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Hot Environment and Health Problems of Outdoor Workers at a Construction Site

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Abstract: The aim of this research was to understand hot working environment at a construction site in summer and its effects on health of workers. In the subjective construction site, some measures, such as taking a break during work, setting tents and electric fans, and drinking cool water, had already been taken to reduce heat stress. Twelve male workers were examined. The WBGT outdoors during work varied from 23 to 34°C. The time-motion study revealed that one subject worked exceeding 7 hours, and that the other one had little rest time and drank little water during work. Few items of subjective symptoms increased after work compared with before work. In blood chemical data, electrolytes and blood urea nitrogen did not change. Blood sugar before work was significantly higher than before lunch and after work. Two subjects showed serum osmotic pressures increased after work. Two had the tendency to increase the blood pressure during work. The measures seemed effective, because the effects of work were not remarkable in general. However, some problems were still pointed out. Thus, stricter work control and health care for workers are necessary, such as controlling working hours strictly and monitoring the water intake during work.

Key words: Hot environment, Construction site, Health problems, Outdoor workers, Measures, Work control

Introduction

Operations under high air temperatures and high humidity, or strenuous physical activities have a high potential for inducing heat stress to workers engaged in such operations. Outdoor operations conducted in hot environment, such as construction and waste site activities, are also likely to cause heat stress among workers.

An epidemiological research[1)] revealed that the death from heat stroke in the occupational field occurred at 27 and more degree at wet bulb globe temperature (WBGT). The relationship between the relative humidity and the dry bulb temperature showed that the death from heat stroke occurred at 34°C and more °C at dry bulb temperature when the relative humidity was less than 40%. On the other hand, it occurred at around 28–30°C at dry bulb temperature when the relative humidity was more than 65%. This shows that the relative humidity plays an important roll in occurring death from heat stroke. In Japan in summer, it continues 30°C and more at air temperature for many days, and the humidity is often high at the same time. Consequently, the risk of heat stroke is frequently high in summer. Some reports have shown heat strokes mainly occurred in summer[2–4)]. The number of heat stoke a year in the occupational field has a tendency to increase year by year from 1993[2)], and two thirds of it occurred in the construction industry in the year from 2000 to 2004[3)].

To prevent heat stroke, American Conference of Governmental Industrial Hygienists (ACGIH)[5)] states that workers should not be permitted to work when their deep body temperature exceeds 38°C (100.4°F). Not for a deep body temperature to exceed this temperature, ACGIH has established the threshold limit value for work according to

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WBGT[5]. With information on WBGT and the type of work being performed, it is determined how long a person can safely work or remain in a particular hot environment. Japan Society for Occupational Health has also established the occupational exposure limits for heat stroke[6, 7]. The conditions are shown for a healthy male person to work safely, effectively and continuously for one or two hours. In addition to such work control, some measures are often taken to reduce heat stress of workers in hot environment. Ventilation, air cooling, fans, shielding, and insulation are the five major types of engineering controls. Workers are allowed to take frequent rests or breaks in a cooler environment. There are, however, few reports on effectiveness of such measures.

The aim of this research was to understand hot working environment at a construction site in summer and its effects on health of the workers. In the construction site examined in this research, some measures, such as taking a break during work, setting tents and electric fans, and drinking cool water, had already been taken to reduce the heat stress of workers.

Material and Method

The subjective construction site was one constructing a flowing type hydroelectric power plant located along Hidakagawa River in the middle area of Wakayama Prefecture, Japan.

The construction had already started in the year before the research was performed. Some measures for safety and hygiene had been taken to get over the construction periods with no accident and no disaster at this construction site by the contract companies together with the parent company. As the measures against heat stroke in summer, the workers were allowed to take a break during work according to the permissible heat exposure threshold limit values established by ACGIH[5]. The manager monitored WBGT in front of the office twice a work day (morning and afternoon). Table 1 shows a sample record on a work day (July 23th, 1998). Temporary using tents were set up for the rest at an airy place within the workshop (Fig. 1). Electric fans were put for ventilation at the workshops constructing power plant premises. Automatic machines for drinking cool water were equipped at convenient places within the work area. Machines to make ice, and pots to keep water temperature cool were provided in front of the office for each party of workers to carry enough cool water.

