Guideline for the Prevention of Heat Disorder in Japan

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Abstract

In a hot and humid environment the risk of heat disorders is increased in general, and in particular in conditions of high rates of metabolic heat generation as during labor or endurance sports. Heat disorders include heat collapse, heat cramps, heat exhaustion, and heat stroke. Appropriate water replenishment, reduced physical activity and relief from heat exposure can prevent heat disorders. Once heat disorders have developed, applying first aid measures immediately is required to prevent serious aftereffects or a fatal outcome. To prevent heat disorders during sports activities, the Japan Amateur Sports Association (JASA) has announced a “Guideline for the Prevention of Heat disorder” with “Eight Key Tips for the Prevention of Heat disorders” in 1993. In Japan they are widely used in various fields of daily activities. Heat disorders may occur, however, also in the absence of intense physical activity, with heat exposed infants and the aged being at particularly high risk. The Japanese Society of Biometeorology (JSB) has launched a study group for the “Prevention of Heat disorder” in 2006, outlining guideline criteria in order to compile a new prevention guideline. This paper mainly provides background information of relevance for the two prevention guidelines and about organizations engaged in Japan in the implementation of guidelines for heat disorder prevention.

Key words: Guideline for the Prevention of Heat disorder, heat disorders

1. Introduction

The author has taken part as one of the authors in a project putting into practice the guide book named A Guidebook for the Prevention of Heat Disorder during Sports Activities (Kawahara & Morimoto, 1993) issued by the Japan Sports Association (JSA). The first edition of the guidebook had been issued in 1993, and a total of approximately 150 million copies have been published and distributed up to November 2008. In addition, the author is engaged in compiling the “Guideline of heat disorders during ordinary life activities” in cooperation with Professor Inaba from Juntendo University as the chairman of the Association for the Prevention of Heat Disorder study group of the Meteorological Society of Japan. The booklet mainly introduces to the public two guidelines how to avoid heat disorders and about activities required for prevention, which have been recommended by various study groups.


According to annual reports regarding payments of death benefit announced by the National Agency for the Advancement of Sports and Health, the percentage of fatal heat disorder casualties among students during sports activities is around 2 to 5%. This is a small fraction compared with the approximately 60% diagnosed as cardiovascular sudden death.

However, the fraction of life-threatening cases of heat disorders may be further reduced because they are often due to avoidable incidents or to accidents resulting from “lack of knowledge and overexertion” and, consequently, could be reduced by educational information about how to prevent heat disorder accidents in advance and about measures to be taken adequately as first aid treatment which is of great importance.

For this purpose JSA had launched and organized a three year project with a study group in 1991 in order to spread and familiarize essential knowledge about heat disorder prevention, starting with the project: “Study regarding the prevention of heat disorder accident.” Since then, this specific project study was continued over eleven years until 2001 with an engagement of more than 20 man-days being required (Asayama, 2001).

2.1 Definition of heat disorders

Upon launching the above-mentioned project study, the definition of the term “heat disorders” had to be discussed. It includes heat collapse, heat cramps, heat...
exhaustion, and heat stroke (Kawahara & Morimoto, 1993; Morimoto, 2005). Heat collapse is caused by orthostatic cerebral malperfusion following from inadequate supply of blood volume to the heart due to a deficit in blood volume or its peripheral accumulation in cutaneous venous vessels. Heat cramps are tonic skeletal muscle contractions, following imbalances of blood electrolytes, e.g., lowered plasma Na⁺ when only water but not salt is ingested to replenish blood loss due to sweating. Heat exhaustion is a fatigue syndrome during strenuous exercise or labor resulting from loss of water and salt in amounts causing major reduction of the extra-cellular body fluid compartment. Heat exhaustion can deteriorate towards heat stroke. Heat stroke is the most damaging and potentially life-threatening disorder. This is characterized by a multitude of path physiological disturbance with symptoms indicating impaired brain function, which may irreversible and ultimately fatal due to structural damage in the central nervous system (CNS). This is the result of excessive CNS hyperthermia or insufficient oxygen supply, if brain food is inadequate, from general circulatory insufficiency, from respiratory insufficiency, or from severe disturbance of electrolyte balance.

