J. Kor. Soc. Cloth. Ind.
Vol. 2, No. 5, pp.411-415(2000)
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Physiological Strains of Asbestos Abatement Work Wearing Protective Clothing in Hot-Humid Environments

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Abstract : To be able to work safely and efficiency, the Threshold Limit Values (TLV) for work in the heat are widely used. Since these TLV are only applicable to workers in regular clothing, TLV should be adjusted when applied to the asbestos removal workers who wear extra impermeable protective clothing. Although abbreviated guidelines for heat stress exposure have been proposed, literature advocating their use in the asbestos removal industry is limited. Therefore, we planed a survey to evaluate the workload of asbestos abatement workers in summer, and an experiment with climatic chambers to evaluate the effects of resting in a cool environment between work periods. From these studies, we got following conclusions. There is a high risk of suffering from heat illness by asbestos abatement work in summer in Japan. It is proposed to create a cool room inside the workplace of asbestos abatement work to reduce thermal stress.

Key words : protective clothing, heat stress, asbestos, rectal temperature, heart rate

INTRODUCTION

Since the health hazard of asbestos fibers has been widely recognized, the number of asbestos abatement projects in buildings has increased rapidly. Because of the asbestos exposure risk, workers in the asbestos removal industry are advised to wear respiratory protective devices to prevent inhalation of asbestos fiber and to put on protective clothing to prevent the contamination of personal clothing.

To be able to work safely and efficiency, the Threshold Limit Values (TLV) for work in the heat (ACGIH 1987, ISO 1989, Japan Association of Industrial Health 1986) are widely used. Since these TLV are only applicable to workers in regular clothing, TLV should be adjusted when applied to the asbestos removal workers who wear extra impermeable protective clothing. Although abbreviated guidelines for heat stress exposure have been proposed, literature advocating their use in the asbestos removal industry is limited (Beckett *et al.* 1986).

Several studies have indicated that the physiological and psychological strains involved in wearing such impermeable protective clothing may be significant (Givoni and Goldman 1972, Atlerbom and Mossman 1978, Tanaka *et al.* 1978, Mihal 1981, Hormer 1988). Although various types of protective clothing and respirators were examined in these studies under several thermal conditions with various levels of workload, available information for use in the asbestos removal industry is not consistent. Thus more research is needed to examine physiological and subjective reactions of workers wearing protective clothing and respirators under practical conditions.

Therefore, we planed a survey (Tochihara *et al.* 1993) to evaluate the workload of asbestos abatement workers in summer and an experiment (Ohnaka *et al.* 1993)with climatic chambers to evaluate the effects of resting in a cool environment between work periods.

SURVEY

Methods

Subjects and protective clothing :

1) Survey in 1988

Physiological strains of eight male workers and their working conditions during asbestos abatement work were examined in an elementary school (School J) on August 4th and 5th in 1988. The workers wore disposable coveralls with hoods and shoe covers (Dupont Co., Type 1020EB), paper shorts and protective masks (Shigematsu Co., DR-28UAH).

2) Survey in 1989

Physiological strains of four male workers and their working conditions were examined in a junior high school (School W) on August 3rd in 1989. The workers wore disposable coveralls with hoods and shoe covers (Dupont Co., Type 1020EB) and paper shorts. In addition they

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wore protective masks with a blower (Shigematsu Co., AP-01-EC).

Measurements : The environmental conditions, i.e. dry and wet bulb temperatures, air velocity and globe temperature were measured outdoors and inside the workplaces. We considered time schedule and the details of the work.

Sweat rate (SR) was estimated from the changes in nude body weight after each segment. Rectal temperature (Tre) and heart rate (HR) were measured every minute by the memories. The measurements of Tre and HR were conducted only for several workers.

Results

Thermal conditions : Since the summer in 1988 was relatively cool, temperatures of the workplaces in 1988 (24.6-26.8°C) were lower than those in 1989 (27.8-28.8°C). Relative humidity at the workplaces was extremely high (over 85%) due to waterspray used to reduce the amount of asbestos in the air. Globe temperatures in the workplaces were almost the same as dry bulb temperatures. Air velocities in the workplaces were between 0.1 and 0.15 m/sec.

