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Ergonomics in Practice: Physical Workload and Heat Stress in Thailand

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This study consists of assessments of the thermal environment and physiological strain in tasks associated with airport, construction, and metal jobs. The number of male and female participants was 108. Environmental heat stress was evaluated with the WBGT index. Physiological strain was evaluated by the relative cardiovascular load (%CVL) based on the measurements of heart rate. Also the increase of body temperature, weight loss, and perceived discomfort were determinated. At work sites the assessments lasted for 2 to 4 hrs for each participant. The mean physiological strain exceeded the level of 30%CVL. Severe peaks (over 60%CVL) were observed in specific tasks being in agreement with perceived discomfort ratings. The increase of body temperature and weight loss in most cases remained within acceptable limits. For the most strenuous tasks, various ergonomic improvements were developed in consultation with workers and managers.

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ergonomics heat stress physiological strain

1. INTRODUCTION

Physical work that sets high demands on main muscle groups, for example, in terms of manual materials handling, static-postural load, repetitive movements, and large output of force, is still the main element of many jobs in Thailand (Intaranont & Vanwonterghem, 1993; Manuaba & Vanwonterghem, 1997; Yoopat, Glinsukon, Toicharoen, Boontong, & Vanwonterghem, 1998). Most of the jobs take place outdoors, where workers are exposed to direct solar radiation and humidity. Also similar conditions often occur in wide-spaced indoor workstations because of radiation from hot steel roofs and high humidity from cooling equipment. About one fourth (24%) of all small and medium-scale Thai enterprises are confronted with these thermal problems (Hasle, Chavalitnitikul, & Takala, 1985). Serious health risks related to excessive physical workload and heat stress have been identified within the frame of the sudden unexplained death syndrome (Gogh, 1990). Despite this it is still consistently denied; in many South-East Asian countries physical workload and heat stress are risk factors for occupational diseases (Yoopat, Glinsukon, Vanwonterghem, Louhevaara, & Vanoeteren, 1999).

The combined effects of physical workload and heat stress on workers have been studied extensively with the Wet Bulb Globe Temperature (WBGT) index (Standard No. ISO 7243; International Organization for Standardization [ISO], 1982). Thailand and other countries in this region approved the use of the WBGT for assessing the working environment in 1982. At present the WBGT has not been implemented in the Thai Working Act where regulations still include a permissive limit of 45°C for environmental temperature and 38°C for core body temperature. However, the Ministry of Labour, recognizing the high risks for health and safety decided to support the present project in order to prepare new legislation for Thai workers (Yoopat et al., 1998).

The aim of this study is to assess heat stress and physiological strain in some Thai work tasks that are demanding in terms of physical work load and heat exposure, and to consider measures of ergonomics for reducing physiological overstrain of workers.

2. MATERIALS AND METHODS

2.1. Participants

The participants were 50 women aged 32 (*SD* 7) years and 58 men aged 31 (*SD* 7) years. Their jobs mainly included materials handling, construction, and metal industrial tasks (Table 1). The materials handling tasks performed by 18 female cleaners of aircrafts and 16 male handlers of luggage were studied at the Bangkok airport. The construction tasks were done by 10 male carpenters, 2 female brick layers, 4 male brick layers, 18 female and 4 male material providers, and 2 male pile drivers. The metal industrial tasks included steel bar production, which was done by 12 female workers, and steel wiring performed by 21 male workers.

The results of a medical screening supplemented by a submaximal cycle-ergometer test, indicated that all participants were healthy. In the aforementioned occupational categories the estimated mean maximal oxygen consumption related to body weight varied from 35.3 to 45.4 ml/min/kg in men and 20.1 to 28.0 ml/min/kg in women (Table 1). The participants were informed about the study methods and protocol.

TABLE 1. Characteristics of the Participants in Different Occupation Categories

	Occupational Category					
	Materials Handling		Construction		Metallurgy	
Characteristics	Female ($N = 18$)	Male ($N = 16$)	Female ($N = 20$)	Male ($N = 21$)	Female ($N = 12$)	Male ($N = 21$)
Age (yrs)						
M	29	29	30	33	40	29
SD	4	4	9	11	6	5
Height (cm)						
M	153	166	153	162	156	167
SD	5	5	6	6	6	5
Weight (kg)						
M	53	64	56	59	57	62
SD	7	8	9	8	9	11
V_{O2max} (L/m)						
M	1.54	2.26	1.57	2.68	1.39	2.33
SD	0.26	0.58	0.35	0.55	0.21	0.43
V_{O2max} (ml/m)						
M	29.1	35.3	28.0	45.4	24.3	37.6
SD	3.3	5.5	5.0	6.1	1.8	7.1

Notes. V_{O2max}—maximum oxygen consumption.

