# Guidelines for the prevention of heat illness in daily life (Ver. 4 in English)

**Japanese Society of Biometeorology**

**Introduction**

Due to global warming and the urban heat island phenomenon, prevention measures for heat illness have become an important health focus during summer in Japan. Cases of heat illness resulting in death have increased in recent years, with 1,745 cases [Note 1] in 2010 — the highest number of recorded deaths from heat illness — due to record-breaking heat waves (Ministry of the Environment of Japan 2018). The mortality rate of those with heat illness aged ≥65 years has also increased, reaching 81% in 2015 (Ministry of the Environment of Japan 2018).

Heat illness occurs not only during sporting activities and physical labor, but also during daily activities. However, there were no appropriate guidelines for the prevention of heat illness in daily life. Therefore, in April 2008, the Japanese Society of Biometeorology first developed and published the "Guidelines for the prevention of heat illness in daily life" (Ver. 1 in Japanese). Thereafter, various power-saving measures were established in response to concerns over power shortages due to the increase in power demand following the heatwave and nuclear power plant accident caused by the Great East Japan Earthquake in March 2011. The Society published an "Urgent proposal for the prevention of heat illness while conserving electricity," and the "Guidelines for the prevention of heat illness in daily life" (Ver. 2 in Japanese) in May 2011, which incorporated specific heat acclimation methods as well as recommendations regarding clothing choices and housing modifications. In 2013, the Society published the "Guidelines for the prevention of heat illness in daily life" (Ver. 3 in Japanese), which included the latest findings. In June 2021, the Society published the "Guidelines for the prevention of heat illness in daily life" (Ver. 3.1 in Japanese), in which a simple method to assess the indoor wet-bulb globe temperature (WBGT) based on the ambient temperature and relative humidity was described. We have developed the "Guidelines for the prevention of heat illness in daily life" (Ver. 4 in English) by including new findings and specifying the literature that provides the scientific basis for each recommendation. We hope that these guidelines will be widely used in our society and serve as a source of enlightenment for the prevention of heat illness.

Note 1: Based on International Classification of Diseases (ICD)-10 "Thermal and Light Effects (T67)" in Vital Statistics "Prevention guidelines and major points."

# Outline of the "Guidelines for the prevention of heat illness in daily life (Ver. 4)"

## 1. Heat illness

Heat illness is a general term for "heat disorders, excluding skin disorders, which occur due to heat." It is categorized into heat syncope, cramps, exhaustion, and stroke (Sugimoto et al. 1980; Ogawa and Sugenoya 2011; Matsumoto 2011; Matsumoto and Yamashita 2013; Matsumoto 2014; Kawahara et al. 2018; Matsumoto 2018). The main causes of the onset of heat illness are dehydration and an excessive increase in body temperature. The mechanisms and symptoms of the four categories are stated below (Japanese Society of Biometeorology 1992; Casa et al. 2015; Kawahara et al. 2018; CDC 2022):

1) Heat syncope: Heat syncope is characterized by dizziness and syncope due to reduced blood pressure and cerebral blood flow. Such reductions occur because of a redistribution of circulating blood from the central circulation to the skin vascular beds (for thermoregulatory heat dissipation). The symptoms of heat syncope are enhanced in a standing position and/or by movement.

2) Heat cramps: Heat cramps are painful spasms of the legs, arms, and abdominal muscles that occur when fluid loss through profuse sweating and is replenished with water alone, leading to a decrease in the salt concentration in the blood. Heat cramps are treated as heat exhaustion if the cramps are accompanied by dizziness, headache, and nausea, among other symptoms.

3) Heat exhaustion: Heat exhaustion is caused by dehydration due to excessive sweating and the resulting circulatory failure (decrease in central blood volume), and may be accompanied by weakness, malaise, headache, and nausea, among other symptoms.

4) Heat stroke: Heat stroke is a state characterized by disorder of the central nervous system due to extreme elevation in body temperature. Anxiety, irritability, hallucination, strange behavior, confusion, seizure, coma, etc. are often observed. Such conditions are life-threatening, and as a result, urgent external cooling and emergency medical treatment are required.

## 2. Guidelines for the prevention of heat illness in daily life

In addition to environmental factors such as ambient temperature, humidity, air currents, and radiant heat, the onset of heat illness is affected by personal factors such as sex, age, medical history and health status, clothing, and workload due to exercise, labor, and activities in daily living. Therefore, it is necessary to consider the influence of these personal factors on the risk of heat illness. However, currently, a quantitative assessment of these personal factors remains unestablished because of their complexity and diversity.

Table 1 denotes the guideline summary. We adopted WBGT (Yaglou and Minard 1957) as an index for the environmental factors involved in the risk of heat illness. Based on WBGT, the environmental factors are classified into four stages: "**Danger**" (WBGT ≥31 °C), "**Severe Warning**" (31 °C > WBGT ≥ 28 °C), "**Warning**" (28 °C > WBGT ≥ 25 °C), and "**Caution**" (WBGT <25 ºC). The intensity of daily activities to monitor at each stage is divided into three categories: "**Light**," "**Moderate**," and "**Heavy**." In addition, the details of precautions to be taken in daily life are also indicated for each environmental stage. “Danger” is marked in red, “Severe warning” in orange, “Warning” in yellow, and “Caution” in white.

Table 1 Guidelines for the prevention of heat illness in daily life

| Reference range by WBGT | Intensity of daily activities to be monitored | Details of precautions to be taken in daily life |
|---|---|---|
| **Danger** **WBGT ≥31 °C** | **All daily activities (Light to Heavy)** | **Older people have a greater risk even at rest. All people are recommended to avoid outdoor activities and stay in an air-conditioned room.** |
| **Severe Warning** **31 °C > WBGT ≥ 28 °C** | | **All people are recommended to avoid direct sun during outdoor activities and be aware of the indoor temperature during indoor activities.** |
| **Warning** **28 °C > WBGT ≥ 25 °C** | **Moderate to Heavy** | **All people should take adequate rest regularly during physical labor and sporting activities.** |
| **Caution** **WBGT <25 °C** | **Heavy** | **The risk is generally low. There is some risk during physical labor and sporting activities with heavy intensity.** |

**3. Explanation of the guidelines for the prevention of heat illness in daily life**

1) An index of the environmental factors, WBGT.

