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Health impact of climate change on occupational health and productivity in Thailand

Uma Langkulsen, Nuntavarn Vichit-Vadakan* and Sasitorn Taptagaporn

Faculty of Public Health, Thammasat University, Rangsit Campus, Pathumthani, Thailand

Background: The rise in global temperature is well documented. Changes in temperature lead to increases in heat exposure, which may impact health ranging from mild heat rashes to deadly heat stroke. Heat exposure can also aggravate several chronic diseases including cardiovascular and respiratory disease.

Objective: This study examined the relationship between climate condition and health status and productivity in two main categories of the occupational setting – where one setting involves heat generated from the industry and the other with heat in a natural setting.

Design: This cross-sectional study included four industrial sites (pottery industry, power plant, knife industry, and construction site) and one agricultural site in the Pathumthani and Ayutthaya provinces. Exposure data were comprised of meteorological data and heat exposure including relative humidity (RH) measured by Wet Bulb Globe Temperature (WBGT) monitor. Heat index was calculated to measure the effects of heat exposure on the study population, which consisted of 21 workers at five worksites; a questionnaire was also used to collect data on workers.

Results: Among the five workplaces, the outdoor WBGT was found to be highest at 34.6°C during 12:00 and 1:00 PM at the agricultural site. It was found that four out of five study sites had heat indices in the 'extreme caution,' where heat cramp and exhaustion may be possible and one site showed a value of 41°C that falls into the category of 'danger,' where sunstroke and heat exhaustion are likely and prolonged exposure may lead to heatstroke. Productivity as perceived by the workers revealed that only the construction and pottery industry workers had a loss of productivity ranged from 10 to 60 %.

Conclusions: Climate conditions in Thailand potentially affect both the health and productivity in occupational settings.

Keywords: *climate change*; *occupational health*; *productivity*; *heat index*; *WBGT*

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Previous studies regarding illness due to heat are minimal due to many reasons. Since high temperature is the norm in Thailand, diagnosis of illness or categorizing causes of death often overlooks heat as a contributing factor. There have been reports of heat stroke among soldiers who receive basic training (1). Heat stroke that leads to serious illness or death in Thailand has been found sporadically for athletes in the marathon and, since 1987, there are reports of soldiers become severely ill with high fever and symptoms of system failures such as cardiovascular, circulatory, respiratory, ingestion system, as well as blood coagulation, decreased platelets, acute renal failure, and even death and these cases have been diagnosed by physicians as exertional heat stroke (2).

Falling ill from the exercise is often found in the Thai military. Pilot studies by the researchers from the Phramongkutklao Hospital with the 1st Infantry Regiment (King's Bodyguards) applied heat index (HI) values as preventive measures for heat stroke during training similarly as in the US Army in Europe, Australia (3). The results showed HI values proved to be satisfactory and effective in reducing the dangers of heat stroke during military training.

In the academic arena, only a small number of studies have been done on the effects of climate change and most have dealt with environmental impact with some focus on the subsequent effects on the health of the population at large. Studies on the impact on occupational health have been sparse with an indirect reference to the effects of

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climate change. Searching through the electronic databases of research literature that may have some reference to the effects of climate change on occupational health, few studies investigated the effects of heat in an occupational setting. Three studies have found similar results showing physiological differences in cardiovascular loading during work performance between Thai workers and their western counterparts where the heart rate of the Thai workers could be 25–30% higher than the Europeans at equal levels of oxygen consumption (4–6). These physiological differences among the Thai workers are suggestive of a review of Thailand's own standards; that is, thermal standards where the Wet Bulb Globe Temperature (WBGT) limit is similar to the American Conference of Governmental Industrial Hygienists (ACGIH) (7, 8). However, one study (9) showed that the incremental heart rate (IHR) in the subjects while performing heavy, moderate, and light work load were related to the WBGT HI. Results of these few studies highlight the need for further study.

Furthermore, some studies showed that exercise and heat stress induced higher heart rate and blood pressure in sedentary subjects (10). Previous studies indicated that the relationship exists between data of the interval between two ventricular depolarizations (R-R interval) deviation of the electrocardiography (ECG) and temperature environment during daily living and work for people living around Bangkok in Thailand (11). A study of Thai industries reported heat problems existed in 24% of small enterprises (12).

