e., removal of heat from the trunk skin by sweating is less effective.

2. *Thermal sweating* becomes reduced with advancing age. This does not apply to the sweating threshold but rather to the rate of sweating. This reduction is, however, moderate and probably will not compromise heat defense in a resting or moderately active person, which is otherwise healthy and normally hydrated. In some skin areas (trunk) sweating becomes reduced with advancing age[9]. Passive body heating (putting legs in water at 42°C in a warm environment (28°C) was found to elevate esophageal temperatures of old people to a level about 0.3°C higher than of younger people.

Table 3.

	Age	Gender	Condition	Environmental temp.	Core temp.	Symptoms	History
1995	85	male	outdoor work in fine weather	33.5°C	42°C	confusion	hypertension 10 yr
	78	female	indoor no air conditioner	36.4°C	40°C	unconsciousness	cardiac infarct
	15	male	outdoor exercise in fine weather	35.5°C	above 40°C	fusion, convulsion, vomitt	empyema
1997	75	male	indoor	32.3°C	38.2°C	fatigue, sweating, coma, dehydration, multiorgan failure	none
1998	53	male	outdoor exercise in fine weather	37.5°C	41°C	coma	cardiac infarct
	86	female	indoor	38.1°C	no record	unconsciousness	none
	72	male	work in a field	35.4°C	no record	unconsciousness	cerebral infarct
2002	91	female	weeding in garden	36.4°C	no record	unconsciousness	none

Reduced sweating at the back is observed as a possible explanation (Inoue, 1996)[9].

3. *Maintenance of body fluid balance* is age-dependent. In general, water turnover does not change much with age. There is some gender influence and some difference in urinary output which is of minor importance[24]. However, total body water is less in old persons than in young persons. If related to lean body mass, the differences become small. The absolutely lower amount of total body water in old persons results mainly from their reduced muscle mass[3, 18].

4. *Control of drinking* also becomes less stringent with advancing age. Reduction of the osmotic drive for drinking is somewhat controversially discussed. Reduced osmotic thirst is reported for healthy elderly men[22]. In a later study, a reduction of the osmotic drive for drinking could not be confirmed[25]. For thirst perception there appears to be some reduction in sensitivity in old as compared to young subjects in conditions when dehydration is induced by exercise in the heat. A change in sensitivity of central volume receptors may be involved[26].

5. *The excretory function of the kidneys* becomes physiologically reduced by an age-related decrease of primary filtration capacity, probably due to the loss of nephrons, and non-symptomatic pathophysiological limitations of excretory kidney functions are not infrequent in aged persons[21]. Further, reduced tubular functions expose the elderly to increased risk of dehydration[23]. Moreover, this is frequently combined with behaviorally motivated restriction of drinking[28]. This means that in critical conditions the compensatory capacity of the kidney to save water for sweating may be severely limited in old as compared to young persons.

6. *Endogenous heat generation* represented by the basal metabolic rate declines from young adulthood to old age by some 20%. This means some reduction of strain in warm conditions at rest. However, the higher the atmospheric temperature, the less important will be this advantage, and it is lost when environmental temperature approaches the level of core temperature.

B. Training and acclimation

As a general observation, old persons with a higher maximum oxygen uptake have better skin blood flow than old persons with lower maximum oxygen uptake[8]. Training in the heat (exercise at 40% maximum oxygen uptake at 45°C for 1 1/2–2 h in a hot environment improves both skin blood flow and local sweat rate in young and old subjects. Differences become quite small between young and old for sweat rate. Skin blood flow is equally well trained in young and old subjects, and the mean body temperature threshold for the increase in skin blood flow was shown to be lower in trained old subjects than in the untrained young subjects[1]. On the other hand, thermal skin vasodilatation in trained old persons starts from a lower basic flow level than in young persons[27] and is, therefore, not as effective as in younger persons.

As a summary, healthy old people are not markedly reduced, on principle, in their capacity to dissipate heat in comparison to younger people. Especially leading an active life and, thus, being trained to some extent improves their capacity to tolerate heat stress. However, their ability to maintain water balance may be reduced, especially, if a non-symptomatic more severe limitation of kidney function exists, as it is frequently the case in the aged. Therefore, in critical conditions liminal fluid homeostasis may predispose for non-exertional heat disorders. As an additional risk of reduced renal excretory functions, complications due to inadequate drug clearance must be taken into consideration for patients under chronical pharmacological treatment.

