ORIGINAL ARTICLE

Heat stress and potential of heat strain among solid waste collectors in Hulu Selangor Local District

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Abstract:

The aim of this study was to determine the level of heat stress and heat strain among waste collectors. The level of heat stress was measured by using environmental monitoring QUESTempº36 Thermal Environment Monitor, heat stress screening checklist and questionnaire. A questionnaire known as Heat Strain Score Index (HSSI) was used to determine the heat strain index among solid waste collectors. The results of the study showed that the average environmental parameter was exceeded with the ACGIH threshold limit value of 29.5ºC. The average humidity value was 63.43%. A chi square analysis was used to determine the *p*-value of HSSI. There was statistically significant differences between green zone and yellow zone of heat strain among the workers due to the *p*-value was less than 0.05 ($p<0.05$). Simple linear regression model was used to determine the relationship between heat stress exposure and heat strain score index. It can be concluded that there is no association between the heat stress exposure level and heat strain score index as proved by the statistical finding in this study.

Keywords: Heat strain score index, heat stress, temperature, waste collector

1. INTRODUCTION

Waste collectors are a group of people who collects refuse generated by the populations at designated locations [1]. These workers are prone to be exposed to excessive temperature while they are working especially during the middle of the day. According to the Department of Safety and Health (DOSH) Malaysia [2], heat stress is the total heat experienced by an employee that may be exposed from the combined contributions of environmental factors such as humidity, air temperature, radiant heat and air movement, metabolic heat of employee, and also clothing type that was used while working. Heat stress occurs when the internal temperature of the body fails to regulate and the temperature cannot return normally by itself. The amount of the heat generated in the body and the heat loss from the body must be balanced for the internal body temperature to be maintained within 36-37.5ºC. Overheating of the body can cause a number of problems, including heat rash which cause discomfort and itchiness, heat cramps due to muscle pain, heat exhaustion due to excessive loss of water and salt in the body, heat syncope, which can cause faint or collapse and heat stroke due to dehydration and prolonged exposure to high temperatures [3]. A recent study by Ncube [4] shows that waste workers complained of headaches, sunburn, heat stress, excessive sweating, dehydration and difficulties in concentration in assigned tasks. However, the level of protection and exposure to health problems may be influenced by the magnitude of work [5]. With the aim of preventing heat stress, employers and employees must be able to acknowledge the factors that are contributing to heat stress. According to DOSH (2016), there are two factors that influences heat stress that can be categorized as environmental and non-environmental factors. Air temperature or known as the surrounding air of the body, radiant temperature, which is present if there are heat sources in the environment such as sun, air velocity or the speed of air moving across the employee, and relative humidity which is the amount of water vapor present in the air are the examples of environmental factors. For non-environmental factors, clothing insulation are important during working hours as the employees have to adapt to the workplace climate, and secondly, work factors which consist of work rate and metabolic heat that is produced while they are working.

2. MATERIALS AND METHODS

2.1 Environmental monitoring

For measuring thermal environment, QUESTempº36 Thermal Environment Monitor model was used to measure and calculate the dry bulb temperature, wet bulb temperature, globe temperature, WBGT outdoor index and relative humidity. ISO 7243 states that for rapid determination of the WBGT index, it is sufficient to carry out one measurement at 1.1 meters from the floor level where the heat stress is maximum. Environmental heat measurements should be made at, or as close as possible to the specific work area where the worker is exposed (DOSH, 2016). The thermal environment was measured during normal working hours with time-interval 30 minutes for 9 days at Taman Bukit Bujang, Kuala Kubu Bharu, Selangor.

2.2 Questionnaire

The questionnaire for the workers was adapted from Heat Strain Score Index (HSSI) which includes socio-demographic characteristics of municipal solid waste collectors, work description, heat exposed during work and effect from the heat [6]. The questionnaire was given to the workers through an interview. Each parameter was described and a risk score was given to each. The evaluation result indicates whether the workers are in safe level (Green Zone), alarm level (Yellow Zone) or danger level (Red Zone).

2.3 Ethical consideration

This study was approved by the Research and Ethics Committee, Universiti Teknologi MARA; reference number REC/346/17. All data were kept confidential throughout the study.

