How Should We Promote Preventive Measures Against Occupational Heat Disorders?  
- Current Status and Issues

SHIN-ICHI SAWADA*

* International Center for Research Promotion and Informatics, National Institute of Occupational Safety and Health, Kanagawa, Japan

Ongoing climate change in recent years has produced higher temperatures and has increased the number of extremely hot days in many parts of the world. With this climate change, casualties due to heat disorders have also tended to increase in the workplace as well as in the local community in Japan. To cope with this urgent occupational and environmental health problem, the Japanese government has been forced to take prompt preventive measures against heat disorders.

This paper firstly reports on the recent trends in the incidence of occupational heat disorders over the last couple of years in Japan and secondly provides an overview of the national administrative measures for occupational heat disorder prevention that have been taken so far by the Japanese Ministry of Health, Labour and Welfare (MHLW). On the basis of these findings, the author discusses how we should promote the preventive measures against occupational heat disorders, particularly focusing on how we should evaluate the effectiveness of products to protect against occupational heat disorders as preventive measures. It is concluded that a comprehensive and multiple assessment approach consisting of physical, physiological and field studies is required to address this challenging issue.

Key words: occupational heat disorders, administrative measures, the 12th Occupational Safety & Health Program, WBGT, protective products against occupational heat disorders

Ongoing climate change in recent years has produced higher temperatures and has increased the number of extremely hot days in many parts of the world. With this climate change, casualties due to heat disorders have also tended to increase in workplaces as well as in local communities in Japan. In particular, the summer of 2010 was the hottest in the last couple of decades, which caused many serious heat-related problems at work.

In the year (March 11th, 2011) following this heat wave, the Great East Japan Earthquake and the accident at TEPCO’s Fukushima Dai-ichi Nuclear Power Plant (NPP) occurred and raised two additional occupational heat problems in hot times of the year. One problem is that, during the recovery work inside and outside areas of the destroyed Fukushima NPP, as well as in the broader areas damaged by the natural disaster, many workers have been likely to be exposed to severe heat stress in summer. This heat stress is exacerbated by the personal protective equipment (PPE) used during the recovery work. The other problem is that, inside office buildings and factories where the use of air-conditioning is restricted by the need to save electricity, workers have to work under indoor heat stress conditions in hot times of the year. The Japanese government (MHLW) has been forced to take prompt preventative measures against these urgent heat problems in workplaces as well as in local communities.

In this paper, the author firstly reports the recent trends in the incidence of occupational heat dis-
orders in Japan, and secondly provides an overview of the administrative measures for occupational heat disorder prevention that have been taken so far by the Japanese government. On the basis of the obtained findings, the author discusses how we should cope with this occupational heat problem and promote preventive measures against occupational heat disorders.

Recent trends in the incidence of occupational heat disorders

Figure-1 shows the change in the annual number of fatalities due to occupational heat disorders officially reported by the Japanese Ministry of Health, Labour and Welfare (MHLW) during the last 25 years (1989-2013). The total number of cases amounted to 419 during this period. As Figure-1 shows, occupational heat disorders were not a salient occupational health problem in the early 1990s (1989-1993). However, the fatalities due to occupational heat disorders spiked and exceeded 20 for the second consecutive year in the scorching hot summers of 1994 and 1995. Thereafter, the incidence of fatalities due to occupational heat disorders has been maintained at a higher level, although the number of incidents has varied from year to year. In particular, in 2010, the highest number of fatalities due to occupational heat disorders (47 cases) in the last 25 years was recorded due to a record-breaking hot summer that year (Figure-1).