The research was done on August 18th and 19th in 1998. They were both fine days. The work started at 8:30 AM and finished at 16:30 PM. The scheduled break was 20 min in the morning (10:00 AM–10:20 AM) and 20 min in the afternoon (14:40 PM–15:00 PM).

Working environment was monitored outdoors at the construction site with a heat index meter (Kyoto Electronics Manufacturing, WBGT-101). This instrument measures air temperature, humidity, wet bulb temperature, glob temperature and WBGT. The WBGT data can be switched outdoor or indoor. The measurement accuracy for WBGT is ± 1.0°C (at 15–35°C). Sampling interval was set 15 min.

Twelve male workers were served as subjects. Their age was 38.1 ± 13.1 yr. The time-motion study was done to understand the working conditions of each worker. The operation characteristics, work time, rest time and volume of water intake were monitored during work. To examine the health effects, questionnaires on subjective symptoms were taken before and after work. The questionnaire included 30 items on subjective symptoms established by Japan Society for Occupation Health[8] and 10 items related to work in hot environment. The blood sampling was taken before work, before lunch and after work. We measured the serum electrolytes, blood urea nitrogen (BUN), blood sugar and serum osmotic pressure.

Table 1. Sample records of work control on a day

Construction type	Worker	Limit for continuous work (°C)	WBGT in the morning (°C)	Work/rest regimen
Light	Reinforced concrete	26.5	29.5	25% Work, each hour
Light	Operation	30.5	29.5	Continuous work
Tunnel	Spraying	27.5	29.5	50% Work, each hour
Building	Air conditioning	29.0	29.5	75% Work, each hour

Fig. 1. Some measures taken at the subjective construction site.
a: a temporary using tent, b: an electric fan, c: an automatic machine for drinking cool water, d: pots available at places close to work area.

The blood pressures and heart rate were monitored during work with an ambulatory blood pressure monitors (A and D company, TM-2425) using an auscultatory technique, with the cuff fitted on the nondominant arm. The subjects were instructed to keep their arms still during blood pressure measurements. The ambulatory blood pressure monitors were programmed to measure blood pressures at intervals of 30 min. The heart rate was recorded every 1 min. Recording for each subject were accepted if more than 80% of the raw data were valid.

All subjects were carefully given an explanation of the contents of this research and then written informed consent was obtained from them.

Statistical analysis was performed using the SPSS statistical package Ver.11.0 for Windows (SPSS Inc.). Data are shown as mean ± standard deviation. A comparison of the differences in serum electrolytes, BUN, blood sugar and serum osmotic pressure at different measured time was performed by ANOVA for repeated measures. Any p-value less than 0.05 were considered statistically significant.

Results

The WBGT varied from 23 to 34°C as shown in Fig. 2. Judging from the occupational exposure limits for heat stroke established by Japan Society for Occupational Health[6, 7], the occupational exposure limit was 30.5°C for the work of which relative metabolic rate (RMR) was from 1 to 2 (light, 130–190 kcal/h), namely 1.8 to 2.7 metabolic equivalent (METs). The WBGT exceeded this temperature from 11:41, beginning of measurements, to 15:11 on Aug. 18th and from 10:50 to 13:05 on Aug. 19th. According to the permissible heat exposure threshold limit values established by ACGIH[5], the work/rest regimen seemed 25% work and 75% rest for each hour when the outdoor work-load on the day was around the upper limit of light work or the lower limit of medium work (200 kcal/h).

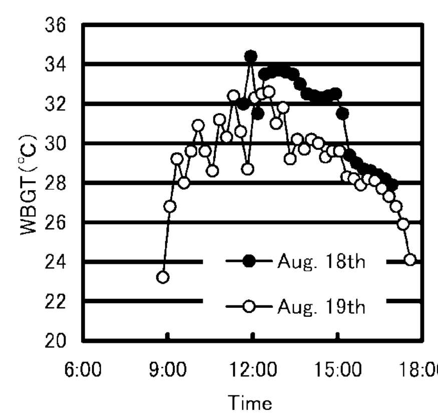

Fig. 2. WBGT measured on research days.