2.2. Methods

The measurements of the work load factors were carried out during habitual work tasks and environmental conditions and were not affected by the research team.

Heat stress was evaluated by the Wet Bulb Globe Temperature (WBGT) index (Standard No. ISO 7243; ISO, 1982). Heart rate (HR) was measured by a BHL6000 system (Bauman & Haldi, 1992), which consists of three disposable electrodes connected to a data logger with a registration capacity of 24 hrs. The HR data were collected in an 8-pulse mode (averaging HR over 8 beats) and expressed in beats/min. The relative cardiovascular load (%CVL) was evaluated on the basis of HR as follows (Intaranont & Vanwonterghem, 1993):

$$\%CVL = 100\ [(HR_{work} - HR_{rest})\ /\ HR_{max(8hr)}],$$

where HR_{work}—mean HR in the job during various task performance, HR_{rest}—the lowest HR registered in a lying position, $HR_{max(8hr)}$—maximum acceptable HR for a work shift of 8 hrs, that is, $1/3(220 - age) + HR_{rest}$.

The %CVL evaluates the cardiovascular load or aerobic strain, and can be classified as follows: <30%CVL, acceptable level, no actions required; 30–60%CVL, moderate level, peak loads should be reduced within a period of weeks; 61–100%CVL, high level, peak loads should be reduced within a period of months; >100%CVL, intolerable high level, peak loads should be reduced immediately or work must be stopped.

The increase of core body temperature was estimated by oral temperature measurement with an Ellab device (CTD Thermometer, Denmark, 1985). Special attention was paid to drinking behaviour preceding the measurements of oral temperature and to breathing during the measurements that required nasal breathing.

Body mass loss was assessed with a weight balance with the accuracy of 100 g. Body mass was measured when participants had removed their shoes and wore dry shorts and t-shirts. During the study period, water and food intake was registered to calculate the amount of sweat released.

Perceived discomfort ratings were obtained with a questionnaire including the index of discomfort, that is, SWI (Vanwonterghem, Verboven, & Op De Beeck, 1985). The SWI rates the level of discomfort due to fatigue, perceived risks, mental concentration, task complexity, work rhythm and annoyance of responsibilities. These six negative factors were compensated by two positive elements: interest in the job and autonomy. The SWI index is calculated as follows:

$$SWI = [(negative) - (positive)] / 8.$$

The SWI index can be interpreted as follows: <1, no discomfort; >1–<2, slight discomfort; >2–<3, moderate discomfort, considering each item separately; >3–<4, annoying, measure are needed to alleviate discomfort within a period of months; >4–<5, very annoying, measures for alleviating discomfort are needed within a period of weeks; >5, intolerable, measures for alleviating discomfort are needed immediately.

2.3. Statistics

The data were evaluated with descriptive statistics using means, standard deviations, and ranges.

3. RESULTS AND DISCUSSION

3.1. Task Analyses

The luggage handling tasks encompassed the loading and unloading of luggage of various weights and sizes both to and from containers (19% of work time), the sorting of luggage (38% of working time). The remaining work time was spent on official breaks or in waiting (standing, sitting, walking) for arriving and departing flights. The cleaning of aircrafts and the handling of pillows, blankets, and bins amounted to 9 and 18%, respectively, of all work time. The remaining work hours included official breaks and waiting for arriving and departing flights. Both luggage handling and cleaning were done as continuous work in three shifts of 10–12 hrs. After three work shifts there were two shifts off.

In construction work, carpenters were occupied by woodwork for 62% of all work time and by assembling for 14% of all work time. The remaining hours were spent on official breaks and in waiting for the next work phases. Providers were occupied by the digging of soil (29 and 9% working time for men and women, respectively), by materials handling (15 and 35% working time for men and women, respectively), and walking 10 and 12% work time for men and women, respectively). The remaining time was spent on small operations and waiting.

Bricklayers were occupied by cement work for 15% of all work time both for men and women and by materials handling (21% of work time).

Pile drivers worked continuously for 80% of all work time. Occasional interruptions were due to supplies of piles or other materials and to the movements of machinery. Normal daily work time varied from 10 to 12 hrs.