3. RESULTS AND DISCUSSION

3.1 WBGT (out) value at workplace

Figure 1 show the WBGT (out) value at workplace. The average reading of WBGT (out) was calculated in order to use as representative for environmental parameter measurement in comparing with the standard. The average reading of the WBGT (out) at workplace had been compared to American Conference of Governmental Industrial Hygienists, the threshold limit value (TLV). From the study, the minimum value is 27.3ºC on Day 9 while the maximum value is 30.9ºC on Day 7. With that, the mean of WBGT (out) is 29.5ºC (SD: 3.38). According to the American Conference of Governmental Industrial Hygienists [7] the threshold limit value (TLV) for outdoor workers with moderate work regime is 28.0ºC. Therefore, the result of the study exceeded from the limit. Most of the temperature will increase as early 9.00 am in day of sampling. From 9 days of study, the reading recorded high on 11.00 am until 1.00 pm and the reading was found exceed ACGIH threshold limit value as early as 9.00 am. This is due to increasing in ambient temperature and decreasing in humidity.

Meanwhile, from 2.00 pm until 4.00 pm, the reading mostly were decreasing because at that moment, the surrounding environment was a bit calm, windy, and cloudy and the ambient temperature was decreasing. A previous study from [8] stated that the WBGT value at the construction site in Japan was exceed from ACGIH threshold limit value from 11.30 am to 15.00 pm with value 30.0ºc to 34.0ºc. Another study from Yoopat [9], stated that the mean wbgt value of construction task in Thailand varied from 29.2ºc to 34.2ºc in the throughout the day. This shows that outdoor workers are susceptible to high ambient temperature while working.

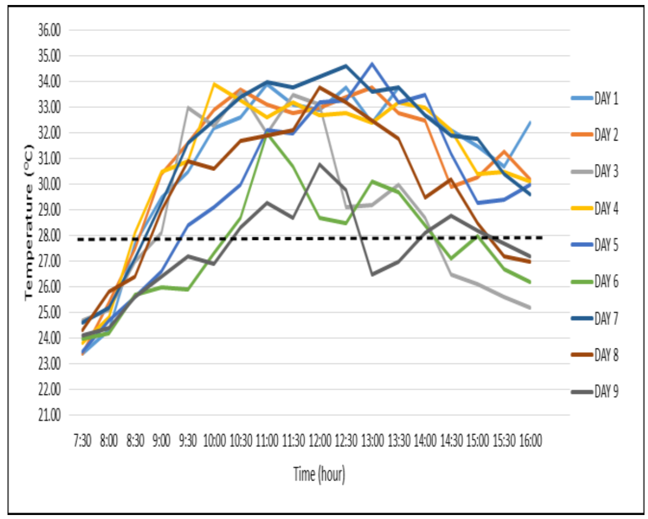

Figure 1: WBGT (out) value at workplace

3.2 Humidity level at workplace

Figure 2 show the humidity level at workplace. The average reading of humidity was calculated in order to use as representative for environmental parameter measurement. From the study, the minimum and maximum value of humidity is 51.63% on Day 1 and 73.95% on Day 6 respectively. The mean of the 9 days assessment is 63.43% (SD: 18.46). From 9 days of study, it can be describe that the humidity value range from 51.63% to 73.95%.

Along with the time, the humidity level decreased as the ambient temperature was increased. According to DOSH [2], humidity is important because less sweat will be evaporated when humidity is high. When humidity is high in the environment, it means it contain a lot of vapour in the air. In India, a previous study of different outdoor workplaces by Venugopal [10] stated that the relative humidity for sectors metal fabrication, building maintenance, agriculture, construction and brick have relative humidity of 39.5%, 39.9%, 41.2%, 41.9%, 38.9% and 39.5% respectively during hotter season. Meanwhile in cooler season, the relative humidity for those sectors are 55.0%, 51.9%, 64.3%, 62.0%, 53.7% and 85.0% respectively. This shows that when the ambient temperature decreased, the relative humidity would increase.