Regarding the terminology, “heat stroke or heat-stroke” has been proposed as an all-including term by some investigators to characterize heat-related pathophysiological states. However, “heat disorder” as the all-inclusive term seems to be more suited because it takes account of the different degrees of severity outlined above. “Thermal fever” as a state of hyperthermia is a specific pathophysiological condition attributable to the action of pyrogens and cytokines. However, in combination with hot conditions it may aggravate heat disorders. Using the term “heat stroke” should be restricted to the most severe and potentially fatal state of heat disorder. The JSA study group has adopted “heat disorder” as the all-inclusive term when explicating heat disorders. Using the term “heat stroke” should be restricted to the most severe and potentially fatal state of heat disorder. The JSA study group has adopted “heat disorder” as the all-inclusive term when explicating heat disorders. As mentioned later, JSB follows the same terminology, which is also used subsequently.

2.2 Study for preventing accidents caused by heat disorders

The project study was carried out to “establish” guidelines to be observed in order to propose adequate strategies how to supervise and control sports activities under hot environmental conditions. It has taken into account a wide variety of worldwide research concerning measures to be taken for heat disorder prevention and presents a survey of the actual state of knowledge about the relationship between frequency of heat disorder accidents and weather conditions. As an important aspect of completing the study, basic research concerning physiological mechanisms of body temperature adjustment in hot (and humid) environments and pathophysiological mechanisms important for the occurrence of heat disorders have been reviewed.

In cooperation with the Japan High School Baseball Federation observations of high school baseball games, where heat-related fatal accidents rank highest in number, have provided information about environmental temperature, amount of sweat loss, amount of water replenishment, as well as body temperatures to define safety limits for physical activity. These results have been well utilized and referred to in setting guidelines. Emphasis has also been put on teaching how to take preventive measures to avoid heat disorders which have materialized in a number of lectures conducted and summarized as a guidebook entitled Guidelines for the Prevention of Heat Disorders in 1993.

2.3 “Guidelines for the Promotion of Heat Disorder Prevention”

The guidebook consists of “Exercise for the prevention of heat disorders” as shown in Table 1, “Eight key tips for the prevention of heat disorder” as shown in Table 2, and supporting documents. The key tips are based on “Guidelines for preventing heat disorders” as the reference work based on the results of epidemiological findings of environmental temperature conditions, number of cases of heat disorders accidents and frequency of casualties (Nakai, 1993; Nakai et al, 1998; Morimoto & Nakai, 2008).

The index considered to be most informative for the environmental thermal conditions indicating heat disorder probability is Wet-Bulb Globe Temperature (WBGT) because it comprises three important factors: air temperature, air humidity, and radiant heat, among four environment factors which are temperature (1), humidity (2), radiant heat (3), and air velocity (4).

WBGT is worked out in two different calculating formula, depending on the survey places or sites (outdoors or indoors).

Outdoors:

\[
WBGT = 0.7 \times \text{wet-bulb temperature} + 0.2 \times \text{globe temperature} + 0.1 \times \text{dry-bulb temperature}
\]

Indoors:

\[
WBGT = 0.7 \times \text{wet-bulb temperature} + 0.3 \times \text{globe temperature}
\]

Globe temperature is usually not measured in daily life. Therefore as an approximation to the actual WBGT, dry-bulb temperature and wet-bulb temperature are weighed as indicated for indoor conditions.

Thanks to the efforts of JASA for the education of preventing heat disorder, the importance of paying attention to the actual climatic conditions and of taking care of appropriate liquid intake or water replenishment has become known widely and generally accepted by the public.
Table 1  Exercise indices for the prevention of heat disorders.

Based on the “Eight key tips for the prevention of heat disorders,” these indices provide guides to how much exercise can be safely performed in various environments. The Wet Bulb Globe Temperature (WBGT) index is employed, but for the case when the WBGT cannot be measured, wet and dry-bulb temperature guides are provided.