In Thailand, there is almost no social security system available offering compensation for unemployment due to sickness absenteeism, accidents, or occupational diseases. Therefore, most construction workers take one day off every second week. They are mainly seasonal workers for a period of 6–8 months after which they return to their farms and families.

The tasks of steel workers consisted of producing steel wire in a highly mechanized process by remote control (5% of work time), machine work (1% work time), maintenance (2% of work time), and a series of short occasional operations like restarting, removing waste with a hammer and pinchers (14% of work time), and waiting (standing, sitting, walking; 57% of work time). In steel wiring, the length of the work shift was 8 hrs in three shifts with a normal sequential weekly rotation.

Female workers in steel production mainly did manual work at three different stations of the mechanized steel bar production process: at station 1 they put the rods to a cooling bed (swinging) for about 61% of working time. At station 2 they dragged the rods to a cutting bed (hooking) for 20% of working time and at station 3 the operators were cutting rods for 20% of working time. The remaining work time was spent on waiting because of technical problems or organizational delays. During break times workers sat or stood. Work time for this group was continuous for 8 hrs. In steel bar swinging, work periods consisted of 2 continual hours of work followed by rest periods of 2 hrs.

3.2. Thermal Environment

The results of physiological strain and the WBGT index in different occupational categories are presented for female participants in Table 2 and for male participants in Table 3.

The mean WBGT value for luggage loaders varied from 24.5 to 31.9 °C, and for sorters from 25.3 to 29.3 °C. The average WBGT value for cleaners when they worked inside the aircraft was 25.3 °C. During the period of waiting outdoors their mean WBGT value increased to 34.1°C.

In construction work, all tasks were performed outdoors. Depending on the time of day, weather conditions, and working environments (sometimes sheltered) the mean WBGT values varied from 29.2 to 34.2 °C. The mean WBGT value for the construction work was 30.3 °C.

TABLE 2. Results of Field Measurements in Female Participants

Occupational Category	Results of Field Measurements				
	CVL%	Increase BT (°C)	Weight Loss (%)	SWI	WBGT (°C)
Construction (*N* = 20)					
M	43	0.3	1.1	2.6	30.1
SD	10	0.2	1.0	0.9	1.1
Materials handling (*N* = 18)					
M	36	0.4	0.7	2.8	25.7
SD	12	0.3	0.6	0.8	3.7
Metallurgy (*N* = 12)					
M	52	0.4	1.1	2.7	29.4
SD	20	0.2	0.5	0.5	0.5
All (*N* = 50)					
M	45	0.4	0.9	2.7	28.9
SD	15	0.2	0.9	0.7	2.8

Notes. CVL%—relative cardiovascular load, Increase BT—increase of body temperature, SWI—rating of perceived annoyance, WBGT—Wet Bulb Globe Temperature.

TABLE 3. Results of Field Measurements in Male Participants

Occupational Category	Results of Field Measurements				
	CVL%	Increase BT (°C)	Weight Loss (%)	SWI	WBGT (°C)
Construction (*N* = 21)					
M	51	0.4	1.5	2.8	30.5
SD	15	0.4	1.2	0.8	2.2
Materials handling (*N* = 16)					
M	38	0.5	0.7	3.4	27.9
SD	14	0.4	0.5	0.6	1.7
Metallurgy (*N* = 21)					
M	39	0.5	0.9	3.0	28.5
SD	12	0.5	1.0	0.8	1.3
All (*N* = 58)					
M	43	0.5	1.1	3.0	29.2
SD	15	0.5	1.0	0.8	2.0

Notes. CVL%—relative cardiovascular load, Increase BT—increase of body temperature, SWI—rating of perceived annoyance, WBGT—Wet Bulb Globe Temperature.

In steel wiring, the mean WBGT value in the production hall was 28.5 °C. There were some heavy radiant sources of heat (42 °C) nearby ovens but they had a low effect on the total thermal environment because the production hall had good natural ventilation. Steel rods workers were subjected to straight radiation of heat from hot bars. The mean WBGT was about 30 °C, and the radiant temperatures exceeded the level of 35 °C. The problem was an obvious risk for the rod swingers who stood close to the bed receiving hot metal bars. Besides local ventilation sources (fans) the work area had natural ventilation as the structure of the production hall was open.