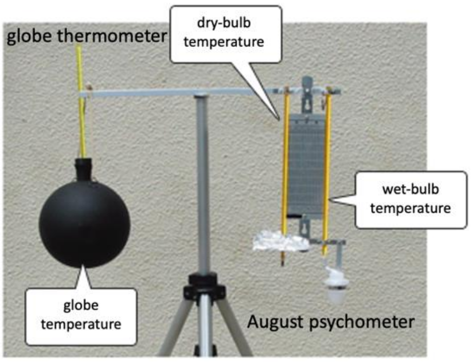
WBGT is a simple index that comprehensively evaluates heat stress caused by several environmental factors (i.e., ambient temperature, humidity, air current, and radiant heat). The index is calculated by the following formula, depending on the presence or absence of solar radiation (International Standards 2017; Japanese Industrial Standards 2021):

WBGT (in the presence of solar radiation)

= 0.7 × wet-bulb temperature + 0.2 × globe temperature + 0.1 × dry-bulb temperature

WBGT (in the absence of solar radiation)

= 0.7 × wet-bulb temperature + 0.3 × globe temperature




When evaluating WBGT, the August psychrometer and a globe thermometer (dry-bulb thermometer in a black ball with a diameter of 150 mm; Fig. 1) are used. The August psychrometer is placed under natural, rather than forced ventilation (International Standards 2017; Japanese Industrial Standards 2021).

Fig. 1 WBGT measurement with the August psychrometer and a globe thermometer (diameter 150 mm)

Commercially available devices for WBGT measurement are widely used. The commercial devices can be classified into the following three types according to their measurement procedures (Fig. 2):

A) Devices using a natural wet-bulb thermometer (Fig. 2a). These devices consist of a dry-bulb, a natural wet-bulb, and a globe thermometer. The measurement is based on the original principles of WBGT; therefore, we can expect accurate data. However, these devices are unpopular due to handling difficulties and cost. The measurement procedure of these devices is standardized by ISO 7243 and JIS Z8504 in Japan (International Standards 2017; Japanese Industrial Standards 2021).

B) Electronic devices (Fig. 2b). These devices use an electric humidity sensor instead of a natural wet bulb thermometer. Because of the easier operation and lower cost, the devices are widely used in the fields of sport physical labor, etc. The procedure is standardized by JIS B7922 (Japanese Industrial Standards 2017) in Japan.

C) Simplified devices without a globe thermometer (Fig. 2c). These devices are simplified by removing the globe thermometer. Some devices have a display unit indicating the WBGT value. The lack of a globe thermometer in these devices may lead to an erroneous WBGT in environments with solar radiation such as outdoor fields (Saito and Sawada 2015).

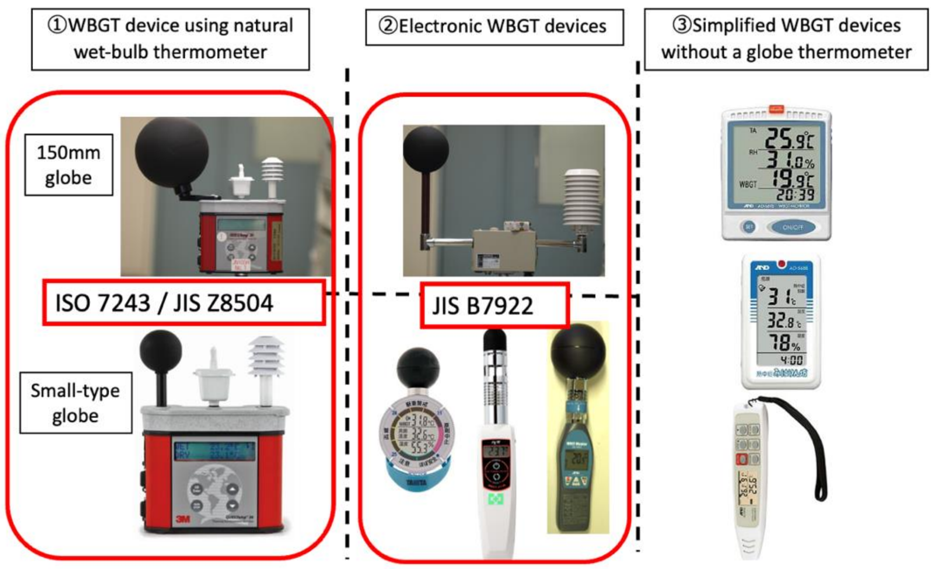



Fig. 2 Commercially available WBGT devices divided to three types based on the measurement procedures

When the actual measurement of WBGT is not possible, there may be an option to use the “heat index” as a reference, which is provided by the Ministry of the Environment of Japan on its website (heat illness prevention information site). The “heat index” is calculated by an approximation formula, based on the observation values reported by the Japan Meteorological Agency (under forced ventilation with solar radiation blocked). The Agency releases hourly reports containing the actual values monitored at 11 points and the estimated values at 829 points across Japan (Japan Meteorological Agency 1998; Ono and Tonouchi 2013; Ministry of the Environment of Japan 2022). The reports also provide the predicted WBGTs for 3 consecutive days (i.e., from the current day to 2 days later). The values do not always match those obtained by actual measurement on site due to differences in the procedure, location, and environment. However, the heat index is useful as a substitution and/or reference for WBGT when the actual measurement of WBGT is not possible.

2) Daily activity levels

Table 2 shows the details of daily activity levels, corresponding to the three categories (i.e., Light, Moderate, and Heavy, as indicated in Table 1; Investigative Committee on Required Amount of Exercise for Health Promotion 1989; Ainsworth et al. 2000). The intensity of physical activities is often expressed using units of metabolic equivalents (METs), kcal/kg body weight/minute, and relative metabolic rate (RMR). In this guideline, we defined the three categories of Light, Moderate, and Heavy as <3.0, 3.0–6.5, and ≥6.5 METs, respectively. Daily activities were classified only according to the intensity. However, the onset of heat illness is largely affected by the duration of an activity. Even when the intensity of the activity is categorized as "Light," cooling-down procedures such as regular breaks and rehydration are required.