<table>
<thead>
<tr>
<th>WBGT °C</th>
<th>Wet-bulb Temp. ºC</th>
<th>Dry-bulb Temp. ºC</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>31</td>
<td>27</td>
<td>35</td>
<td>Exercise: Prohibited Above the WBGT 31ºC, the actual temperature is higher than the skin temperature, so the body cannot let heat escape, and except for special cases, all exercise should be stopped.</td>
</tr>
<tr>
<td>28</td>
<td>24</td>
<td>31</td>
<td>Severe Warning: Heavy exercise prohibited. Above the WBGT 28ºC, danger of heat disorders is high, so events that require heavy exercise or events where the body temperature will rise, like endurance races should be avoided. When such events are held, rest periods should be provided often and water replenishment conducted aggressively. People who are weak or not used to the heat should stop exercise.</td>
</tr>
<tr>
<td>25</td>
<td>21</td>
<td>28</td>
<td>Warning: Rests should be provided often. Above the WBGT 25ºC, the danger of heat disorders increases, so rest periods should be provided often and water replenishment conducted. Rest periods should be provided every 30 minutes for events requiring heavy exercise.</td>
</tr>
<tr>
<td>21</td>
<td>18</td>
<td>24</td>
<td>Caution: Water should be replenished often. Above the WBGT 25ºC, the danger of heat disorders increases, so rest periods should be provided often and water replenishment conducted. Rest period should be provided every 30 minutes for events requiring heavy exercise.</td>
</tr>
</tbody>
</table>

WBGT (Wet Bulb Globe Temperature): Outdoors: WBGT = 0.7 × wet-bulb temperature + 0.2 × globe temperature + 0.1 × dry-bulb temperature Indoors: WBGT = 0.7 × wet-bulb temperature + 0.3 × globe temperature

The WBGT is desirable for assessments of environmental conditions. Assessments based on wet-bulb temperature can be underestimated when the humidity is high, so the dry-bulb temperature should also be considered.

(I CB2008, Human 1, Symposium)

Table 2  Eight Key Tips for the Prevention of Heat disorder.

1. Knowledge is the key to the prevention of heat disorders
2. Don’t panic, but apply first aid immediately
3. When it is hot, strenuous exercise can cause accidents
4. Heat waves require caution
5. Replenish lost water and salt
6. Body weight loss indicates sweat loss and dehydration
7. Dress lightly and stay cool
8. Poor physical condition can cause accidents


The JSB has been established in 1962, in order to study those aspects of environmental biology which have to be analyzed in order to understand how life and performance of plants, animals and, in particular humans respond to climatic and meteorological challenges and which adaptive processes are available to plant and animal species to cope with long lasting changes of meteorological and climatic parameters. Because of the complexity of interactions that are effective between life functions and the physical and chemical environment, research in Biometeorology encompasses a wide field of disciplines including Geography, Atmospheric Research and Oceanography which, together with Hydrology and Glaciology, serve as important sources of information for short-term and long-term developments in Climatology. Associated with these studies, the introduction of sophisticated technologies for corresponding research is. The results are of indispensable prognostic value to analyze and predict the development of those parameters which ultimately determine regional and local climates with special consideration of Global Warming. Targets in the Biosphere of the environmental impacts identified and predicted by the multitude of environmental research activities are in the focus of Life Sciences which encompass biological and ecological aspects of life including agriculture and Cattle raising as important fields of research. With special respect to human life, Medicine, Environmental Epidemiology, Exercise Physiology, Physical Education are complemented by a multitude of scientific approaches to study Adaptation to the Environment including hyperbaric (deep sea) and real or simulated spacecraft conditions.