The annual number of fatalities due to occupational heat disorders was closely correlated with the annual summer outdoor temperature level from June to August ($R^2=0.5419$), as shown in Figure-2: the higher the outdoor temperature in summer, the higher the number of fatalities due to occupational heat disorders. This was further characterized by a nonlinear correlation that the fatalities ($y$) would increase exponentially if the outdoor temperature ($x$) would increase due to a heat wave in summer ($y = 10.229e^{0.9934x}$). By recounting the fatalities reported during the last 12 years (2000-2011), the following characteristics were found: the highest risk of occupational heat disorder fatality is associated with construction work within a few days from the onset of work in the afternoon (14:00 - 17:00) between July and August. It was espe-
cially noteworthy that the summer heat wave in 2010 increased not only the number of occupational heat disorder fatalities but also industrial accidents, suggesting that extreme heat stress at work would likely cause occupational safety problems as well as occupational health problems.

National administrative preventive measures against occupational heat disorders

1. Past administrative measures

As mentioned above, occupational heat disorder fatalities exceeded 20 for two consecutive years in the scorching hot summers of 1994 and 1995 (Figure-1). In order to cope with this situation, the former Ministry of Labour issued a notice in 1996 for concise guidance to implement qualitative working practices for occupational heat disorder prevention (the Notice 1996).

Nevertheless, occupational heat disorder fatalities did not decrease drastically thereafter (Figure-1). Thus, the Japanese Ministry of Health, Labour and Welfare (MHLW) issued a notice in 2005 to recommend the WBGT (wet-bulb globe temperature) index for occupational heat strain.

Table-1 Outline of preventive measures against occupational heat disorders (Notice 2009)

1. Work environment management
   
   (1) Reduction of WBGT values at workplace
      - Provide general air movement, reduce process heat and water vapor release and shield radiant heat sources such as direct sunlight
   
   (2) Development and maintenance of resting area
      - Air-conditioned or shaded cool resting area,
      - Body cooling facility,
      - Hydration equipment

2. Work management

   (1) Reduction of work time
      - Ensure cessation or break at work,
      - Shorten continuous work time,
      - Avoid high metabolic rate work,
      - Change in workplace
   
   (2) Heat acclimatization (acclimation)
      - Set heat acclimation period more than 7 days for unacclimatized workers at end of rainy season
   
   (3) Encouragement of water and salt intake
      - Regular intake of salted water (0.1〜0.2%) before, during and after work regardless of thirst feeling (encourage drinking 1 or 2 cup of salted water every 20 or 30 minutes depending on physical work level)
      - Checklist for drinking salted water

3. Work clothing

   - Wear work clothing of high air and moisture permeability,
   - Use cooling vest,
   - Don a hat of high air permeability under direct sunlight

4. Inspection of work

   - Check drinking salted water at periodical interval,
   - Monitor health status and early signs of heat disorders of workers

5. Health management

   (1) Action to the result of health examination
      - Workplace change or job reallocation based on occupational physicians’ opinions for high risk workers with diabetes, hypertension, cardiovascular diseases, renal failure, neuropsychiatric disorders, dermatosis
   
   (2) Maintenance of healthy lifestyle
      - Guidance and consultation for high risk lifestyle such as sleep deprivation, poor physical condition, excessive drinking overnight, excluding breakfast, fever caused by flu etc, dehydration by diarrhea etc, obesity
      - Health guidance to workers with high risk to heat disorders and proposal of the need to employers

6. Monitoring of heat strain

   - Prepare clinical thermometer and scales at resting area and monitoring heat strain of worker
   - Discontinue work when any of the following:
     > Sustained (several minutes) heart rate is in excess of 180 bpm (beats per minutes) minus the worker’s age in years (180-age) for workers with assessed normal cardiac performance
     > Recovery heart rate at one minute after a peak work effort is greater than 120 bpm
     > Body core temperature does not recover to the level before work
     > Weight loss over a shift is greater than 1.5% of the weight
     > Subjective signs such as extreme fatigue feeling, nausea, dizziness and blackout occur

7. Occupational health education

   - Provide accurate instruction, training programs, and information about heat stress and strain early sign and preventive and first aid method and cases of heat disorders

8. Emergency measures

   - Ensure emergency contact
   - First aid procedure
for use to evaluate environmental heat risk at work quantitatively and objectively (the Notice 2005). Furthermore, reexamining the Notice 1996, working practices for occupational heat disorder prevention, MHLW newly proposed a comprehensive occupational health management approach and issued a notice in 2009 requesting that the relevant industries and entities implement new occupational health management for occupational heat disorder prevention (the Notice 2009). The Notice 2009 stipulated a systemic and integrated approach consisting of environmental management based on WBGT reference values, work management, health management, occupational health education, and first aid (Table-1). The Notice 2009 has become a theoretical and practical basis of preventive measures against occupational heat disorders that have been implemented by MHLW; most of the notices issued thereafter have referred to it.