Thai media gives attention to the issue of climate change where articles including global warming and impact on health appear in several Thai newspapers periodically. These articles cover diverse topics ranging from academic research on health effects, clinical studies in heat stroke patients (13–21), adverse health effects from physical hazards in Thailand (22, 23), prevention and relief (24, 25) as well as policy issues, and policy strategies to reduce deaths (26). Thermal stress may be assessed by several factors but temperature has become a widely used measurement, while the WBGT is a more specific occupational heat-stress index (27). Due to its acceptance in the monitoring and control of hot environment standards of the International Standards Organization (ISO 7243) (27), WBGT is often used in occupational health and safety guidelines for working in hot environments.

In Thailand, the Ministry of Industry (MOI) and the Ministry of Labor (MOL) have enacted compatible thermal standards using WBGT as indicators for thermal stress conditions in the workplace. Both ministries' occupational health and safety laws prescribe the same WBGT levels for workers working with light, medium, and heavy work of 34, 32, and 30°C, respectively (8). There is a report of WBGT measurements in several workplaces during a 3-year study (28). At a construction site, indoor WBGT was found to be 22–30°C during winter (November–December 1991). In three foundry industries, WBGT varied from 21 to 37°C from June to October of 1992. As expected, the summer season showed the highest WBGT measurements. The WBGT in two ceramics factories ranged from 20 to 33°C during the rainy season to winter (August–December 1992), while WBGT in two glass factories were found to be 27–34°C during winter (November–December 1992). In the sugar cane and rice fields where working outdoors predominates, WBGT was found to be 20°C–32°C during winter (January–February 1992) and 26–29°C during summer (March–May 1993). Those who work in industries that involve heat in its production were exposed to the higher heat level, but high levels were record in all workplaces including the agricultural sector.

Recognizing the importance of heat in the area of occupational health, mitigation programs have been introduced to reduce problems related to heat stress. Work Improvement in Small Enterprises (WISE) was implemented at a lamp manufacturer where environmental heat posed the possible problem of heat stress to Thai workers. The program aimed at improving the workers' productivity (29, 30). Similarly, the implementation of the participatory WIND (Work Improvement in Neighborhood Development) program led to concrete improvements in the daily work life of farmers (31). To narrow the gap in evidence that can be utilized for policy and mitigation measures development, this study provided information that can be used: (1) to analyze the effects of climate change on workers, and (2) to recommend appropriate/applicable cooling approaches for workers to prevent health impacts and to increase productivity.

Methods

Our study was descriptive in nature and aimed to examine the relationship between climate variables and health status in two main categories of an occupational setting where one setting involves heat generated from the industry and the other deals with heat in a natural setting. The data collection took place between September and October of 2009, which was considered the rainy season in Thailand when the temperature may not be in the highest annual range.

Selection of study location

The study focused on two provinces, Pathumthani and Ayutthaya, where there is a high concentration of factories as well as a well-established agricultural sector. These two provinces represented typical occupational settings with environmental conditions (high temperature and relative humidity – RH) that were the main interest of this study. Ayutthaya as well as Pathumthani, located

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in the central plains, experiences three seasons: the hot season from March to May, the rainy season from June to October, and the cool season from November to February.

Information gathering and data collection

Data collected for this study composed of both primary and secondary data, and the data collection period extended from October 5 to October 16, 2009. Data routinely collected related to the climate situation in Pathumthani and Ayutthaya. These data were collected by the Meteorological Department at Pathumthani and Ayutthaya meteorological stations and publicly available electronically.

The WBGT is a heat exposure index that combines temperature, humidity, wind speed, and heat radiation into one number expressed as degrees Celsius. It can be interpreted in terms of health risk and impact on productivity (32–34). The HI is a simpler index that combines air temperature and humidity (either the RH or the dew point – a measure of absolute humidity) (35). The relationship between these measurements provides a more scientific way to identify the health risks of heat than just temperature. The heat index chart gives some guidance on the heat categories and gives predictions as to the likelihood of heat illnesses in particular categories as shown in Table 1.