With special respect to Heat disorders and Global warming the JBS has started a working group named “Heat disorders prevention survey committee” in 2006, and launched the setting of “Guidelines of preventing heat disorders during daily life activities.” Analysis of age-related mortality has revealed that the frequency of heat disorder incidences increases in the 7th age decade and culminates in the 8th age decade (Fig. 1) (Nakai et al, 1992; Morimoto & Nakai, 2008). This is understandable by the fact that physiological capacities to counteract heat loads imposed on the body decline progressively with advancing age. Infants also show a high score of casualties; they are particularly susceptible to fluid losses and to insolation, i.e., absorption of heat from solar radiation including its ultraviolet component. A peak during the phase of adolescence may be attributable to excess physical activity, especially of those engaged in sports. There is also an enhanced level of casualties among the middle-aged, i.e., among those persons engaged in professional work which may imply heat exposure in factories and mines as well as during outdoor work in the field. Among the aged or seniors, a
Comparably high frequency of heat disorders occurs even during ordinary life activities (Yamanouchi et al., 2004; Iriki & Simon, 2006). These observations have found their expression in the publication of additional information by the JSB, as *Guidelines to Prevent Heat Disorders in Daily life*, from a draft by Dr. Hoshi, one of the committee members of JSB. It is introduced into this survey as shown in Table 3 on behalf of JSB (2008) as a guidance especially for the aged.

### 3.1 Outlines of Guidelines

Individual physiological limits such as gender, anamnesis for health risks and state of training have to be considered and weighed against the actual conditions of thermal strain and against exercise intensity required for the desired level of performance in order to judge on degrees of heat stress which an individual may safely tolerate during strenuous (endurance) exercise. Preconditions would be presence of a competent supervisor and measures to be taken (supply of energy, water and electrolytes) to prevent deterioration of the subject’s ability to remove heat from the body without becoming dangerously hyperthermic and not to run out of fuel (so to speak). When setting Prevention Guidelines to avoid heat stroke only general recommendations are possible, as they are listed in Tables 1 and 2.

However, a general and clear distinction may be made between healthy adults and aged persons. Even if the aged are healthy, they are at higher risk to suffer from heat disorders or heat stroke. Therefore age-related-risks have to be outlined separately, i.e., generally for persons who are at or beyond the age of retirement. Although there are still large individual differences, a general outline is presented in Table 3.

As a general guide for the average individual, the committee has adopted “Life activity standards” qualitatively describing the intensity of daily life activities. They are listed in Table 4. The life activity standards listed in the table present a survey for individuals with normal fitness. “Life activity standards” are presented at three levels and categorize all everyday activities according to whether they represent “everyday activities categorized as light work,” “life activities categorized as middle work” or “life activities at the level of hard work or strenuous exercise.” As an attempt to provide information about the compatibility of the various exercise levels listed in Table 4 with the WBGT levels, sections are colored to indicate the activity levels permitted at the respective WBGT levels. For the highest WBGT level activities are most limited. The lowest WBGT level is considered to permit all activities listed in Table 4.

Within these categories of work intensities the four levels presenting recommendations according to the level of WBGT, as they were listed in Table 3, should be observed too: Danger of heat stroke: Exercise prohibited (above 31°C WBGT). Severe warning: Awareness of danger for heat stroke (at 28°C-31°C WBGT). Warning: Awareness of heat disorders (at 25°C-28°C WBGT). Caution: Not to exaggerate physical activities towards the degree of exhaustion (<25°C WBGT). As a fifth category the JSA defines a category when even intense exercise is Almost safe: (<21°C WBGT), provided that maintenance of water and electrolyte balance is observed.

As safety measures for students at Sports Faculties the limits set by the four WBGT levels should be observed. The limiting conditions for sports exercise are presented in Table 5 showing a comparison between “Guidelines for the prevention of heat disorder during sports activities” by JSA and “Guidelines for prevention of heat disorder in daily life” by JSB.

These guidelines do not set strict limits, however, for individuals who are fully trained for heavy physical exercise, e.g., when doing advanced amateur or professional sports. But supervision by trainers or comrades should pay attention to avoid that highly trained competitive athletes transgress their individual limits.

Reflecting the fact that standard temperature segmentation by “Heat disorders prevention guidelines” by JSA is widely known, the same classifications are ap-
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Table 4  Popular listing of examples for light, middle and heavy exercise, three respective metabolic levels of internal heat production and ambient thermal conditions. Colored fields corresponding to different levels of WBGT temperatures indicate what may be permitted within a given range of WBGT.