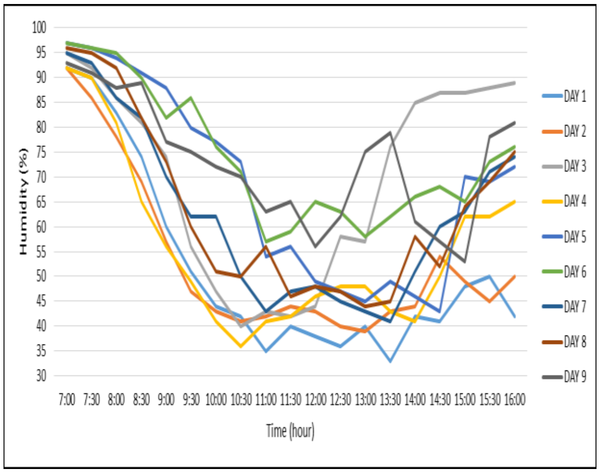

Figure 2: Humidity level at workplace

3.3 Clothing-adjustment factors

Clothing type at work is important because it will affect the final temperature for WBGT. It is a screening criteria suggested by ACGIH on the ability of the body to cool itself. Clothing type is one of the non-environmental factors which can lead to heat stress. Generally, clothing acts as a barrier to heat balance by inhibiting evaporative and convective cooling [11]. This is also supported by Rowlinson [12] as clothing may influences the effect of heat stress on heat strain through thermal insulation, which also affect the transfer of heat through radiation and conduction. The insulating characteristics of clothing also shall influence the transfer of heat from and to the body through resistance to air movement and water, permeability and ventilation [13].Unsuitable material of clothing may cause body overheating and body's natural cooling system is suppressed due to metabolic heat production [14]. A study from McLellan[15] stated that a worker who is wearing impermeable clothing and working in hot conditions will experienced severe fatigue after 15 minutes of working because the clothing is interferes with heat loss from the skin and limiting sweat evaporation and therefore causes rise in skin temperature. From this study, the solid waste collectors only wear long sleeve shirt and pants when performing their job. The clothing material they worn during working is cotton. Dehghan [6] stated that clothes that are made up from natural fibers such as wool and cotton could absorb large amount of moisture than polyester.

3.4 Workplace description of solid waste collectors

Table 1 shows the workplace description of solid waste collectors. For workplace air temperature, majority of the respondents (47.4%) declared that the air temperature is slightly warm, 40.8% (31) respondents declared as warm, 10.5% (8) respondents declared as normal and 1.3% (1) respondents declared as very warm. As for humidity level at workplace, 46.1% (35) respondents declared that their clothes sticking to the skin surface, 18.4% (14) respondents declared their skin is fully wet, 11.8% (9) respondents declared their skin is wet and sweat loss from the skin surface, 7.9% (6) respondents declared the humidity level is appropriate and desirable, and 3.9% (3) respondents declared as dry. Other than that, as for temperature of adjacent surface, all respondents declared they feel neutral; do not feel cold or hot. In terms of flow of air in workplace, 65.8% (50) respondents declared there were gentle stream of pleasing air, while the other 34.2% (26) respondents declared they sense of stability in the gentle flow of air or warm air. Furthermore, 81.6% (62) respondents declared the physical activity is starting to get hard, 15.8% (12) respondents declared as easy, and 2.6% (2) respondents declared as very hard. In addition, 92.1% (70) respondents declared size of working spacious is spacious, while the other 7.9% (6) opposite. Besides, in terms of ventilation system in workplace, due to outdoor work environment, 77.6% (59) respondents declared as appropriate ventilation, no need to be ventilated, and the other 22.4% (17) respondents declared as active and high ventilation.

Table 1: Workplace description of solid waste collectors

Characteristics	Mean (SD)	n	%
Workplace air temperature			
Normal	5.33	8	10.5
Slightly warm	(0.68)	36	47.4
Warm		31	40.8
Very warm		1	1.3
Humidity level			
Dry	4.03	3	3.9
Appropriate and desirable	(1.21)	6	7.9
Wet skin		9	11.8
Clothes sticking to the skin surface		35	46.1
Fully wet skin		14	18.4
Sweat loss from the skin surface		9	11.8
Temperature of adjacent surface			
I do not feel cold or hot		76	100
Flow of air in workplace			
Gentle stream of pleasing air	3.34	50	65.8
Sense of stability in the gentle flow of air or warm air	(0.48)	26	34.2
Intensity of physical activity			
Easy	2.87	12	15.8
Starting to get hard	(0.41)	62	81.6
Very hard		2	2.6
Size of working space			
Spacious	1.08	70	92.1
Appropriate common space	(0.27)	6	7.9
Ventilation system in workplace			
Active and high ventilation	1.78	17	22.4
Appropriate ventilation, it is not needed to be ventilated	(0.42)	59	77.6
Work environment			
Outdoor		76	100

3.5 Consequences of heat at workplace

Table 2: The consequences of heat at workplace.