Table 2. Examples of daily activities categorized by intensity

| Light | Moderate | Heavy |
|---|---|---|
| Break/conversation | Cycling (<16 km/hour) | Jogging |
| Preparing and eating food and daily necessities | Brisk walking (95–107 m/minute) | Soccer |
| Playing a musical instrument | Cleaning (sweeping/wiping) | Tennis |
| Sewing (hand or machine) | Laying out and folding up a futon | Cycling (approx. 20 km/hour) |
| Car driving | Physical exercise (intense) | Rhythmic exercises |
| Office work | Climbing up and down stairs | Aerobics |
| Commute (standing on the train/bus) | Polishing the floor | Table tennis |
| Laundry | Pruning hedges | Badminton |
| Washing hands, washing face, and brushing teeth | Weeding the garden | Hiking |
| Cooking (cooking/cleaning up) | Lawn mowing | Kendo |
| Shopping | Walking (107 m/minute) | Swimming |
| Cleaning (vacuum cleaner) | Calisthenics | Basketball |
| Normal walking (67 m/min) | Jazz dance | Jump rope |
| Stretching Method | Golf[a] | Running (134 m/min) |
| Gate ball[a] | Baseball/softball[a] | Marathon |

[a] Baseball/softball, golf, and gate ball are low intensity activities, but require precautions since they take a long time.

3) Guidelines for fluid and salt replacement

A) In daily life, individuals (who are not involved in heavy exercise or labor and not exposed to heat) should drink 1.2 L of water a day in addition to the water contained in meals (Gamble 1954; Ministry of the Environment of Japan 2018).

B) During exercise and physical labor, the volume of fluid replacement is recommended to be approximately 70–80% of the body weight loss (Ministry of the Environment of Japan 2018). Dehydration of >2% of the body weight should be avoided (Yoshida et al. 2002). In case of excess sweating, fluid with a salt concentration of 0.2% such as sports drinks (Okuno et al. 1988; Gisolfi et al. 1990) should be used to replenish losses. The recommended amount of fluid replacement is as follows: approximately 200–400 mL of water with salt before exercise or physical labor; 100–200 mL water with salt every 20–30 minutes during exercise or physical labor; and water and salt within 30 minutes after the activity ends.

C) When drinking alcohol, replacement of water during and after alcohol intake is necessary, as alcoholic beverages promote diuresis (Kuriyama and Okuma 1995; Hobson and Maughan 2010).

D) Even in an airconditioned room, water replacement is necessary (Doi et al. 2004).

4) Precautions for the application of the guidelines

It is widely acknowledged that physical and psychological responses to environment differ among individuals. However, this guideline has been prepared with the aim of preventing heat illness for the general population. Therefore, in addition to several notes in these guidelines, we expect the consideration of age, sex, heat acclimation, and other factors affecting the onset of heat illness when interpreting the guidelines for prevention.

## Detailed explanation of “Guidelines for the precautions against heat illness in daily life (Ver. 4)”

**1. Thermoregulatory responses to heat and the etiology of heat illness**

1) Behavioral and autonomic thermoregulatory responses

When exposed to heat, humans engage in behaviors such as removing closing and/or choosing light clothing, moving to a cooler environment, and turning on fans and/or air conditioners. These behaviors aim to reduce thermal discomfort and prevent increasing body temperature, known as behavioral thermoregulation. At the same time, skin blood flow increases, resulting in heat loss from the skin’s surface to the environment (conductive or non-evaporative heat dissipation). Greater heat loads also activate sweating (perspiration), increasing heat loss due to subsequent evaporation of sweat from the skin surface (evaporative heat dissipation). Such increases in skin blood flow and sweating are termed autonomic thermoregulation, which unconsciously occurs via the autonomic nervous system. Homeothermic animals, including humans, maintain their body temperature by activating both behavioral and autonomic thermoregulation (Nagashima 2021).

Excessive heat leads to a redistribution of circulating blood volume from the central part of the body (visceral organs, such as the liver and kidneys) to the skin and dehydration due to sweating, causing a decline in blood volume. When fluid is not adequately replenished, dehydration rapidly progresses, suppressing blood flow to the skin and, consequently, sweating. In this case, thermoregulatory responses are impaired and body temperature increases, which further progresses dehydration, decreased blood volume, impaired thermoregulation, and increased body temperature. If this vicious cycle is not stopped, the risk of heat illness increases. Therefore, in an environment where we feel hot, it is important to take a break in a cooler place (i.e., behavioral thermoregulation) and frequently consume adequate volumes of water to maintain skin blood flow, sweating (i.e., autonomic thermoregulation), and body temperature (Ministry of the Environment of Japan 2018).

2) Types of heat illness and their etiology

A) Heat syncope: Heat syncope occasionally occurs when a person stands in extreme heat with strong sunlight. Due to the increased blood flow to the skin for thermoregulatory heat dissipation and redistribution of the circulating blood volume to the lower extremities, blood flow to the brain decreases, resulting in loss of consciousness (fainting). Orthostatic hypotension is believed to be the etiology (Vicario 2006). Prior to fainting, facial pallor and dizziness are often observed (Ogawa and Sugenoya 2011; Matsumoto 2011; Matsumoto and Yamashita 2013; Matsumoto 2014; Kawahara et al. 2018; Matsumoto 2018).

B) Heat cramps: Heat cramps are painful spasms that occur in fatigued muscles after prolonged exercise in a hot environment with excessive sweating. Heat cramps usually occur in the leg muscles but may also affect the upper extremities and abdominal muscles. Heat cramps are induced particularly when fresh water or low-salt beverages are consumed for rehydration. Such rehydration processes decrease the blood's salt concentration and increase muscle irritability. Muscle cramps during exercise occur for other reasons besides heat and dehydration. However, when the cramps occur during exercise in the heat, the case should be treated as heat cramps. When heat cramps are accompanied by symptoms such as dizziness, headache, and nausea, the condition is diagnosed and treated as heat exhaustion, which is described below (Ogawa and Sugenoya 2011; Matsumoto 2011; Matsumoto and Yamashita 2013; Matsumoto 2014; Kawahara et al. 2018; Matsumoto 2018).

C) Heat exhaustion: Heat exhaustion is the core pathological condition of heat illness. Exercise in heat induces sweating as the workload and/or duration increase. Excess sweating leads to loss of water and salt from the body, decreased circulating blood volume, and insufficient blood flow to vital organs such as the brain. Severe dehydration and the subsequent circulatory insufficiency are the etiology behind heat exhaustion. There are no specific symptoms of heat exhaustion, but it is often accompanied by headache, dizziness, nausea, vomiting, weakness, and malaise. In cases of heat exhaustion, body temperature is within a normal range or slightly elevated but does not exceed 40 °C.