Work schedule : Work schedules of asbestos abatement work for Subject A and B in 1988 and Subject I and J in 1989 were shown in Table1. There were several kinds of work in the workplaces, e.g. removing asbestos from ceiling, putting asbestos into bags, repairing of ceiling, preparation of spraying, spraying, sweeping. The length of one work segment without the sweeping were between 46 and 95 minutes. The average time was 72 minutes.

Sweat rate : Sweat rates per one hour for each work segment were presented in Fig. 1. Average SR during the removal of asbestos from the ceiling at AM1 and AM2 on August 4th in 1988 were 217 and 415 g/h, respectively. The SR at AM2 were larger than those for any other conditions. Average SR during the removal of asbestos from the ceiling at AM1 and during the disposal of asbestos into bags at AM2 on August 3rd in 1989 were 504 and 605 g/h, respectively. These values were considerably higher than the corresponding values in 1988.

Table 1. Work schedule of asbestos abatement

August 4, 1988	August 5, 1988	August 3, 1989
9:15(AM1) removing asbestos from ceiling 10:30(85min)	11:15(AM1) repairing of ceiling 12:01(46 min)	9:50(AM1) removing asbestos from ceiling 11:25(95 min)
11:29(AM2) removing asbestos from ceiling 12:25(56 min)	13:42(PM1) preparing for spraying 15:05 (83 min)	13:30(PM1) putting asbestos into bags 14:55(75 min)
13:50(PM1) removing asbestos putting asbestos 14:55(65 min)	16:00(PM2) spraying 17:21(81 min)	15:52(PM2) sweeping 16:11(19 min)
15:56(PM2) putting asbestos into bags 16:58(62 min)		

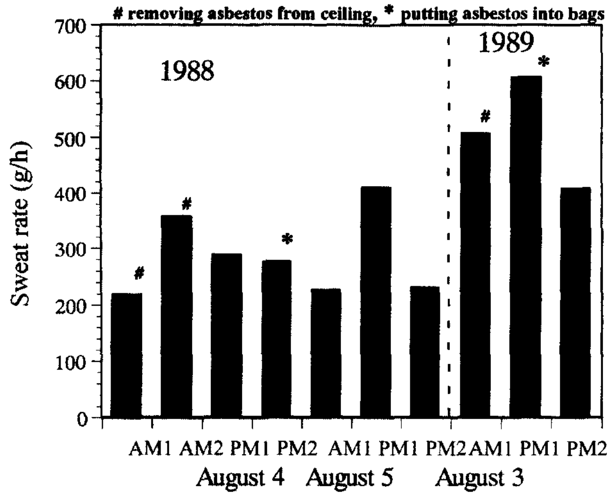

Fig. 1. Sweat rate during asbestos abatement work.

Rectal temperature and heart rate : The maximum Tre during work in 1988 was 38.3°C. Heart rates during work in 1988 were between 100 and 140 beats/min. Fig. 2 showed the changes in HR and Tre of Subject J during the removal of asbestos from the ceiling at AM1 in 1989. The heart rates of the worker increased up to 170 beats/min and stayed on this level for 50 minutes during the asbestos abatement work. During this work, Tre of this subject increased 2.3°C,

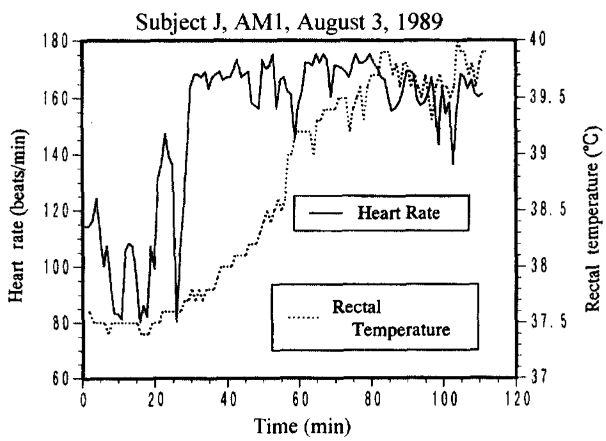

Fig. 2. Changes in rectal temperature and heart rate during asbestos abatement work (Subject J).

and body weight loss was 573 g/h. Similar changes in HR and Tre were also found at PM1 in 1989.