Characteristics	Mean (SD)	n	%
Amount of sweating throughout working	4.04 (1.23)		
I do not feel like sweating		1	1.3
I feel the sweat on the armpit and inguinal		4	5.3
I feel the sweat on the chest and back		29	38.2
Sweating is so severe that the underwear clothing get wet		7	9.2
Sweating is so severe that I feel it on my face		27	35.5
Sweating is so severe that it is flowing all over my body		8	10.5
Level of fatigue at work	2.71 (0.88)		
I'm a little tired		41	53.9
I'm tired		18	23.7
I'm exhausted		15	19.7
I'm so exhausted that I desire to have a break		2	2.6
Intensity of thirst while working	3.20 (0.77)		
I get a little thirsty		15	19.7
I get thirsty		32	42.1
I get very thirsty		28	36.8
I get so thirsty that my mouth and throat get dry and they can't be wet with saliva		1	1.3
Intensity suffering from heat	2.49 (0.72)		
I'm not annoyed		4	5.3
I'm a little annoyed		37	48.7
I'm annoyed		29	38.2
I'm very annoyed		6	7.9

Table 2 shows the consequences of heat at workplace. In terms of amount of sweating throughout working, 38.2% (29) respondents mentioned they feel the sweat on the chest and back, 35.5% (27) respondents mentioned the sweating is so severe that they feel it on their face, 10.5% (8) respondents mentioned the sweating is so severe that it is flowing all over their body, 9.2% (7) respondents mentioned the sweating is so severe that the underwear clothing get wet, 5.3% (4) respondents mentioned they feel the sweat on the armpit and inguinal, and only 1.3% (1) respondent mentioned he did not feel like sweating.

Meanwhile, for the level of fatigue at work, 53.9% (41) respondents mentioned they were a little tired, 23.7% (18) respondents mentioned they were tired, 19.7% (15) respondents mentioned they were exhausted, and the other 2.6% (2) respondents mentioned they were so exhausted that they desire to have a break. In terms of intensity of thirst while working, 42.1% (32) respondents mentioned they get thirsty, 36.8% (28) respondents mentioned they get very thirsty, 19.7% (15) they get a little thirsty, and only 1.3% (1) respondent mentioned they get so thirsty that his mouth and throat get dry and they can't be wet with saliva. In terms of intensity suffering from heat, 48.7% (37) respondents mentioned they get a little annoyed, 38.2% (29) respondents mentioned they get annoyed, 7.9% (6) respondents mentioned they get very annoyed, and the other 5.3% (4) respondents mentioned they do not annoyed with the heat.

3.6 Total score of Heat Strain Score Index (HSSI)

Table 3 shows the total score of heat strain score index conducted among 76 solid waste collectors. From the survey conducted on the participants, 69.7% (53) participants were in green zone, which is in safe level of heat strain. Whereas the other 30.3% (23) participants were in yellow zone, which is in alarm level.

Table 3: Total score of heat strain score index

Characteristics	Mean (SD)	n	%
Total score			
Green zone (Safe level)	1.30 (0.46)	53	69.7
Yellow zone (Alarm level)		23	30.3

From the survey conducted by the researcher, the result of comparative between green zone and yellow zone is shown in Table 4. A chi square analysis is being used to determine the p-value of HSSI. There was statistically significant between green zone and yellow zone of heat strain among the workers due to the p-value is less than 0.05 ($p<0.05$).

Table 4: The comparative of heat strain score index variable

Variable	Type of analysis	p-value
Total score	$x^2 = 11.842$	0.001
Green zone (Safe level)		
Yellow zone (Alarm level)		

According to Stoecklin-Marois [16], heat strain is the collective physiological response to heat stress in which it represents the individual cost of the heat stress exposure. The physiological strains associated with heat stress are core and skin temperature, and heart rate. Human have a tightly regulated internal body temperature range approximately 37.0ºC at rest [17]. When the heat generated from the muscular work in the body cannot be adequately dissipated by heat loss mechanisms, the deep body temperature exceeds the allowable limit of 38.0ºC and causing heat accumulated in the body, therefore lead to increases in body temperature [18]. Ashley [18] stated that individual factors that contribute to heat strain are acclimatization state, fitness and gender. Acclimatization is important as it improves heat tolerance by increasing sweat rate, increasing plasma volume, and decreasing heart rate, which helps to reduce body temperature and fatigue during work in the heat.