Primary data involved information pertaining to anthropometry data of the workers and the measurements of WBGT, RH, and workers productivity. The WBGT and humidity were measured by using QuestTemp° 34 equipment. The WBGT measurements were taken during five consecutive days from 6:00 AM to 6:00 PM at one point in the workplace such as the worksite area near a heat source.

Information on the workers' perception of their workplace environment and other related information were collected by face-to-face interviews. Questions included age, type of work or occupation, and heat stress. Information was also collected on how bad the heat stress can be in the hot season, as well as questions about the hot season heat affecting different aspects of the work. The questionnaire also contained questions concerning workers taking time off during the hotter parts of the day as well as the workers actions to reduce any heat effects.

Interview questions regarding productivity loss were asked about daily work output that could be quantified and how much work output can change as a result of heat. This study expressed productivity loss in terms of change of the daily work output. Daily work output was measured in terms of volume or quantity of items produced. Productivity loss was calculated as a change of daily work output using the formula:

$$\text{Productivity loss (\%)} = \left[\frac{\text{Change of daily work output as a result of heat (unit)}}{\text{Daily work output could be quantified (unit)}}\right] \times 100$$

Study population and sampling design

The study population consisted of workers at five worksites employed in industrial, agricultural, and construction sectors in Pathumthani and Ayutthaya. Types of industry include pottery industry, power plant, and knife industry. Purposive sampling was used in this study.

Exposure results

Since WBGT and RH measurements were monitored during the end of the rainy season, RH was very high or close to 100% in the early morning and decreased gradually after sunrise. WBGT was highest during 12:00 and 3:00 PM each day and can be expected to be much higher during summer. Among the five workplaces, outdoor WBGT was found to be highest at 34.6°C during 12:00 and 1:00 PM at Sam Khok vegetable field. The

Table 1. Heat index chart

Category	Heat index	Possible heat disorders for people in high risk groups
Extreme danger	130°F or higher (54°C or higher)	Heat stroke or sunstroke likely
Danger	105–129°F (41–54°C)	Sunstroke, muscle cramps, and/or heat exhaustion likely Heatstroke possible with prolonged exposure and/or physical activity
Extreme caution	90–105°F (32–41°C)	Sunstroke, muscle cramps, and/or heat exhaustion possible with prolonged exposure and/or physical activity
Caution	80–90°F (27–32°C)	Fatigue possible with prolonged exposure and/or physical activity

Source: National Oceanic and Atmospheric Administration's National Weather Service (NOAA's NWS), U.S. Department of Commerce, 2009.