3.4. Physiological Responses

In the studied tasks, the estimated core temperature increased, on average, by 0.4 °C, which can be considered acceptable. Also within an acceptable range was the loss of body mass, which averages 1.1%, however the mean loss of body mass for construction workers was 1.5 and 2.3% for pilers. This is considerably too high.

The cardiovascular strain was, on average, moderate (43%CVL, Table 2). The lowest mean value registered was for cleaners (37%CVL), and the highest values were for female steel rod swingers (69%CVL) and pile drivers (65%CVL). These levels considerably exceeded the acceptable level of 30%CVL and measures should be undertaken soon to reduce cardiovascular strain during these tasks.

The SWI reached, on average, level 3, which indicates the need for rapid measures to reduce cardiovascular work load. On the basis of WBGT values, the work tasks can be classified as acceptable for continuous work. However, in some tasks %CVL values were high (>60%CVL, Table 2). The highest mean values were registered for bar swingers in steel production (69%CVL), for pile drivers in construction work (65%CVL), and for both female and male brick layers (62%CVL). In these tasks measures for reducing cardiovascular workload should be carried out as soon as possible.

The results for the female workers in rod swinging, rod hooking, and rod cutting suggested that the thermal environment had a weaker effect on physical strain than did muscular work. Proposed measures for reducing heat stress should include reducing direct radiation from bars and extruding machines by means of using reflecting screens, protective clothing, more efficient ventilation and alternating workplace between the two operators every second hour.

The results of pile drivers in construction work suggested that work load had a greater effect on the physical strain than the thermal environment, even though pile drivers worked outdoors and were exposed to direct solar radiation. Their muscular work consisted of movements of large muscle groups with a high output of force. The most strenuous work phases included heavy handling of materials such as arranging concrete piles, machine handling, and moving of machines. Unfavorable working postures were also common in these phases.

In construction pile driving, the piecework system should be reviewed for reducing excessive muscular load, which was the most significant problem. In most of the work phases the level of 50%CVL was excessive. This was true even at rest when the mean level was 55%CVL. Obviously this was due to the slow recovery of HR. For machine pile drivers, very high mean values were registered (96%CVL), and, correspondingly, for material handlers (100%CVL) and assistants of materials handlers (80%CVL). Firstly, physical work load should be reduced with a new work-rest regimen that prevents long continuous working phases. In a second phase, when all other technical improvement measures fail, a decrease of the production rate (number of piles per work shift) is recommended .

Female bricklayers had a mean %CVL value of 79% for walking, 78% for materials handling, and 77% for manual cement work. The corresponding values for waiting in a standing position were 51%. The results suggested that heavy heat stress affected physiological strain more than muscular work. This was probably due to the almost continuous exposure to direct solar radiation. Besides the use of protective shelters during rest pauses, changes in the work organization should be considered carefully in order to minimize walking. Improvements can be made in the storing of basic materials, as well as in providing technical aids and machinery.

Male bricklayers had similar jobs but conducted more specific and more physically demanding tasks. For digging and woodwork the mean %CVL values were 80 and 76%, respectively. In principle, similar measures should be undertaken to decrease the physiological strain for this group as for females: re-organization, the increased use of technical aids, and personal protection.

3.5. Methodological Considerations

The methodology used in the present study included the assessment of an impact of the thermal environment by monitoring physiological responses. This offered some advantages when the effects of physical strain were evaluated in the exposed individuals. The use of the WBGT is only partly satisfactory. As proposed before by Intaranont & Vanwonterghem (1993) and Yoopat et al. (1998) more fundamental study on physiological responses of different ethnic groups exposed to various physical workloads should be carried out in the near future.

The methods used allowed an efficient feedback from the physiological responses to the external work load factors of jobs (task, organization, and environment), and gave background for setting priorities, developmental measures, national guidelines, standards, or regulations associated with muscular work and the thermal environment.

Special attention should be paid to the assessment of physical and thermal load and strain of Thai workers as a direct implementation of international reference values may lead to biased results.

4. CONCLUSIONS

The results justified the following main conclusions:

1. In Thailand, physiological strain during auxiliary type jobs is high and may result in negative consequences for health, safety, well-being, and productivity.
2. Physiological strain is due to both heavy dynamic muscular work and high heat stress.
3. In many jobs immediate measures for reducing excessive strain are needed.
4. Physiological strain can be reduced by using more technical aids, improving the thermal environment, and introducing efficient work-rest regimens.

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