Discussion

Since the summer in 1988 was a cool summer (Tokyo Astronomical Observatory 1989), the temperature in the workplaces were between 25 and 27°C. Although SR during the work were larger than those during work with regular clothing, HR and Tre were not high enough to raise fears of heat illness.

On the other hand, physiological strains during work in 1989 were considerably higher than in 1988. Average SR during the removal of asbestos from the ceiling in 1989 was 504 g/h; this value was 2.3 times higher than the average SR during the same work in 1988. Moreover, HR were between 140 and 170 beats/min, and Tre reached almost 40°C. These results indicate that there is a high risk of suffering from heat illness during asbestos abatement work in summer in Japan.

Since work intensity and protective clothing were almost same in 1988 and in 1989, the differences in physiological strains might be due to the differences in temperatures of the workplaces. The temperatures of the workplaces in 1989 were 28-29°C, which is only 2-3°C higher than the temperatures in 1988. The effect of this difference on physiological strain would be negligible under regular humidity (Miura *et al.* 1972), but under high humidity (almost 90%), the physiological strains were very high for the workers.

The workers did not always work during the work segment, they took several rests inside the workplaces. Since every time they leave the workplaces, they have to dispose of their clothing and take a shower. It is difficult to shorten the time in the workplaces. Moreover, it is impossible to replace water loss in the workplaces. Therefore, there is a high risk of suffering from heat illness during asbestos abatement work compared to other work in hot environments.

EXPERIMENT

Methods

Subjects and protective clothing : Seven healthy male students (Subject A-G) volunteered as subjects. They were informed of the protocol and potential risks and gave written consent to participation. Their mean (SD) age, height, weight and Vo_2max were 19.1 (0.6) years, 1.71 (0.05) m, 69.6 (5.9) kg and 3.5 (0.4) l/min, respectively. The protective clothing commonly used by the asbestos removal industry-light, disposable coveralls with hoods and shoe covers (Dupont Co., Type 1422, Polyethelene)-were worn over shorts. Protective air masks (Shigematsu Co., DR-28UAH) were also worn.

Procedure : Thermal conditions adopted in this study were as follows: (1) hot conditions (35°C/85%RH), cool condition (20°C/85%RH), and (3) hot/cool conditions (working in hot conditions and resting in cool conditions). After 11-min rest, the subjects worked on an ergometer (70W) for 18 min. This work/rest schedule was repeated three times under the three thermal conditions. In hot/cool conditions, the subjects rested after work in another climate chamber which was set at 20°C. Only the third recovery in hot/cool conditions was taken in hot conditions. All tests lasted until one of the following criteria was met: (1) Tre over 39.0°C; (2) HR over 170 beats/min; (3) objective signs of severe fatigue; or (4) subjective feelings of inability of proceed.

Measurements : Rectal and skin temperatures at five sites were recorded every minute during the experiments. Mean skin temperature (Tsk) was calculated by the formula of Ramanathan (1964). Heart rate was obtained continuously by electrocardiogram using chest leads. Total SR was estimated from the changes in nude body weight.

Results

In hot conditions, two tests were terminated because of high HR (at 74 min in Subject F) and Tre (at 83 min in Subject G). On the other hand, the subjects were able to continue for the entire 100 min in cool and hot/cool conditions.

The average (SD) of SR in hot and hot/cool conditions were 751(308) and 660(246) g/h, respectively, which were five and four times greater than that in cool conditions (149(40) g/h).

Average Tre responses were presented in Fig. 2. Rectal temperatures in cool conditions did not change significantly through the experiments. On the other hand, Tre elevated gradually after the first work period in both hot and hot/cool conditions. At the end of the experiments,

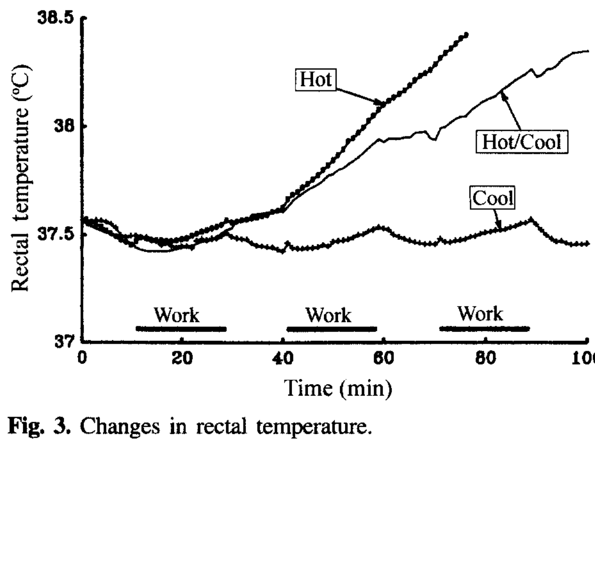

Fig. 3. Changes in rectal temperature.