Mild confusion may occur, but severe disturbance of consciousness, such as coma, does not. Recovery from heat exhaustion can usually be achieved through proper treatment, and it is not life-threatening. It is sometimes difficult for us to discriminate between mild heat exhaustion and life-threatening heat stroke (explained in the next point) because the pathological conditions for heat illness are sequential (Ogawa and Sugenoya 2011; Matsumoto 2011; Matsumoto and Yamashita 2013; Matsumoto 2014; Kawahara et al. 2018; Matsumoto 2018).

D) Heat stroke: With the progress of heat exhaustion, dehydration inhibits the autonomic responses of heat dissipation (i.e., skin blood flow and sweating) and leads to further increases in body temperature. Excessive increases in body temperature (usually at the level of >40 °C) impair several central nervous system functions, which are observed in the form of disturbances in consciousness and thermoregulatory dysfunction (e.g., cessation of sweating) (Bouchama and Knochel 2002; Vicario 2006; Kawahara et al. 2018; Ogawa and Sugenoya 2011; Matsumoto 2011; Matsumoto and Yamashita 2013; Matsumoto 2014; Matsumoto 2018; Epstein and Yanovich 2019). These conditions constitute heat stroke. It is important to note that sweating is occasionally observed in cases of heat stroke during exercise (Vicario 2006; Ogawa and Sugenoya 2011; Matsumoto 2011; Matsumoto and Yamashita 2013; Matsumoto 2014; Kawahara et al. 2018; Matsumoto 2018) and even if body temperature is

<40 °C at the time of the measurement, heat stroke cannot be negated (Vicario 2006).

It is important to monitor the consciousness level of individuals in situations, where heat illness can be expected to occur. Consciousness disturbance is a key symptom linked with heat stroke, and includes not only severe coma but also mild individual symptoms such as a sluggish response, slurred speech, strange behavior, and confusion regarding the present time and/or place. In addition, headache, hyperventilation, vomiting, diarrhea, staggered gait, tachycardia, and shock (low blood pressure) often accompany heat stroke and complications such as multiple organ failure and/or disseminated intravascular coagulation (DIC) can lead to death. Once heat stroke develops, rapid and appropriate first aid may not be effective in saving the patient's life. Therefore, it is important to prevent heat exhaustion from progressing to heat stroke (Ogawa and Sugenoya 2011; Matsumoto 2011; Matsumoto and Yamashita 2013; Matsumoto 2014; Kawahara et al. 2018; Matsumoto 2018).

## 2. The basics of prevention are the suppression of the excessive increase in body temperature and prevention of dehydration

1) Suppressing the increase in body temperature

A) Heat acclimation

Getting used to heat using interventions such as exercise training in heat is termed heat acclimation. Heat acclimation suppresses excessive increases in body temperature, and is achieved through increased blood volume and sweating (Gagge and Gonzalez 1996). Repeated exercise in hot environments induces sweating and an increase in skin blood flow more quickly after the onset of exercise, which enhances heat dissipation and improves thermoregulation (Lind and Bass 1963; Sawka et al. 2001). Furthermore, the heart rate during exercise is lowered.

a) To build a heat-resistant physique (heat acclimation) before midsummer (e.g., May and June in Japan), it has been recommended for individuals to conduct exercise with “light intensity” in a “slightly hot environment” for 30 minutes daily, 5 days a week for 1–4 weeks (Goto et al. 2010; Ikegawa et al. 2011). In addition, there are several reports that heat acclimation is effectively achieved by consuming foods rich in carbohydrates and proteins, such as milk (200–400 mL) immediately after the exercise (Okazaki et al. 2009a; 2009b; 2009c; Goto et al. 2010).

For middle-aged and older individuals or younger people who are not confident in their physical strength, “interval walking: 3-minutes of brisk walking (swinging arms with long strides and stepping with the heels of the feet) followed by 3-minutes of slow walking, at least five times a day, four times a week, for 4 weeks” is recommended (Nemoto et al. 2007; Morikawa et al. 2011). “Slightly intense exercise” for young people with physical strength refers to the use of a treadmill or bicycle ergometer in a gym or outdoor jogging. These exercises increase the heart rate to approximately 130 beats/minute for people in their twenties and about 120 beats per minute for those in their forties 5 minutes after onset (Karvonen 1957; Garber et al. 2011). An intensity equivalent to 50% of maximal oxygen uptake is also recommended as “moderately intense exercise” (Garber et al. 2011). The target heart rate at a particular exercise intensity is calculated using a formula derived from the resting heart rate and the estimated maximum heart rate by age (Karvonen 1957), which is shown below. The heart rate can be estimated using the pulse rate.

Target HR = (estimated maximum HR – resting HR) × 0.5 + resting HR

(HR, heart rate (beats per minute). Heart rate can be estimated by pulse rate)

Estimated maximum HR = (220 in male and 210 in female) − age.

(e.g., the target HR is 130 for a 20-year-old male with a resting HR of 60)

b) Humans walk upright with two legs. In addition, humans have a superior thermoregulation system compared to other animals. For example, in heat, humans can dissipate heat by increasing skin blood flow and sweating during exercise (Nose 2007). The two abilities are part of the reason humans inhabit a wide range of areas on the earth. However, standing on two legs poses a risk for the circulatory regulation. In a standing position, 70% of the total blood volume is below the heart (Rowell 1983). In extreme heat, even a slight reduction in blood volume due to dehydration decreases the venous return (i.e., the blood volume returning to the heart) and the stroke volume of the heart (i.e., the blood volume pumped by one contraction of the heart) (Nadel et al. 1980). If blood distribution to the skin is not suppressed, blood pressure cannot be maintained, which may lead to an insufficient blood supply to the brain and syncope (Armstrong et al. 2007a; Ministry of the Environment of Japan 2018). The venous return to the heart is monitored by the baroreceptors (i.e., stretch receptors) in the atrial and pulmonary arterial walls, etc. Therefore, when the venous return decreases, the distribution to the skin is suppressed, contributing to the maintenance of arterial pressure (Ahmad et al. 1977). It is reported that the reduction of venous return also suppresses sweating (Fortney et al. 1981); however, the true cause of this phenomenon remains controversial. As a result, heat dissipation from the skin surface is reduced, increasing heat retention. Heat acclimation also increases blood volume, which means a surplus of blood pumped from the heart in heat. In addition, the increased blood volume improves heat dissipation by increasing cutaneous blood flow, contributing to the prevention of heat illness.