<table>
<thead>
<tr>
<th>Exercise</th>
<th>Light exercise</th>
<th>Middle exercise</th>
<th>Heavy exercise</th>
</tr>
</thead>
<tbody>
<tr>
<td>RMR : below 2.5</td>
<td>RMR : below 2.5-6.0</td>
<td>RMR : above 6.0</td>
<td></td>
</tr>
<tr>
<td>METS : below 3.0</td>
<td>METS : below 3.0-6.0</td>
<td>METS : above 6.0</td>
<td></td>
</tr>
<tr>
<td>kcal/h : below 250 (less than 290 Watt)</td>
<td>kcal/h : below 250-490 (250 to 570 Watt)</td>
<td>kcal/h : above 490 (higher than 570 Watt)</td>
<td></td>
</tr>
</tbody>
</table>

Table 5  Comparison between JSA and JSB in guidelines for the preventions of heat disorder.

<table>
<thead>
<tr>
<th>Guidelines for the prevention of heat disorder during sports activities by JSA</th>
<th>WBGT (°C)</th>
<th>Guidelines for the preventions of heat disorder in daily life by JSB</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exercise: Prohibit</td>
<td>Higher than 31°C</td>
<td>Threat of heat stroke</td>
</tr>
<tr>
<td>Severe warning: Heavy exercise prohibited.</td>
<td>28-31°C</td>
<td>Severe warning</td>
</tr>
<tr>
<td>Warning: Rests should be often provided.</td>
<td>25-28°C</td>
<td>Warning</td>
</tr>
<tr>
<td>Caution: Water should be replenished often.</td>
<td>21-25°C</td>
<td>Caution</td>
</tr>
<tr>
<td>Almost safe: Appropriate water replenishment suggested.</td>
<td>Less than 25°C</td>
<td>Caution</td>
</tr>
<tr>
<td></td>
<td>Less than 21°C</td>
<td>Caution</td>
</tr>
</tbody>
</table>

4. Activities of Related Organizations

These days various educational activities regarding heat disorders are getting more and more promoted, including publishing of guidebooks and leaflets, with information provided on websites by related organizations. Below some introductory remarks on these activities follow.

4.1 “Let us prevent heat disorders” by the Ministry of Education

Under the planning and editorship of the Ministry of Education, Culture, Sports, Science and Technology, in National Agency for the Advancement of Sports and Health, which is an Independent Administrative Legal Entity, an investigation committee has been established with Professor Saito of Musashigaoka Junior College as chairman to put forward information about countermeasures against heat disorders.

The committee has issued and is distributing a booklet consisting of eight pages with A4 in size, whose content is a digest version of the Guidebook for the Prevention of Heat Disorder during Sports Activities, published by JSA.
4.2 “Prevent heat disorders” by the Japan Industrial Safety and Health Association

Seichi Horie, a professor of the University of Occupational and Environmental Health has written and published guidebooks called Let Us Protect Our Body from Heat and Let Us Prevent Heat Disease with a Healthy Life, which are both B5 in size and total seven pages in amount. Let Us Protect Our Body from Heat has gone through several revisions since first issued in 1998, accordingly explaining how to escape from heat disorders during labor, while Let Us Prevent Heat Disease with a Healthy Life clarifies and summarizes the points to prevent heat disorders for laboring men and their family.

4.3 Heat disorders health guidance manual by the Ministry of the Environment

Expecting everyone to make efforts in prevention of heat island phenomena and earth warming, attention is paid to prevent heat disorders by providing good and correct knowledge, including how to perform adequate treatment of heat disorder victims. It is not only meant to inform public health advisors but is of interest for many others who are widely utilizing the respective manual. Since such information has contributed to prevention of heat disorders (quoted from foreword), the first issue, released in 2005, has been revised and published in 2006 and 2007, thus covering three consecutive years. Twelve members of the editorial board are specialists in industrial hygiene, first-aid medicine, environmental science, aerography, sports medicine, and of other relevant fields. The manual presents five chapters including I. Definition of heat disorders, II. What to do when heat disorders takes place, III. How to prevent the heat disorder, and so on.