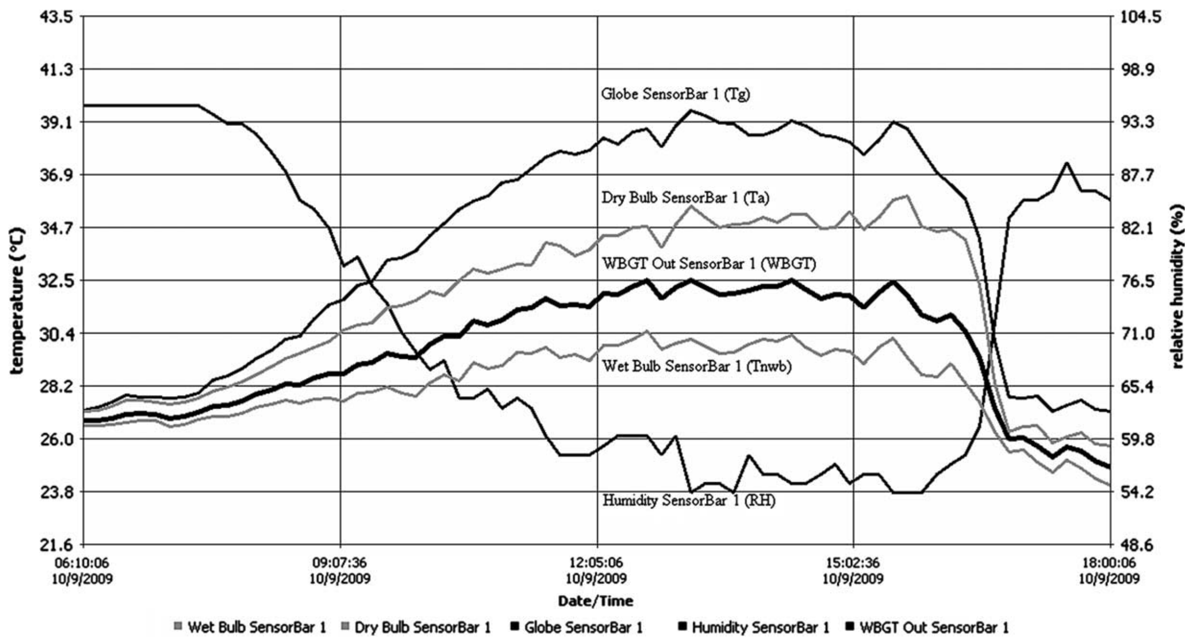

Fig. 1. WBGT, temperatures, and RH variation within 1 day at Sam Khok pottery industry.

results of heat exposure at five workplaces and a brief summary for each worksite are as follows.

Worksite 1: Sam Khok pottery industry

The outdoor WBGT data for one day, 6:00 AM to 6:00 PM, varied from 25.6 to 32.5°C with an average of 29.6°C as shown in Fig. 1. RH ranged from 54 to 95% with an average of 71.4%. The ambient temperature ranged from 26.1 to 35.9°C with an average of 31.5°C.

Worksite 2: Sam Khok vegetable field

The outdoor WBGT data for one day, 6:00 AM to 6:00 PM, varied from 25.2 to 34.6°C with an average of 30.7°C as shown in Fig. 2. RH ranged from 44 to 100% with an average of 60.0%. The ambient temperature ranged from 25.3 to 36.8°C with an average of 32.4°C.

Worksite 3: Ratchasuda construction building

The indoor WBGT data for one day, 6:00 AM to 6:00 PM, varied from 26.4 to 28.3°C with an average of

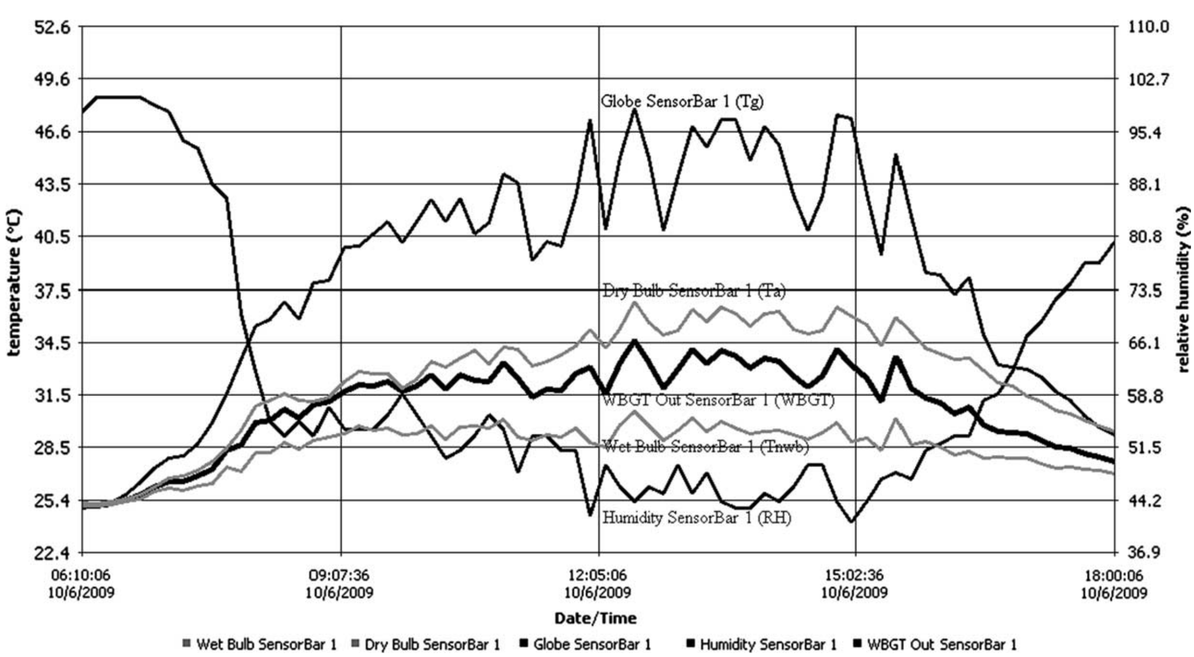

Fig. 2. WBGT, temperatures, and RH variation within 1 day at Sam Khok vegetable field.