B) Precautions during times of high ambient temperature (break and change of plans)

a) Outdoor physical activities or indoor physical activities without air conditioning at high ambient temperatures often induce hyperthermia (i.e., excessive body temperature) and dehydration, increasing the risk of heat illness. In principle, physical activity in a hot environment requires “frequent breaks and rehydration” and “never going beyond one’s limits” (Ministry of the Environment of Japan 2018). Moreover, it is important to choose shaded areas as much as possible to alleviate heat stress when outdoors (Hoshi et al. 2007; Ministry of the Environment of Japan 2018).

b) Information on WBGT and ambient temperature is provided by the Ministry of the Environment of Japan, Japan Meteorological Agency, private weather companies, etc.; therefore, we should frequently collect information through TV, radio, and the internet. The risk of heat illness becomes higher under conditions with i) an expected sudden increase in ambient temperature, such as after the rainy season (Hoshi and Inaba 2002, 2004; Nakai et al. 1992); ii) persisting WBGT >31 °C (Nakai et al. 1998; Hoshi and Inaba 2005; Hoshi et al. 2007; Nakai 2007); and iii) lasting tropical nights (with a minimum ambient temperature of >25 °C from the evening to dawn) (Nakai 1993). The values provided by weather forecasts, such as ambient temperatures, are measured on a lawn with solar radiation blocked. The actual conditions in direct summer sun or in a room with intense sunlight often become worse than the forecasted information. Therefore, it is important to check the environmental conditions frequently with a thermometer or WBGT meter.

c) Support system and heat avoidance

When an extremely high ambient temperature is expected, it is essential to provide necessary information, check room temperatures (Shibata et al. 2018), encourage water intake, and confirm the health support system (Yamashita et al. 2020) for those vulnerable to heat. Close and frequent communication with older adults who have little social interaction are also important. We should also favor shade under trees and/or buildings when walking in a town (Hoshi et al. 2007; Ministry of the Environment of Japan 2018).

2) Water and salt replacement

A) Beverage composition (sugar/salt content) and temperature

When blood volume decreases and the salt concentration in the blood increases due to sweating, heat dissipation through sweating (Fortney et al. 1984) and skin blood flow (Kenney et al. 1990) decrease, thereby increasing the risk of heat illness. Adequate hydration prevents this (Armstrong et al. 2007a). Reduced urination and urine with a darker color are signs of dehydration and should be a warning in times of heat (Armstrong 2007b). We should drink water before feeling thirsty. However, if only pure water is ingested for recovery from dehydration, the salt concentration in the blood reaches the normal level before the full recovery of blood volume. At this time, the feeling of thirst decreases, which suppresses water intake and keeps the blood volume decreased (Nose et al. 1985, 1988). The body works to maintain a constant salt concentration in the blood. This means that, in this state, drinking more water does not increase blood volume but increases urine output (Nose et al. 1985, 1988). This phenomenon is called "spontaneous dehydration" and it delays the recovery of blood volume, decreasing skin blood flow. Therefore, it is necessary to rehydrate with beverages containing moderate concentrations of salt to fully restore blood volume (Nose et al. 1985, 1988). Furthermore, absorption of water in the intestinal tract runs in parallel with that of $Na^+$ absorption (Gisolfi et al. 1990). Absorption of $Na^+$ is promoted by glucose in beverages. A glucose concentration of 1–2% is effective for water absorption in the intestinal tract (Gisolfi et al. 1990). Moreover, the temperature of the beverages should be <22 °C (Costill and Saltin 1974; Burdon et al. 2012).

B) Fluid replacement in daily life

a) Fluid replacement in daily life requires compensating for water loss due to insensible water loss and sweating. Sweating occurs during sleep (Kitado et al. 2004) and bathing (Miwa et al. 2004). It is necessary to hydrate with a glass of water (approximately 200 mL) before going to bed, when waking up, and before and after bathing. During the day, it is recommended to hydrate with approximately half a glass of water regularly (approximately hourly). We should rehydrate before feeling thirsty (Kenefick 2018). Since older adults have particularly weak thirst sensations (Kenney and Chiu 2001), they should exercise due caution regarding dehydration.

b) The amount of water replenished during exercise or labor should be approximately 70–80% of body weight loss (Ministry of the Environment of Japan 2018). Dehydration of more than 2% body weight should be avoided (Yoshida et al. 2002). It is important to replenish water and salt at the same time when a large amount of sweating is observed during exercise or physical labor. We should be supplementing with beverages containing approximately 0.2% salt (Gisolfi et al. 1990).

c) As alcohol is a strong diuretic and causes more water loss than the amount of fluid consumed (Kuriyama and Okuma 1995; Hobson and Maughan 2010), we should drink more water after drinking alcohol.

d) As an air-conditioned room is often dry, dehydration occurs unexpectedly (Doi et al. 2004). Therefore, we need to replenish body water frequently.

3) Adjustments of clothing and home environment

A) The basics of heat protection with clothing are to ventilate air containing heat, vapor, and sweat between the clothing and the body surface and to protect solar radiation. As for clothing materials in humid environment, highly breathable and hygroscopic materials, such as cotton, are suitable (Satsumoto et al. 2007). In a condition people sweat sweating a lot, synthetic fibers absorbing greater water and increasing evaporation are suitable (Miyake 2019a). Regarding the shape of closing for indoor environments, that exposing skin surface is effective such as tank tops and shorts should be worn indoors because these clothes expose the skin. For outdoor environments, the shape should minimize skin exposure and be loosely fitted to the skin. In addition, a parasol and wide-brimmed hat are effective for sun protection.

a) Protection against radiant heat penetration by wearing clothing

Protection of radiant heat such as direct sunlight is necessary for the prevention of heat illness. The protection can be accomplished using items which are placed away from the human body torso such as umbrellas, sedges, and hats, and those which are placed on the body torso such as clothes. Umbrellas have a strong heat-protective effect since they do not transfer solar heat to the human body even if the shielding material absorbs heat. When wearing a hat, we should select a material with high brightness and low emissivity that shields us from the solar radiation of the sunlight (Mase and Satsumoto 2015). It is recommended to choose a hat with high ventilation so as not to inhibit the evaporation of sweat (Yorimoto et al. 1982). Proper hat selection may contribute to selective cooling of the head (Hirata 1995). Clothing could shield large body areas from radiant heat. However, heat absorbed by clothing is transmitted to the body surface and heat radiation from the body surface is suppressed by clothing. Therefore, it is necessary to improve ventilation by placing spaces between clothing and the skin surface and selecting materials that do not hinder the evaporation of sweat.