4.4 Heat disorders prevention system of Kusatsu city by local administration

Kusatsu city in Shiga prefecture has established “An Ordinance regarding Heat disorders Prevention,” to start a “severe heat disorders accidental warning system” in 2005. The large number of citizens have been carried by ambulance as victims of heat disorders in the summer of 2004. This was a turning point, recognized by the mayor of the city who realized the necessity of a “Prevention of Heat Disorder” scheme, with the crisis management team of the city environmental department. The team played a central role in setting up corresponding ordinance, as well as establishing an official “Announcement system.” These measures have attracted attention of both national and international academic organizations. In 2006, Tajimi city in Gifu prefecture has introduced a same type of system, which has been operating up to now.

4.5 Websites regarding heat disorders

Information regarding “heat disorders” could be obtained by accessing to websites as listed below.

Ministry of the Environment
http://www.env.go.jp/

Japan Sports Association
http://www.japan-sports.or.jp/

Japan Weather Association
http://www.jwa.or.jp/

Japanese Society of Biometeorology
http://www.med.shimane-u.ac.jp/

National Institute for Environmental Studies
http://www.nies.go.jp/

5. Challenges for the Future

Increasing numbers of casualties or fatalities resulting from heat disorders are expected, firstly because the old-old, who are over 75 of age, and largest in number of fatal cases, will rise in number rapidly. Secondly, with global heating urban heat island phenomena will become more frequent. Thirdly, low adaptability or acclimatization to heat is prevailing because with increasing civilization the fraction of the population experiencing physiological heat defense, e.g., “sweating” will diminish with the progress in comfort of the living conditions, especially with the progress of installation of air conditioning equipment and the transformation of facilities for labor and for playing (and amateur sports) with the aim to establish indoor environments imposing no heat challenge.

The accidents during sports activities certainly tend to increase by “heat environment of 25˚C and above,” “sudden heating up,” and “long time lasting physical exercise.” It is obvious that adequate liquid or water replenishment and avoidance of heavy load physical exercise in hot environments are effective measures to prevent heat disorders.

However, there are reports claiming that there is even an increase of heat disorders occurring in conditions of “cool environment,” “right after starting exercise,” and “with light exercise.” There are reports that aged persons are even prone to be afflicted by heat disorders in conditions that are characterized as “indoor and calm” where conditions may be warm in the absence of air conditions but not aggravated by elevated interior heat loads due to physical activity. These cases could be explained as resulting from high body temperature which may be indicative of a febrile disease but may also be caused by insufficient heat dissipation following dysfunction of autonomic circulatory and sweat gland control resulting in insufficient sweat gland secretion and compromised peripheral blood perfusion, including capillary fragility. Attention has to be focused in the aged on these causes of physiological deconditioning, and the best precaution to avoid such complications in the aged would be effective air conditioning.

For these reasons, I think that among the eight key tips for prevention of heat disorder, “Poor physical condition factors can cause accidents,” which is introduced by JASA, has to be emphasized most, in order to prevent heat disorders. In other words, physical training, training to adapt heat dissipating capabilities are very
important preventive measures, and air conditioning may be indispensable in the aged.

In Aichi prefecture, concerned parties have sent reports or papers to prosecutors in charge of professional negligence resulting in the death, in a case of incidental mortality of a junior high school student. The issue disputed here is whether the eight key articles were followed accordingly or not. One decade ago, as a result of ignorance of the concerned parties, not knowing even the word or term of heat disorders was a major issue; while nowadays the responsibilities of “not having enough knowledge of heat disorders” are increasingly under consideration.

There are many schools with poor facilities of water supply and resort facilities for avoiding heat. Besides taking measures for corresponding improvement of infrastructure further improvements are sought including the development of forecast systems at field site levels and availability for reviewing emergency aid systems for treating heat victims. Further survey is sought, with countermeasures against heat disorders based on individual difference considered, e.g., the epidemic occurrence of heat disorders among obese individuals.

References


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