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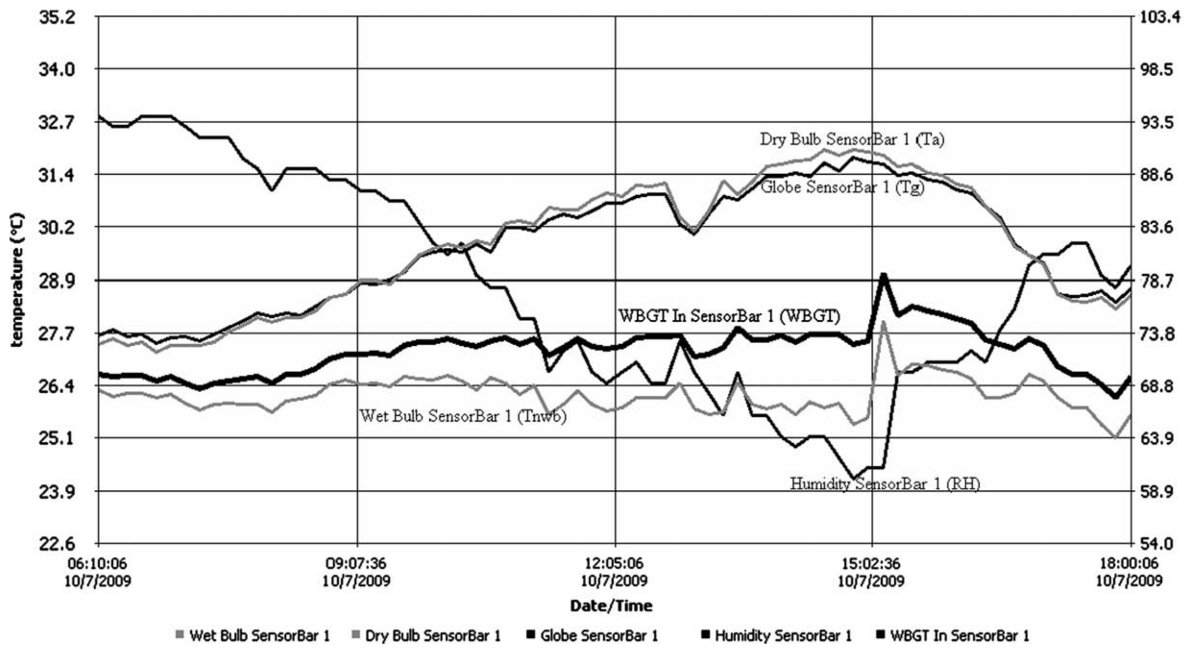

Fig. 3. WBGT, temperatures, and RH variation within 1 day at Ratchasuda construction building.

27.2°C as shown in Fig. 3. RH ranged from 64 to 93% with an average of 77.8%. The ambient temperature ranged from 27.4 to 32.0°C with an average of 29.7°C.

Worksite 4: Wang Noi power plant

The indoor WBGT data for one day, 6:00 AM to 6:00 PM, varied from 28.7 to 30.5°C with an average of 29.8°C as shown in Fig. 4. RH ranged from 54 to 75% with an average of 61.8%. The ambient temperature ranged from 31.1 to 35.3°C with an average of 33.6°C.

Worksite 5: Aranyik knife industry

The outdoor WBGT data for one day, 6:00 AM to 6:00 PM, varied from 25.5 to 29.6°C with an average of 27.7°C as shown in Fig. 5. RH ranged from 73 to 100% with an average of 84.1%. The ambient temperature ranged from 25.7 to 31.5°C with an average of 29.3°C.