The time-motion study revealed that the working hours of the subjects varied from 5 h 20 min to 7 h 15 min, and that the mean working hours were 5 h 59 min (Table 2). The resting hours including lunch time was from 1 h 10 min to 2 h 50 min. Their average was 2 h 9 min. The scheduled break was 40 min during work excluding 1-h lunch time. The subjects also took the breaks at the wish of the worker. Water intake during work was from 450 to 1,550 ml and its average was 930 ml. There was no relationship between the resting hours and the volume of water intake.

Table 2. Working and resting hours, and volume of water intake

ID	Age (yr)	Working h	Working min	Resting h	Resting min	Water intake (ml)
1	20	5	50	2	10	450
2	50	5	35	2	5	1,150
3	46	5	45	2	15	1,550
4	46	5	20	2	50	830
5	37	5	50	2	0	910
6	23	5	50	2	20	1,200
7	29	6	20	1	55	780
8	60	6	50	1	10	550
9	24	6	0	2	0	650
10	27	7	15	2	0	700
11	46	5	50	2	30	1,450
12	49	5	20	2	30	900

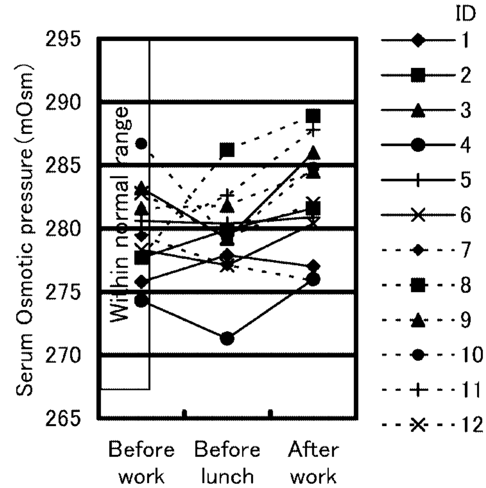

Fig. 3. Changes in serum osmotic pressure.

Table 3. Results of blood pressures and heart rate in ambulatory monitoring

ID	Before work: Systolic blood pressure (mmHg)	Before work: Diastolic blood pressure (mmHg)	Before work: Heat rate (beats per min)	During work: Systolic blood pressure 180 and more (%)	During work: Diastolic blood pressure 100 and more (%)	During work: Heart rate 110 and more (%)	
1	115	62	85	11	0	17	N
2	116	75	89	21	32	20	BP
3	118	83	89	0	6	50	N
4	96	74	81	0	0	2	N
5	117	94	84	-	-	21	-
6	115	78	87	0	0	29	N
7	138	78	92	0	0	7	N
8	208	122	92	50	25	4	HT
9	137	79	79	0	6	1	N
10	153	87	98	20	5	27	BP
11	-	-	-	-	-	29	-
12	151	110	94	39	44	44	HT

N: no significant change.
BP: tendency of increased blood pressure.
HT: hypertension (160/100 mmHg and more at before work).
-: missing.

Comparing the subjective symptoms after work with ones before work, some subjective symptoms of sleepiness and languidness, such as "feel sleepy" and "want to lie", difficulty to concentrate the attention, such as "feel anxious", localized body incongruity, such as "have stiff shoulder" and "feel thirsty (2 person)" and some symptoms related to work in hot environment, such as "perspire easily (2 person)" and "have a frequent heat rash", occurred after the work. However, few items of subjective symptoms increased after work. The subjective symptoms related to fatigue were not remarkable.