General Discussion

This study considers the incidence of heat disorders in a defined population living in a warm-temperate climate during a 10-yr period in which global warming is presumed to have proceeded. A recent overview presented epidemiological data on heat stroke mortality in the entire Japanese population for an extended period of 30 yr until 1997. It shows a maximum in 1994 reflecting the occurrence of a first severe heat wave, and the year with the second highest heat stroke mortality was 1995[19]. The present study overlaps only little with this period of observation and concentrates on the incidence of heat disorders as a function of atmospheric temperature. For this purpose, it presents more closely the relationship between the annual course of maximum and minimum temperatures during the hottest months of the year and the incidence of heat disorders. It is clear from the comparison of the different years that the distribution of phases with high atmospheric temperatures varied considerably during the 10 yr of observation. Compared with the long-year survey ending 1997, in the 10-yr period covered by the present study there were 3 yr (1995, 2002, 2004) with periods of intense heat which may be considered as heat waves, at least on the regional basis of Yamanashi prefecture. Interestingly, the high incidence of heat disorder cases in 1995 corresponds to the fact that 1995 was the year with the second-highest high heat stroke mortality rate for Japan as a whole in the period from 1968–1997. This congruence suggests that the extended survey over the three decades and the survey over the subsequent decade reported in the present study have both dealt with the same phenomenon, although carried out on different populations and by looking at different medical aspects of the impact of global warming on human health. The comparison of the preceding three decades with the following decade analyzed in the present study further suggests that the occurrence of periods with very high summer temperatures is, indeed, increasing as the consequence of global warming.

The present study offers some additional information by emphasizing not only the role of a steady high temperature over a prolonged period of time, but also by drawing attention to the impact of a sudden onset of high atmospheric temperature. As suggested above, during sustained periods of high atmospheric temperature behavioral adjustments may be important in reducing the danger of heat disorders.

In the present study information on the lethal outcome of heat disorders was obtained for 8 cases among which 6 cases could be attributed with certainty as due to heat disorder. This is fortunately a low number in comparison to the incidence of heat disorders. Among these few lethal cases, persons of old age (>70 yr) clearly prevailed. The low mortality rate suggests that the more frequent occurrence of summer periods with very high atmospheric temperatures has aroused increasing awareness to consider the diagnosis “heat disorder” if a patient complains about feeling ill on hot days. This explanation would be in line with a similar suggestion derived from a completely different set of temperature parameters[15].

The survey on heat stroke mortality over the three decades from 1968 to 1997 in Japan[19] contains no information about the frequency of heat disorder cases. Therefore, it is not possible to make conclusions on whether or not there were changes in mortality from heat disorders between this period of time and the decade from 1995 to 2004 covered by the present study.

With special respect to strategies reducing the incidence of heat disorders especially in an aging population, the importance of social activity has to be emphasized. From the viewpoint of physiology, two aspects seem particularly important. First, it is highly advantageous, if social activity involves physical activity, because it would support maintenance or even improvement of physical fitness which is positively correlated with the ability to meet external heat by effective autonomic heat dissipation. Second, engagement in social activities facilitates the transmission and mutual exchange of useful information among aged people. With special respect to protection from heat disorders, both the elderly themselves, as well as their younger relatives should be encouraged to communicate the message that not only physical activity but especially sufficient drinking is important for aged individuals. Observing this message would help to reduce the incidence of heat disorders on hot days, apart from the fact that maintenance of fluid balance is generally desirable for well-being.

While improvement of the individual capability to cope with heat stress by increasing fitness and by maintaining fluid balance is useful at any age, it is clear that advancing age limits these positive effects. The expectation that summer periods with excessively high atmospheric temperatures will occur with increasing frequency in the future, consequently, cannot be met alone by individual physiological preventive measures. Therefore, protection, especially of the aged, by adequate air conditioning will become increasingly important.

Finally, it has to be emphasized that the epidemiological data presented in this study do not permit conclusions about the incidence of heat disorders in industrial working conditions characterized by extremely hot temperatures and high humidity, as they exist more or less permanently in parts of the steel and mining industries. As emphasized already in the introduction, measures to facilitate heat dissipation in order to reduce exertional heat stress and proper supply with fluid and minerals to account for water and electrolyte loss by sweating are well established today in industrialized countries like Japan. In addition, surveillance of laborers with respect to their fitness or to occurrence of a diseased state have proceeded to a degree that heat disorders are kept at a minimum level. On the other hand, the knowledge attained in the field of work physiology has been most useful to deal with those cases in which working conditions are less well controlled, as in open air exercise. It may be presumed that the occurrence of exertional heat disorders among the cases collected in the present study, especially in the group of aged persons, resulted from work that carried out incidentally and voluntarily without taking regard of the physical capabilities of the exercising subject.

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