Table 2 provides a summary of the heat exposure as measured by WBGT at the five workplaces during the study period. The vegetable field had the largest variation of WBGT – about 9°C within one day followed by the

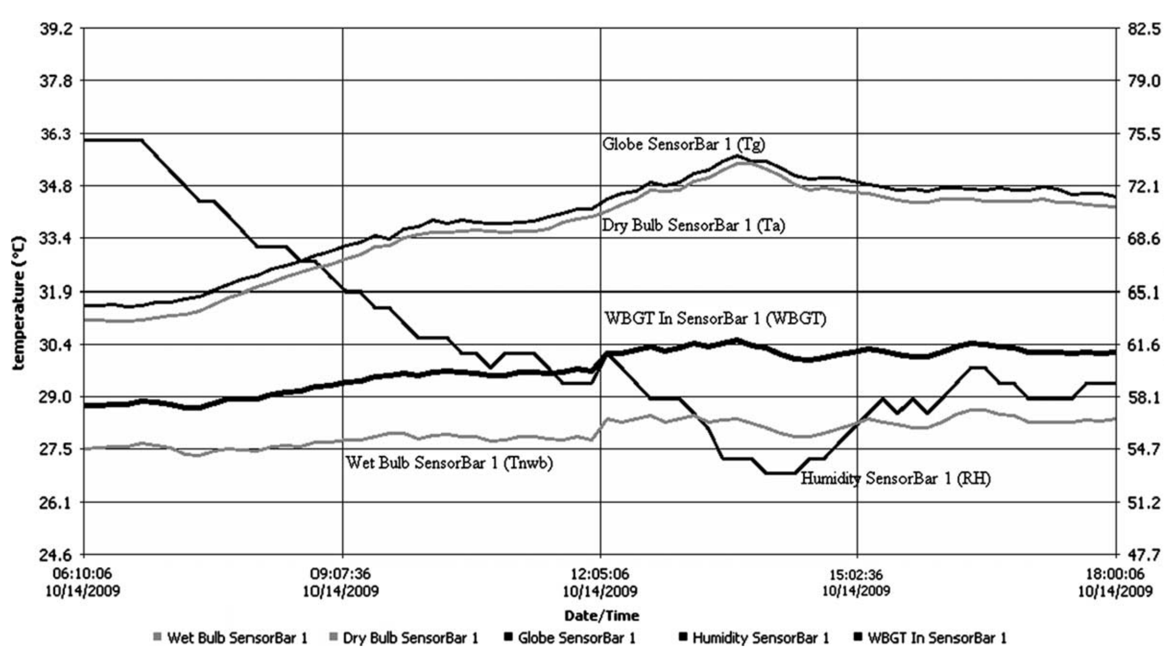

Fig. 4. WBGT, temperatures, and RH variation within 1 day at Wang Noi Power Plant.