Serum electrolytes (Na, K, Cl) and BUN did not show the change. Blood sugar before work (103.4 ± 15.5 mg/dl) was significantly higher than one before lunch (89.6 ± 7.9 mg/dl; $p<0.01$) and one after work (93.0 ± 10.5 mg/dl; $p<0.05$). There was no significant change in the mean of serum osmotic pressure. We, then, examined the change of osmotic pressure using the individual data (Fig. 3). Serum osmotic pressures increased after work with two subjects (ID 8 and ID 11) compared with ones before work, although

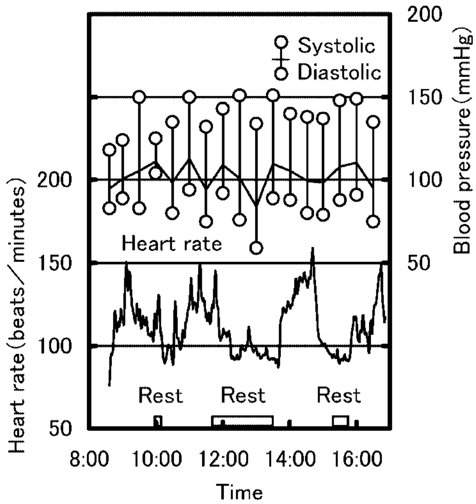

Fig. 4. Changes in blood pressures and heart rate with the subject (ID 3).

they did not reach to the abnormal level. One (ID 10) showed high serum osmotic pressure before work.

The results of the blood pressures and heart rate in ambulatory monitoring were shown in Table 3. The blood pressure data were accepted with 10 subjects. We defined the significant changes in blood pressures and heart rate when the systolic blood pressure exceeds 180 mmHg, the diastolic blood pressure exceeds 100 mmHg, or the heart rate exceeds 110 beats per minute. Six subjects had no significant change. Two (ID 2 and ID 10) had the tendency to increase the blood pressure. Two (ID 8 and ID 12) were hypertensive. With one subject (ID 3) 50 percent of heart rate exceeded 110 beats per minute (Fig. 4).

Discussion

In this research the effects of hot working environment on health of the workers were not remarkable in general because some measures had already been taken to reduce heat stress. However, one subject worked exceeding 7 h. The other one had little rest time and drank little water during work. Thus, stricter work control and health care for workers are necessary, such as controlling working hours strictly and monitoring the water intake during work.

Some engineering controls are taken to reduce the heat stress of indoor workers. General ventilation is used to dilute hot air with cooler air from the outside. Air conditioning is a method of air cooling. Local air cooling can be effective in reducing air temperature in specific areas. Another way is to increase the air flow or convection using fans, etc. in the work area. These engineering controls seem to be difficult to apply to measures for outdoor workers. Electric fans were put only indoors in the subjective construction site. Thus, administrative controls are important.

One of the measures is fluid replacement[9]. Cool water or liquid should be placed close to the work area, and workers should be encouraged to drink small amounts frequently. In some cases, drinks containing salt is recommended to prevent heat cramp caused by hyponatremia. In this research, cool water was made available to workers at places close to the work area. This may be the reason why serum osmotic pressures were within the normal range. The voluntary water intake may have been effective to prevent dehydration, although two subjects showed high serum osmotic pressure after work. One showed high serum osmotic pressure before work. It is also important to drink water before feeling thirsty at the beginning of work.

Blood sugar was higher before work than before lunch and after work. The subjects were not instructed to skip breakfast, and thereby they had the breakfast on the research day. They were often educated to have breakfast. Since serum electrolytes and BUN did not change during work, the breakfast may be effective to replenish the salinity before work.

Workers should be personally monitored, such as checking the heart rate, or body water loss[9]. Although standard is difficult to be set, the worker should be take a break, if the heart rate exceeds the standard. As shown in Fig. 4, the heart rate decreased quickly after the subject began to take a rest. Body water loss can be measured by weighing the worker on a scale at the beginning and end of each work day. Occupational Safety & Health Administration of U.S. Department of Labor recommends to shorten the next work cycle by one third if the heart rate exceeds 110 beats per minute, and to increase fluid intake if a weight loss exceeding 1.5% of total body weight is observed in a work day[9].