The main points of preventive measures stipulated in the Notice 2009 are summarized as the following five items:

1) Reduction of WBGT value based on measurement and evaluation of it
2) Planning to set a period of acclimatization to heat
3) Regular intake of water and salt regardless of feeling thirsty
4) Wearing a work uniform with high permeability to air and moisture
5) Health management in daily life (such as the prevention of ill health or sleep deprivation, care for workers with acute and chronic diseases).

In fact, when a total of 65 occupational heat disorder fatalities occurring during the two years of 2010 and 2011 were examined in terms of implementation status of the above five points as preventive measures against occupational heat disorder, the following characteristics were found: in 62 cases (95%), the WBGT values had not been measured for evaluating environmental heat stress at work; in 54 cases (83%), water and salt intake regardless of feeling thirsty had not regularly been performed; and in 46 cases (71%), the setting of a heat acclimatization period before work had not been planned. These findings suggest that the implementation of the measures stipulated in the Notice 2009 may have a close association with occupational heat disorder prevention.

2. Current administrative measures

Through the Notice 2009, MHLW strengthened the preventive measures against occupational heat disorders more thoroughly than in the past. However, according to a report on occupational casualties prepared by MHLW, casualties as well as fatalities due to occupational heat disorders were found still to occur frequently, especially in summer outdoor work (Table-2). Therefore, the further enhancement of preventive measures against occupational heat disorders has been an urgent issue to address.

Thus, MHLW listed preventive measures against occupational heat disorders as one of the priority measures in the 12th Occupational Safety & Health Program (2013-2017 fiscal year). Reviewing the recent change in the number of occupational heat disorder casualties (Table-2), MHLW set a goal of reducing the number of individuals taking at least four days of sick leave due to occupational heat disorders by at least 20% in the five years from 2013 to 2017 relative to the status in the five years from 2008 to 2012.

Furthermore, the following two items are stated as measures to be implemented.

1) Introduce regulations governing outdoor work:
   By reviewing the situations in which occupational heat disorders tend to occur, consider the mandatory measurement and evaluation of the work environment when taking necessary measures regarding outdoor work during a certain period in summer.

2) Formulate objective evaluation criteria for protective products against occupational heat disorders:
   Some products used as measures against occupational heat disorders at the workplace may

Table-2 Change in the number of occupational heat disorder cases during the last 10 years (2002-2011) (total number of cases in five years)

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<tbody>
<tr>
<td>Number of cases</td>
<td>1,066</td>
<td>1,211</td>
<td>1,354</td>
<td>1,267</td>
<td>1,733</td>
<td>1,886</td>
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(Source: Report on occupational casualties)
somewhat lower the temperature in some body parts, but they may not always reduce the heat strain. To evaluate products, formulate and disseminate functional evaluation criteria from the standpoint of the effectiveness of reducing the WBGT value.

In the next section, the author gives his personal view of how we should address the challenges of formulating objective criteria to evaluate the effectiveness of protective products against occupational heat disorders.

Issues of administrative measures: How should we evaluate the effectiveness of products to protect against occupational heat disorders?

There are many kinds of body cooling products to protect against occupational heat disorders, such as a cool vest or a cool scarf, which are currently commercially available. However, how is the effectiveness for occupational heat disorder prevention or for the reduction of heat stress and strain evaluated before they are released onto the market?