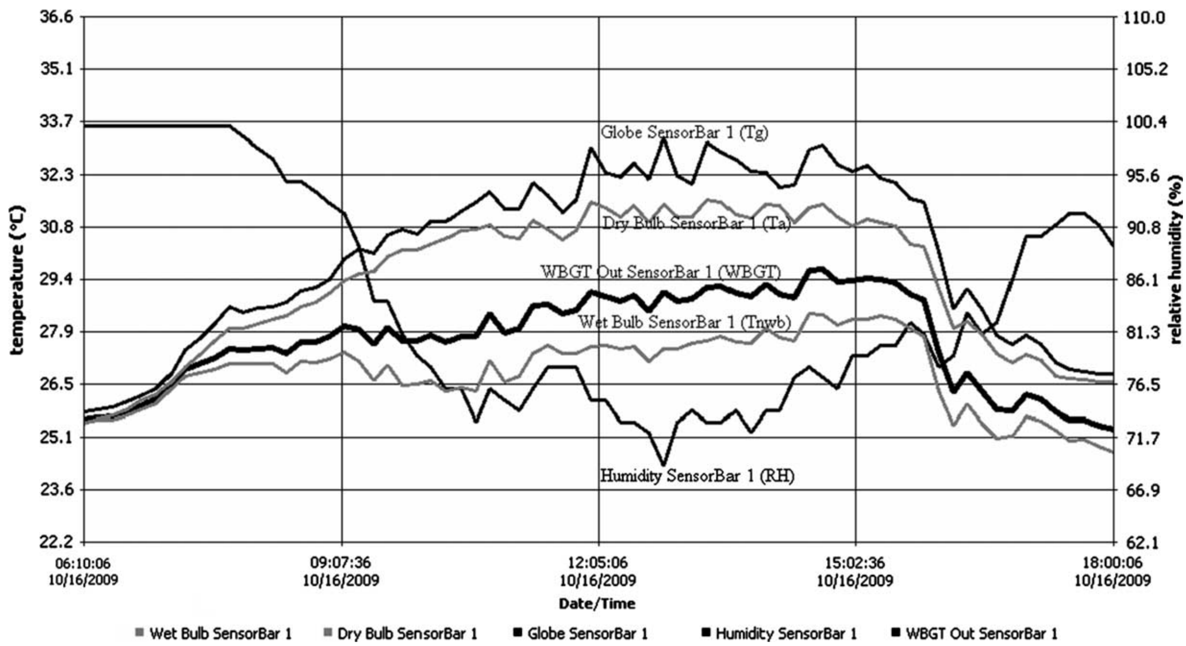

Fig. 5. WBGT, temperatures, and RH variation within 1 day at Aranyik knife industry.

pottery industry, knife industry, construction, and power plant. Interestingly, both vegetable fields and construction involved outdoor-related work activities but the vegetable field had a greater variation of WBGT. This may due to the surrounding environment of each place—the vegetable field was completely open to the sunlight, whereas the construction site may have structures providing shading areas.

Exposure-response estimation

In examining the HI for the five worksites in this study (Table 3), it was found that four out of five sites have HI in the 'extreme caution' where heat cramps and exhaustion may be possible. Closer examination of the HI for the power plant revealed that the value of 41°C may also fall into the category of 'danger,' where sunstroke and heat exhaustion were likely and prolonged exposure may lead to heatstroke. However, the risk of workers at the power plant being affected by this extreme heat may be minimal because most of the workers worked indoors with restricted involvement with outdoor activities.

Table 2. WBGT measurement data in five workplaces during October 2009

	WBGT (°C)
Sam Khok pottery industry	25.6–32.5
Sam Khok vegetable field	25.2–34.6
Ratchasuda construction building	26.4–28.3
Wang Noi power plant	28.7–30.5
Aranyik knife industry	25.5–29.6

Heat impacts and productivity loss

The production rate is presented as the productivity of the workers. Productivity loss is presented for each site for workers who reported a change of daily work output as a result of heat. Change of daily work outputs are compared with the measured values of the temperature, RH, WBGT, and HI as shown in Table 4. Vegetable field workers displayed no loss of productivity similar to workers in the knife industry, although the sample sizes were small. The information with regards to productivity as perceived by the workers revealed that only the construction and pottery industry workers assessed themselves with regards to loss of productivity. Two out of five (40%) pottery industry workers reported the average productivity loss per worker as 15%, while the others reported no loss of productivity. For construction workers, more than half (60%) the workers, productivity loss varied from 10 to 66.7%. However, daily

Table 3. Heat indices for the five workplaces

	Temperature (Celsius)	Relative humidity (%)	Heat index (Celsius)
Sam Khok pottery industry	31	72	38.4
Sam Khok vegetable field	31	65	36.6
Ratchasuda construction building	29	81	35.8
Wang Noi power plant	33	63	40.9
Aranyik knife industry	29	86	35.5

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Table 4. Exposure level and productivity loss