b) Promotion of heat dissipation with clothing

i) Clothing sometimes inhibits heat dissipation from the human body surface (i.e., convection, radiation, and evaporation). In general, the thermal resistance of closing increases in proportion to the coverage area (i.e., the body surface area covered by clothing) (Tamura et al. 2004). Therefore, for heat protection, it is effective to reduce the area covered by clothing using short sleeves rather than long sleeves, short pants rather than long pants, and sandals rather than shoes.

ii) Extremities have a larger body surface-to-mass ratio. Thus, when the skin is exposed in a hot environment, greater heat dissipation occurs from the skin of the extremities (Tamura et al. 2004).

iii) Openings, such as the collars, cuffs, and hems of closing act in a similar way to the windows of a house, and they influence ventilation inside the clothing. The most effective ventilation occurs when the opening is vertical

(Miyake 2019b), and the chimney effect is exhibited, in which the air entering from the lower end escapes from the upper end (Satsumoto 2014). A forced air current, known as the bellows action, is generated when clothes swing when walking, which further facilitates heat dissipation (Miyake 2019b).

iv) To release the hot and humid air and moisture from inside clothing to outside, the shape of the clothing and the material's properties are important. It is important to use materials with good air permeability for ventilation through the fabric.

v) Wearing closing that prevent sweat from evaporating, increases ineffective sweating (i.e., sweating not involved in evaporative heat dissipation) as sweat remains on the skin or runs off. Therefore, clothing materials that allow sweat to evaporate easily (breathable, moisture-absorbing, water-absorbing, moisture-permeable, and quick-drying materials) should be selected.

B) Adjustments of housing (innovations to stay cool indoors)

a) Roofs get irradiated from sun exposure, resulting in heat development. To suppress the absorption, roofing materials with high reflectance are recommended. The roof and ceiling should be sufficiently insulated by extending the ceiling under the roof. A ventilation opening in the attic lets the wind in and discharges hot air to lower the temperature. Since west-facing walls receive sunlight in the afternoon when the outside temperature is high, it is easy for them to become hot, so caution is required. Double glazing, solar blocking film, and other methods may be used for windows, and double glazing improves heat insulation. Deciduous trees should be planted outside since the shade provided reduces the amount of solar heat hitting the building in summer. Therefore, a "green curtain" should be placed a little away from the wall (Shokokusha 2000).

b) Building insulation alone is not enough in the summer. On the south-facing side, the eaves should be set at one-third or more of the window height to block the sunlight in the summer (this allows sunlight to penetrate the interior of the room in winter). On the east- and west-facing sides, the sun shines into the interior of the room in the mornings and evenings during the lingering summer heat, so the eaves are useless. A cooling effect can also be expected from trees and "green curtains" due to the transpiration of leaves. To prevent glare on the ground, create shade from trees and plant grass with low solar reflectance (Shokokusha 2000).

c) The room should be ventilated so that the air currents hit the people in the room. Windows facing the main wind direction and the opposite direction may be opened, depending on the prevailing wind in the area. Installing a screen door at the entrance and a wing wall outside the window makes it easier for the wind to pass through. If opposite windows at different heights are opened, such as windows in an atrium or other high windows, even if the wind is weak, the wind coming in from the low windows passes through to the high windows, and the heat accumulating above can be discharged. We should be careful not to obstruct ventilation with furniture, and avoid placing objects near where the wind enters. The upper floors should be better ventilated. At night, cool outside air can be introduced into the room through windows and ventilation fans (Shokokusha 2000).

d) About 40% of heat illness cases in Japan occur at home (Fire and Disaster Management Agency, Ministry of Internal Affairs and Communications of Japan 2021). As it is often difficult to withstand heat without air conditioning, people often refuse to tolerate the heat and use an air conditioner instead. The room temperature may not match the air conditioner's set temperature, so it should be checked using a thermometer (using a WBGT device is recommended and the risk of heat illness should be checked by comparing it with these guidelines). To prevent heat shock that affects the human body thermally and physiologically due to the temperature difference between indoors and outdoors when going out, the temperature difference should not be too large (a difference within 5–7 °C is recommended (Nakayama 1981)). Fans and air circulators can be used to circulate cold air within the room, improve cooling efficiency, and prevent cold air from hitting people directly (Watanabe et al. 2007). Buildings with high heat capacity, such as those with concrete structures and thick insulation, accumulate heat during the day and gradually dissipate the heat as the outside temperature drops at night (Lechner 2014a). In addition, since it takes a considerable amount of time for a room to cool down, an air conditioner should be turned on before the room is used, and once cooled, the windows should be closed to prevent the cool air from escaping (Lechner 2014b). In recent years, tropical nights (days with a minimum temperature of ≥25 °C) have become frequent in urban areas, so it is not recommended to set the cooling timer to stop during sleep. Mechanical ventilation forces the heat and humidity of the outside air into the room (Tsuzuki et al. 2021).

e) The ambient temperature can be lowered by using sprinkled water or a water field, which augment heat dissipation through water vaporization. However, highly insulated buildings do not cool down to the level of room temperature (Zhou et al. 2004). Furthermore, when the humidity is high, the cooling effect of the water vaporization cannot be expected.

## 3. Matters requiring special attention

1) Measures for people vulnerable to heat

People who are aged, ill, or on medication, and infants, etc., are vulnerable to heat and need more intense measures to prevent heat illness than the general population. When abnormal heat (e.g., heat with an ambient temperature of >35 °C) lasts for several consecutive days, it is necessary to actively use an air conditioner and maintain a room temperature <28 °C. If there is no air conditioner at home, the residents need to evacuate to an air-conditioned public or commercial facility. Resting in a cool place even for a few hours is effective at preventing heat illness. People vulnerable to heat should refrain from unnecessary outdoor activities or physical labor when WBGT is ≥28 °C (i.e., "Severe Warning" based on the WBGT reference range in Table 1). Cold showers and bathing are also effective for lowering body temperature. Water supplementation before going to bed is the way to lessen the onset of heat illness. During summer nights when ambient temperature does not decrease, people must use an air conditioner (Epstein and Yanovich 2019).