There may be some cases in which the effectiveness is determined simply based on the wearer’s subjective judgment, such as a cool sensation or a pleasant feeling. Upon light physical work in a moderately hot environment, there is only a small risk of a rise in the body core temperature. In such conditions, we could consider that the products are effective, at least psychologically. From this result, however, it does not necessarily follow that these products could also be effective for suppressing a rise in body core temperature upon heavy physical work in extremely hot environments.

In fact, from our experimental study simulating recovery work at TEPCO’s Fukushima Dai-ichi NPP in extremely hot conditions, we found that, upon heavy physical work, some body cooling products available on the market had little effect on suppressing a rise in body core temperature. We also found that, upon light physical work, single use of a powered air-purifying respirator or cool vest is not effective, but that their combined use is significantly effective for reducing physiological and psychological heat strain.

1. Physical approach for evaluating the effectiveness of products to protect against occupational heat disorders

For evaluating the effectiveness of commercial products to protect against occupational heat disorders, we should first understand the physical mechanism of how human body temperature is maintained at about 37°C.

Body core temperature (hypothalamus temperature, aortic blood temperature, rectal temperature, etc.) is kept at about 37°C, even when the human body is exposed to hot or cold environmental stress. This is due to the fact that the amount of internal body heat produced by physical activity and basal metabolism is approximately balanced with that of body heat dissipated to the external environment as a result of body temperature regulation.

If the balance is disturbed and the amount of heat production is more than that of heat dissipation, heat is accumulated in the body (body heat storage), resulting in a rise in body temperature. On the other hand, when the amount of heat dissipation is more than that of heat production, body heat storage decreases, resulting in a fall in body temperature. This relationship can be simply expressed by the following equation.

Body heat storage \( S = \text{Heat production} - \text{Heat dissipation} \)

Body temperature rises when \( S > 0 \). This occurs if heat dissipation decreases and heat production concurrently increases. It also occurs if heat dissipation decreases even without any change in heat production and if heat production increases even without any change in heat dissipation.

Heat stress is a thermal condition in which the body heat storage becomes positive \( (S > 0) \), where heat production is greater than heat dissipation. Therefore, even in a cool or cold environment, body temperature is likely to increase due to heat stress if heat production becomes greater than heat dissipation \( (S > 0) \) upon strenuous physical activity with heavy clothing. It follows that strenuous physical work with protective clothing in very hot and sunny conditions outdoors without wind will cause extremely harsh heat stress, where the body core temperature easily increases, resulting from a situation in which heat production is much greater than heat dissipation \( (S >> 0) \).
One of the most effective measures against such severe heat stress at work is to reduce the amount of heat production. In other words, this involves replacing strenuous physical work with light physical work and taking frequent breaks. If it is difficult to take such measures, the alternative is to increase the amount of heat dissipation. The main factors relating to the amount of heat dissipation are air temperature, humidity, surface temperature of surrounding objects, radiant heat from the sun or a heating element, air velocity, and the thermal properties of clothing. Therefore, the increase in the amount of heat dissipation is made possible by lowering the air temperature and humidity in the workplace artificially using air-conditioning, spending time in the shade, wearing light clothes, or using a fan.

However, in situations in which even such measures are difficult to take, there is no alternative but to use a body cooling apparatus for protecting against overheating. As a consequence, many kinds of body cooling products have been released onto the market. However, as mentioned above, it is not clear how effective the products are for reducing heat stress and strain and for protecting against occupational heat disorders. The basic principle for evaluation is to verify whether the use of such products could decrease body heat storage by facilitating heat dissipation and preferably suppress a rise of body core temperature.

2. Physiological and psychological approaches for evaluating effectiveness of products to protect against occupational heat disorders

Upon the evaluation of commercial products to protect against occupational heat disorders, physiological and psychological approaches are also required, along with the above physical approach. Whether the products are effective as preventive measures against occupational heat disorders depends on whether heat strain is alleviated not only psychologically but also physiologically by using them.