The hot environment effects on circulatory functions[10]. In the hot environment the skin vessels dilate, the blood flow increases in the skin, the skin temperature increases and then the heat radiation increases from the skin. The dilation of skin vessels simultaneously leads the decrease of blood pressures. The heart rate, then, increases against it, and the blood water increases to keep the circulatory blood volume. In this research, one (ID 3) had frequent the heart rate exceeding 110 beats per minute. He occasionally took short breaks and drank much water voluntarily. Two were hypertensive at the before work. One (ID 12) rested more than other workers, although he drank less water. One (ID 8) had blood pressures classified as severe hypertension and had not taken antihypertensive medication. He had the less resting time and the less water intake than others, resulting high serum osmotic pressure after work. It is necessary for hypertensive worker to reduce work voluntarily and to take more breaks for drinking water. The administrative control should be offered based on the individual profiles. Although the changes in the blood pressures were not remarkable in this research, monitoring the blood pressures is useful to evaluate the effect of work in hot environment on the health.

In the aged people, the reaction in the circulatory function seems weak[11, 12]. In this research, two (ID 2, 8) subjects were 50 yr old and more. Both were positive findings in the testing of blood pressures. Accordingly we should take the age of a worker into consideration[13].

Providing recovery areas can reduce the heat stress of workers. In the subjective construction site, temporary using tents were set up. Although we did not measure the air temperature under the tent, the conditions under the tent seemed to be satisfactory to reduce heat stress. An air-conditioned room is preferable, but it may be difficult to build it up at all sites, partially because of financial problems.

The human body can adapt to heat stress to some extent. This physiological adaptation is called acclimatization. The reaction of the autonomic nerves to prevent the increase of the body temperature is quick 3 to 4 d after beginning the work in hot environments. The hormonal regulation starts after 3–4 wk later[12]. The subjects in this research seemed to be acclimatized to hot environment, because they had been working there from the beginning of the summer in the research year. However, the acclimatization becomes less when the worker disengages from hot environment for a while. We should take it into the consideration. The permissible heat exposure threshold limit values established by ACGIH can be applied to nearly all acclimatized workers[5]. When workers are not acclimatized to hot environment, the rest regimen should be increased for such workers. International Organization for Standardization (ISO) provides the threshold limit value with differentiating those who are not acclimatized from those who are[14].

Behavioral adaptation is also important as a part of the acclimatization. In this research the work load is relatively low. This is one of the behavioral adaptations. It is a major behavioral adaptation to reduce working regimen voluntarily. The workers were allowed to take a break during work at the wish of the worker, when the WBGT in the morning or in the afternoon exceeded the limit for continuous work.

As one of the administrative controls, health education and training is the key to prevent heat stroke. National Institute for Occupational Safety and Health[15] states that a good heat stress training program should include at least the following components: 1) Knowledge of the hazards of heat stress, 2) Recognition of predisposing factors, danger signs, and symptoms, 3) Awareness of first-aid procedures for, and the potential health effects of, heat stroke, 4) Employee responsibilities in avoiding heat stress, 5) Dangers of using drugs, including therapeutic ones, and alcohol in hot working environment, 6) Use of protective clothing and equipment, and 7) Purpose and coverage of environmental and medical surveillance programs and the advantages of worker participation in such programs. In this research, a worker had little resting time and little water intake, although the subjects were often given health education to. The health education should be taken effectively.

At the construction site it is difficult to take engineering controls. Consequently, administrative controls play important rolls to reduce the heat stress of workers. At the subjective construction site the managers measured WBGT for the purpose of evaluating the risk of heat stroke[16], and thereby limited working hours of the workers. They gave health education to workers and encouraged them to drink cool water frequently. Such measures were effective to reduce the heat stress of workers, because the effects of work in hot environment were not remarkable in general. This report is one of the good examples to show the effectiveness of the measures for outdoor workers at the construction site. We expect that some measures in this research will be applied to other outdoor workplaces.

Some problems were, however, still pointed out in the time-motion study. Thus, stricter work control and health care are necessary, such as controlling working hours strictly and monitoring the water intake during work. Workers themselves should pay attention to take a rest even in light work load and drink enough water.

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