A) Approximately 80% of deaths related to heat illness occur in older people. Older individuals and those with underlying diseases have poor thermoregulation and need particular care for heat illness. Air conditioning is used to keep the room temperature >28 °C. If there are older people around, their safety should be confirmed with regular visits or calls (approximately twice daily).

B) Disabled people, especially those with spinal cord injury, are more susceptible to changes in the environment than healthy people. The level of the spinal injury is strongly related to thermoregulatory dysfunction. Disturbances in heat dissipation, especially perspiration, require particular attention during periods with elevated temperatures.

C) Infants, schoolchildren, and obese people are also vulnerable to heat. It is important for the guardians of infants and schoolchildren, and relatives of other heat-vulnerable people to understand the characteristics of heat illness and respond adequately to heat.

2) Temperature reference ranges for heat-vulnerable people

If any of the following criteria apply, special caution is required. The precautions in daily life for the WGBT reference range (Table 1) should be applied at one level above the actual level. It is necessary to pay attention not only to the vulnerable persons but also to people nearby.

A) Infants and schoolchildren have an underdeveloped thermoregulatory function (Inoue 2004). They are also prone to developing symptoms of heat illness if their guardians do not respond to heat appropriately.

B) Older people aged ≥65 years, particularly those aged ≥75 years, have decreased thermoregulatory function. Therefore, older people are largely influenced by changes in environmental conditions when their thermoregulatory function decreases. Their sweat rate and thirst sensation decrease in heat (Inoue 2004). Therefore, heat stress easily develops into heat illness.

C) Heat stress easily increases body temperature in obese people. Thus, they are more likely to develop heat illness (Kawahara 2002; Kawahara et al. 2018).

D) People who tend to work hard in physical labor and in sports are more likely to develop heat illness (Worfolk 2000; Kawahara et al. 2018).

E) People with underlying diseases such as hypertension, heart disease, chronic pulmonary disease, liver disease, kidney disease, and endocrine disease, and those who are bedridden easily develop heat illness. The following medications promote the onset of heat illness:

a) Drugs with anticholinergic effects (antispasmodics*, drugs for frequent urination*, drugs for Parkinson's disease*, antihistamines, antiepileptic drugs, hypnotics/antianxiety drugs, autonomic nerve modulators, antidepressants, β-blockers, and certain antiarrhythmic drugs) suppress sweating.

b) Diuretics can easily cause dehydration.

c) Stimulants and psychoactive drugs increase metabolism (WHO 2003). Many antipsychotic drugs* may suppress the thermoregulatory center.

*Drugs where the package inserts states that “the body temperature may rise in a high-temperature environment because sweating (or the thermoregulatory center) is suppressed.”

F) People who are unwell, such as those with fever, diarrhea, hangover, and lack of sleep, are more likely to develop heat illness (Worfolk 2000).

G) Heat illness is likely to develop when the whole body is covered with thicker clothing or safety clothing during agricultural or safety work (Kurokawa et al. 2002).

H) Heat illness can easily occur when the temperature increases suddenly before summer (i.e., in months that people are not accustomed to being hot, such as June). Those who have little experience of exposure to high ambient temperature in their daily lives can also be victims. Traveling or moving from a cooler to a hotter place and a sudden rise in ambient temperature due to weather changes are also situations where heat illness can easily occur (Hoshi and Inaba 2004; Hoshi and Inaba 2005).

3) Protection of infants

Parental negligence often causes heat illness in infants who are left in a car, although this is a special case. The temperatures in a parked car can reach >50 °C within a few minutes. Even if the engine and air conditioner are running, they may get shut off unexpectedly. Therefore, regardless of the season, it is important to never leave children alone in the car even for a short time.

**4. Statistics for the onset of heat illness**

The number of deaths [Note 1] due to heat illness was 19,373 (11,074 men and 8,299 women) in the 49-year period from 1972 to 2020, and the average was 395 per year. The annual average from 1972 to 1994 was 89, while that from 1995 to 2020 was 666. The number of deaths in 2010 was 1,745.

Among the deaths due to heat illness, older people aged ≥65 years accounted for 56% in 1995, 72% in 2008, and 81% in 2015, showing an increasing trend in recent years. One possible reason is the increased population of older people. However, the age-adjusted mortality rate has also increased (Ministry of Health, Labour and Welfare of Japan 2020). More than half of the cases occurred at home, suggesting an urgent need for measures to prevent heat illness at home. According to the statistics for the cases transferred by ambulance to hospital, the number was 95,137 in the summer of 2018, of which 48% were older people (Fire and Disaster Management Agency, Ministry of Internal Affairs and Communications of Japan 2021)

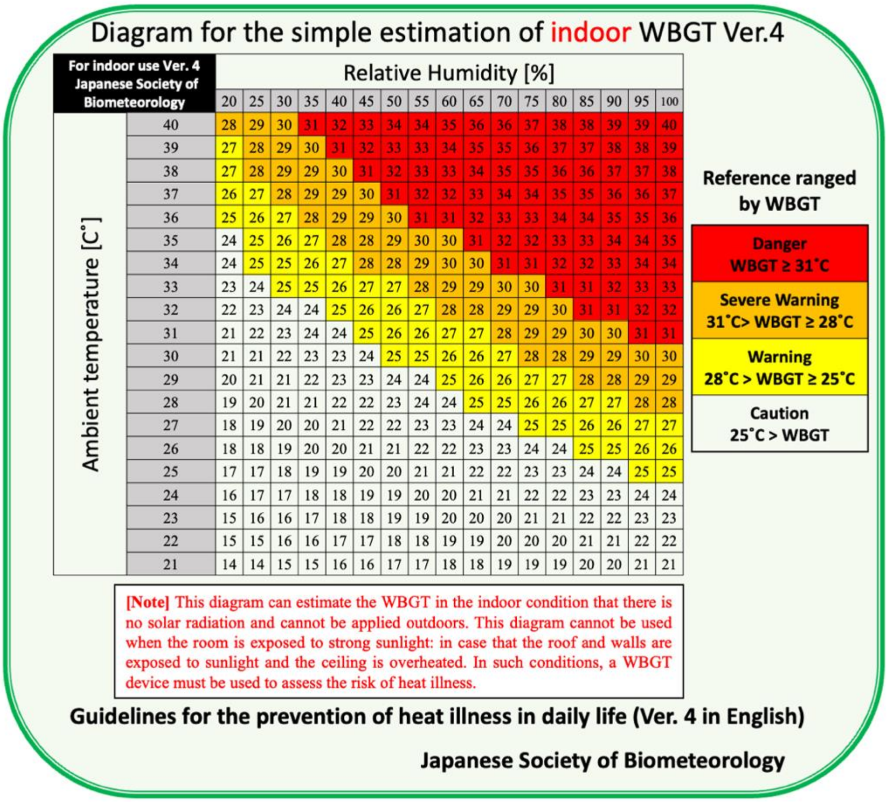
Note 1, The data were based on Vital Statistics ICD-10 “Thermal and Light Effects (T67)”

# <Appendix> "Simple WBGT estimation for indoors without sunlight”

Wet-bulb, globe, and dry-bulb temperatures must be measured for the correct calculation of WBGT. WBGT devices with a globe (black ball) have recently been used for the safety in physical labor and sports activities.