Heat strain consists of physiological strain (body temperature rise, heart rate increase, body weight loss due to sweating, etc.) and psychological strain (hot sensation, thermal discomfort, feeling of exhaustion, etc.). It is important to confirm that the above-mentioned products could reduce all of these physiological and psychological strains.

You may feel comfortably cool by wearing commercial cooling products, or body sites at which these products are applied may look blue upon thermography analysis, suggesting their beneficial effect. These findings are, however, only part of the alleviation of overall heat strain. We should not ignore these effects, but additional information is required. In addition to these effects, we need to confirm that the body cooling products could alleviate physiological heat strain, such as a rise in body core temperature, heart rate increase, and body weight loss.

An early well-known physiological study characterized thermal comfort (pleasure) \( \text{[27]} \). This study demonstrated that a feeling of thermal comfort is not determined only by skin temperature, showing that subjects feel comfortable or uncomfortable with the same thermal stimulus on the skin depending on the temperature status of their body core. That is, hyperthermic subjects (rectal temperature: 37.8°C) felt very comfortable upon skin thermal stimulus (15°C), whereas hypothermic subjects (rectal temperature: 36.3°C) felt very uncomfortable with the same stimulus. From this physiological principle, it follows that hyperthermic individuals working in extremely hot environments would feel very comfortably cool if they use local body cooling products such as a cool vest. However, this measure to protect against heat stress does not necessarily ensure a reduction of body heat storage or result in the alleviation of physiological heat strain, such as a rise of body core temperature or heart rate increase. Therefore, it is essential to evaluate how effective these local body cooling products are for facilitating body heat dissipation and suppressing a rise of body heat storage.

3. Requisites for evaluating the effectiveness of products to protect against occupational heat disorders

In order to evaluate the effectiveness of commercial products to protect against occupational heat disorders, a practical and comprehensive assessment based on the above-mentioned physical, physiological, and psychological approaches is required.

To achieve this, the following three assessments should be implemented: (1) thermo-physical and heat-transfer engineering assessment, (2) work physiological assessment by real-work simulation...
experiments, and (3) feasibility and usability assessments in the field.

As for the first assessment (1), by utilizing a sweating head manikin and a movable sweating thermal manikin (Photo-1), it is possible physically and quantitatively to evaluate the cooling performance and thermal properties (thermal insulation and evaporative resistance) of cooling products for the head and body that are available on the market.

As for the second assessment (2), this requires examination of how much these cooling products could alleviate heat strain physiologically and psychologically through thermo-physiological experiments simulating real-work conditions in artificial climate chambers. In addition, there is also a need to examine whether they could improve work efficiency and performance as well (Photo-2). This is essential from the viewpoint of work physiology, so that you could avoid such situations as cooling products reducing work efficiency as well as heat strain, or improving work efficiency but exacerbating heat strain.

Even though the above two assessments are carried out, they are insufficient.

There still remains the third assessment (3): this involves confirming that the products are effective and feasible in actual workplaces in terms of wearability, usability, and durability, among others. Through these comprehensive and multiple assessments, the effectiveness and limitations of commercial products should be ultimately identified for preventive measures against occupational heat disorders.

**Conclusion**

It may be inevitable that global warming will continue in the coming decades. As a consequence, the numbers of heat waves and extremely hot days may increase in Japanese summers. There is also concern about a decrease in worker productivity as well as an increase in occupational heat disorders. To cope with this serious situation, the Japanese Ministry of Health, Labour and Welfare listed preventive measures against occupational heat disorders as one of the priority issues in the 12th Occupational Safety & Health Program (2013-2017...
fiscal years) and has been making sustained efforts to reduce occupational heat disorders by setting specific quantitative goals.

One of the issues of these administrative measures is to formulate objective criteria to evaluate products to protect against occupational heat disorders. To address this challenging issue, the following comprehensive approach consisting of multiple assessments would be required: (1) thermo-physical and heat-transfer engineering assessment, (2) work physiological assessment by real-work simulation experiments, and (3) feasibility and usability assessments in the field.

References