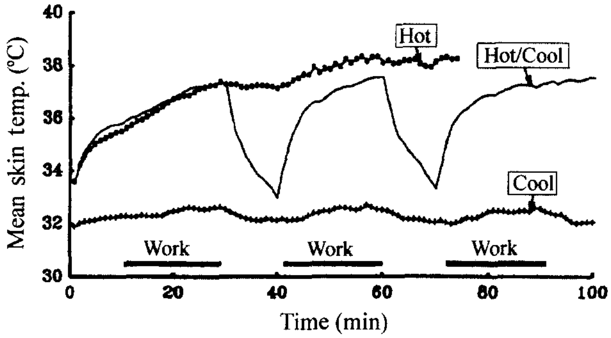

Fig. 4. Changes in mean skin temperature.

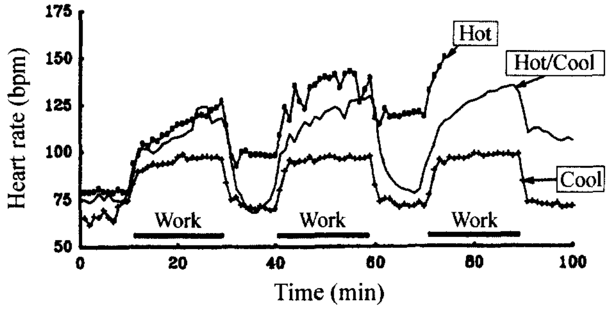

Fig. 5. Changes in heart rate.

Tre increased, on average, by 1.3°C in hot conditions. Although Tre increased in hot/cool conditions by 0.7°C, it was almost half of that in hot conditions. The time at which average Tre exceeded 38°C were 56 and 73 minutes, respectively.

Average Tsk responses were presented in Fig. 3. Mean skin temperatures in cool conditions were approximately 32°C and did not change with the time course of experiment. On the other hand, Tsk increased with time in hot conditions, and crossover to Tre after 30 minutes. Although Tsk increased to 37°C or more in hot conditions, it decreased to almost 33°C in resting under cool conditions.

Average HR responses were presented in Fig. 4. Heart rate during work in hot conditions did not approach steady state levels in contrast to those in cool conditions. During 12-min rest periods, HR in hot conditions did not recover to near resting levels and remained higher than those in cool conditions. Although HR during work in hot/cool conditions were higher than those in cool conditions, HR at pre-work was almost the same as that in cool conditions because of rapid recovery during rest periods.

Discussion

In summary, the increases in Tre and HR during the work period were not found in cool conditions. Although Tre increased in hot/cool conditions, it was almost half of that in hot conditions. The physiological strains were dramatically reduced by resting between work periods in a cool environment. Therefore, it is proposed to create a "cool room" inside the workplace to reduce thermal stress.

It is easy to create a small 'cool room' or 'cool space' by the use of a portable cooling device. Since the amelioration of thermal strain by resting between work periods in the cool environment was found in the present study, provision of a cool space inside the workplace and resting there between work periods should be required in asbestos removal work. Personal cooling equipment (Nunnely 1970, Mc Cullough *et al.* 1982, Bolockey 1970, Webbon *et al.* 1978, Kamon *et al.* 1986) is inappropriate in this industry as the workerís mobility is reduced and will affect the safety and efficiency of working at a height, when, e.g., scraping asbestos off the ceiling.

CONCLUSIONS

1. There is a high risk of suffering from heat illness by asbestos abatement work in summer in Japan.
2. It is proposed to create a cool room inside the workplace of asbestos abatement work to reduce thermal stress.

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(Received December 12, 2000)