However, this is not the case in daily living situations. The risk of heat illness in our daily lives is usually assessed by the ambient temperature and relative humidity. Therefore, a simple method for estimating WBGT based on the values of ambient temperature and relative humidity may be useful and practical.

Fig. 3 denotes a diagram to estimate WBGT from the values of indoor temperature and relative humidity. The diagram can estimate WBGT indoors when there is no solar radiation (i.e., globe temperature is equal to dry bulb temperature), uniform ambient temperature and humidity, and weak airflow (i.e., wind speed of about 0.2 m/s). WBGT is calculated only by the two values of ambient temperature and relative humidity [Note 2]. Therefore, this diagram cannot be applied outdoors. In addition, the diagram cannot be used when the room is exposed to strong sunlight (i.e., when the roof and walls are exposed to sunlight and the ceiling is overheated), and the diagram may not be suitable to assess the room without direct sunlight. There is a possibility that the WBGT value is underestimated, and the risk is overlooked. In such conditions, a WBGT device must be used to assess the risk of heat illness.




| Ambient temperature [C˚] \ Relative Humidity [%] | 20 | 25 | 30 | 35 | 40 | 45 | 50 | 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 | 95 | 100 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 40 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 34 | 35 | 36 | 36 | 37 | 38 | 38 | 39 | 39 | 40 |
| 39 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 33 | 34 | 35 | 35 | 36 | 37 | 37 | 38 | 38 | 39 |
| 38 | 27 | 28 | 29 | 29 | 30 | 31 | 32 | 33 | 33 | 34 | 35 | 35 | 36 | 36 | 37 | 37 | 38 |
| 37 | 26 | 27 | 28 | 29 | 29 | 30 | 31 | 32 | 32 | 33 | 34 | 34 | 35 | 35 | 36 | 36 | 37 |
| 36 | 25 | 26 | 27 | 28 | 29 | 29 | 30 | 31 | 31 | 32 | 33 | 33 | 34 | 34 | 35 | 35 | 36 |
| 35 | 24 | 25 | 26 | 27 | 28 | 28 | 29 | 30 | 30 | 31 | 32 | 32 | 33 | 33 | 34 | 34 | 35 |
| 34 | 24 | 25 | 25 | 26 | 27 | 28 | 28 | 29 | 30 | 30 | 31 | 31 | 32 | 32 | 33 | 34 | 34 |
| 33 | 23 | 24 | 25 | 25 | 26 | 27 | 27 | 28 | 29 | 29 | 30 | 30 | 31 | 31 | 32 | 33 | 33 |
| 32 | 22 | 23 | 24 | 24 | 25 | 26 | 26 | 27 | 28 | 28 | 29 | 29 | 30 | 31 | 31 | 32 | 32 |
| 31 | 21 | 22 | 23 | 24 | 24 | 25 | 26 | 26 | 27 | 27 | 28 | 29 | 29 | 30 | 30 | 31 | 31 |
| 30 | 21 | 21 | 22 | 23 | 23 | 24 | 25 | 25 | 26 | 26 | 27 | 28 | 28 | 29 | 29 | 30 | 30 |
| 29 | 20 | 21 | 21 | 22 | 23 | 23 | 24 | 24 | 25 | 26 | 26 | 27 | 27 | 28 | 28 | 29 | 29 |
| 28 | 19 | 20 | 21 | 21 | 22 | 22 | 23 | 24 | 24 | 25 | 25 | 26 | 26 | 27 | 27 | 28 | 28 |
| 27 | 18 | 19 | 20 | 20 | 21 | 22 | 22 | 23 | 23 | 24 | 24 | 25 | 25 | 26 | 26 | 27 | 27 |
| 26 | 18 | 18 | 19 | 20 | 20 | 21 | 21 | 22 | 22 | 23 | 23 | 24 | 24 | 25 | 25 | 26 | 26 |
| 25 | 17 | 17 | 18 | 19 | 19 | 20 | 20 | 21 | 21 | 22 | 22 | 23 | 23 | 24 | 24 | 25 | 25 |
| 24 | 16 | 17 | 17 | 18 | 18 | 19 | 19 | 20 | 20 | 21 | 21 | 22 | 22 | 23 | 23 | 24 | 24 |
| 23 | 15 | 16 | 16 | 17 | 18 | 18 | 19 | 19 | 20 | 20 | 20 | 21 | 21 | 22 | 22 | 23 | 23 |
| 22 | 15 | 15 | 16 | 16 | 17 | 17 | 18 | 18 | 19 | 19 | 20 | 20 | 20 | 21 | 21 | 22 | 22 |
| 21 | 14 | 14 | 15 | 15 | 16 | 16 | 17 | 17 | 18 | 18 | 19 | 19 | 19 | 20 | 20 | 21 | 21 |

Fig. 3 Diagram for simple WBGT estimation indoor without sunlight using ambient temperature and relative humidity (Diagram for the simple estimation of indoor WBGT)

Note 2: The diagrams in the “Guidelines for the Prevention of Heat Illness in Daily Life” did not precisely indicate the applicable conditions (i.e., indoor or outdoor, the presence or absence of sunlight, and wind flow) in the Ver. 3 and earlier versions. The conditions largely affect the estimation of WBGT, which leads to the underestimation of heat stress and overlooking of risks of heat illness. In the revision (“Guidelines for the Prevention of Heat Illness in Daily Life” [Ver. 3.1]), we clarified the conditions to which the estimation is applicable and the estimation diagram for WBGT. The diagram in Fig. 3 is the same as that of Ver. 3.1 but renamed as “Diagram for the simple estimation of indoor WBGT, Ver. 4.”

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