Exposure conditions				Type of work: industry / Workers[a]						
T (°C)	RH (%)	WBGT (°C)	HI (°C)	Age (yr)	Gender	Working hour (h)	Length of breaks (min)	Cooling actions	Productivity loss (%)	Working conditions
Worksite 1: Sam Khok pottery industry										
31.2	72.3	29.3	38.4	36	F	8	10	Shade, drink	20	Outdoors
31.2	72.3	29.3	38.4	39	F	8	10	Shade, drink, bath	10	Outdoors
31.2	72.3	29.3	38.4	39	M	8	5	None	No change	Outdoors
31.2	72.3	29.3	38.4	38	M	8	10	Shade, drink	No change	Outdoors
31.2	72.3	29.3	38.4	32	F	8	5	Shade, drink	No change	Outdoors
Worksite 2: Sam Khok vegetable field				Type of work: agriculture						
31.3	65.2	30.1	36.6	58	F	6	120	Shade, drink	No change	Outdoors
31.3	65.2	30.1	36.6	49	M	6	90	Shade, bath	No change	Outdoors
Worksite 3: Ratchasuda construction building				Type of work: construction						
29.3	81.0	27.1	35.8	27	M	8	60	AC, drink	No change	Indoors
29.3	81.0	27.1	35.8	35	M	9	10	Shade	66.7	Indoors
29.3	81.0	27.1	35.8	45	M	9	15	Shade, drink	40	Indoors
29.3	81.0	27.1	35.8	32	M	8	120	AC, drink	20	Indoors
29.3	81.0	27.1	35.8	63	M	8	10	Shade, fan	No change	Indoors
Worksite 4: Wang Noi Power Plant				Type of work: industry						
33.1	62.9	29.4	40.9	49	M	8	–	Fan, AC	N/A	Indoors
33.1	62.9	29.4	40.9	33	M	8	–	AC	N/A	Indoors
33.1	62.9	29.4	40.9	58	M	5	–	AC	N/A	Indoors
33.1	62.9	29.4	40.9	44	M	8	–	shade, AC	N/A	Indoors
33.1	62.9	29.4	40.9	40	M	7	20	Fan, AC	N/A	Indoors
33.1	62.9	29.4	40.9	45	M	7	15	Fan, drink	N/A	Indoors
Worksite 5: Aranyik knife industry				Type of work: industry						
28.8	85.6	27.3	35.5	76	M	3	30	Shade, drink	No change	Outdoors
28.8	85.6	27.3	35.5	43	F	4	60	Shade	No change	Outdoors
28.8	85.6	27.3	35.5	74	F	3	20	Shade, fan, drink	No change	Outdoors

[a]Productivity loss = change of daily work output as a result of heat; Working conditions of indoor = no direct sunlight exposure.
Note. T, temperature; RH, relative humidity; HI, heat index; M, male; F, female; AC, air conditioner; N/A, not applicable.

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work outputs among power plant workers were not applicable.

Prevention methods

Prevention methods used to reduce heat exposure and effects at five worksites found that most workers reported consuming fluids as needed during the course of their work shift. Each worker noted that when they feel themselves becoming overheated, they would find a cool place to sit down and drink fluids.

Conclusion

This study may be viewed as a pilot study to examine the effects of occupational heat exposure on the health and productivity of the workers. Although the study involved only five worksites, the results elucidated us to the presence of heat exposure problems at the workplace and provided useful insights for further research in this area. This study documented the WBGT and HI in the different types of industries where heat may be a health hazard. Results in all five sites indicated working conditions that can be defined as 'extreme caution' or 'danger' where heat cramps, exhaustion, and heat stroke may be possible. Taking into account that the study took place during the rainy season when the temperature may not be its highest of the year, the occupational heat stress in the summer season when the temperature reached its maximum may pose even greater danger to the workers' health and productivity.

Priorities of the problems of heat exposure in an occupational setting should be placed on its health effects. Other impacts from heat exposure need to be highlighted as well. Thailand strives to be an emerging industrial economy where we have transformed ourselves from an agriculture economy for the last few decades. Consequently, industrial growth is placed on the national agenda in all the previous as well as the present government. Productivity rests at the core of this growth. As shown in this study, heat stress may reduce productivity of the workers. Although most workers have adapted themselves to heat exposure and have taken action to find relief, the government sector must consider heat as a health hazard along with other industrial pollutants that threatens the health of workers as well as the public.

The management of heat stress at the workplace requires efforts from all stakeholders and not placing the burden only on the employees themselves. The stakeholders should include the employer as well as responsible government agencies both at the local and central levels. Interviews with the governmental officer from the local health Center revealed that there is a lack of awareness with regards to policy concerning maximum heat exposure at work. Moreover, the impact of heat on workers health has not been considered as a priority by the Ministry of Public Health at the central level as stated by a key informant of the Bureau of Occupational and Environmental Diseases, Department of Disease Control. Our aim is to develop further, more detailed research on this public health issue.

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***Nuntavarn Vichit-Vadakan**
Faculty of Public Health
Thammasat University
Rangsit Campus
Tambol Klong Nueng
Amphur Klong Luang
Pathumthani 12121, Thailand
Tel: +662 986 9213 9 ext. 7449
Fax: +662 5162704
Email: nuntavarn@tu.ac.th