In addition, weather conditions of workplace including air temperature, radiant heat and humidity, may also affect the person's risk for heat strain [17]. According to Morioka [8], American Conference of Governmental Industrial Hygienists (ACGIH) stated that workers is not be permitted to work when their deep body temperature exceeds 38.0ºC to prevent heat related illness from occurring. ACGIH has established the threshold limit value for work according to WBGT value. With information on WBGT and the type of work being performed, how long a person can safely work or remain in a particular hot environment can be determined. The overall weather condition in this study is sunny and sometimes cloudy as weather condition cannot be predicted in every hour. Even if the WBGT (out) value is exceeded from the ACGIH threshold limit value, however, the solid waste collectors are still in safe work condition and were not exposed extreme weather condition as the weather in Malaysia always warm and humid throughout the year.

Increasing in ambient temperature and how people working can lead to occupational hazards such as heat stress [13]. The effect of heat stress has proven to interrupt work efficiency of employees [3]. In this study, majority of the participants claimed to experience several symptoms following exposure of heat such as mild headache, dizziness and muscle pain. Present study by Ncube [4] also shows that waste workers complained of headaches, sunburn, heat stress, excessive sweating, dehydration and difficulties in concentration in assigned tasks. Heat stress may lead to several conditions such as loss of alertness, discomfort, rashness, and dizziness [10].

Clothing also plays an important role in influencing the heat strain. Unsuitable material of clothing may cause body overheating and body's natural cooling system is suppressed due to metabolic heat production [15]. When unclothed, heat may transfer directly across the skin surface with surrounding ambient layer. However, when multiple layers are worn, a trapped air layers are formed and encapsulate air pockets between the folds [16]. A study Rowlinson [12] stated that clothing may influences the effect of heat stress on heat strain through thermal insulation, which also affect the transfer of heat through radiation and conduction. The insulating characteristics of clothing also shall influence the transfer of heat from and to the body through resistance to air movement and water, permeability and ventilation [13]. The participants in this study wore normal cotton work clothes without any coverall. They also only use non-cotton gloves as their personal protective equipment (PPE) when handling the waste. This shows that the solid waste collectors use less barriers which might interrupt the thermal balance in their body. The use of PPE is one of the alternatives used to protect the worker but sometimes it may interfere with this thermal balance by hindering the loss of excess heat by the human body by convection, radiation and evaporation [19].

4. CONCLUSION

In this study, a total number of 76 solid waste collectors were being selected as participants. The average reading of workplace area was exceeded with the ACGIH limit value, which is 29.5ºC. The humidity value recorded was 63.43%. The relationship between the heat stress exposure and heat strain score index has no significant correlation since the *p*-value is more than 0.05 ($p>0.05$). Therefore, the hypothesis is rejected, since there is no association between the heat stress exposure level and heat strain score index due to p-value determined to be than 0.05.

REFERENCES

[1] Mohammed, S. & Latif, P. A. "Possible health danger associated with gabbage/refuse collectors". *Journal of Environmental Science, Toxicology and Food Technology*, 8(9), 22-30. 2014.

[2] Department of Safety and Health. *Guidelines on heat stress management at workplace 2016*. Malaysia: Ministry of Human Resources. (2016).

[3] Monazzam, M. R.*et al*.,"Evaluation of DI, WBGT, and SWreq/PHS heat stress indices for estimating the heat load on the employees of a petrochemical industry". *International Journal of Occupational Hygiene*, 6(1), 6-10,2014.

[4] Ncube, F. *et al.,* "Bioaerosols, noise, and ultraviolet radiation exposure for municipal solid waste handlers" *Journal of Environmental and Public Health*, 8.(2017)

[5] Kretchy, J-P. *et al*., "Exposure, protection and self-reported health problems among solid waste handlers in a Coastal Peri-urban community in Ghana". *International Journal of Public Health and Epidemiology*, 4(2), 121-128,2015.

[6] Dehghan, H. *et al.,* "Development and validation of a questionnaire for preliminary assessment of heat stress at workplace". *Journal of Research in Health Sciences*, 15(3), 175-181.(2015)

[7] American Conference of Governmental Industrial Hygienists (ACGIH)**:** *2017 TLVs® and BEIs®: Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices*. Cincinnati, OH: American Conference of Governmental Industrial Hygienists.(2017)

[8] Morioka, I. *et al*., "Hot environment and health problems of outdoor workers at a construction site". *Industrial Health*, 44, 474-480 (2006)

[9] Yoopat, P. *et al.,* "Ergonomics in practice: physical workload and heat stress in Thailand". *International Journal of Occupational Safety and Ergonomics*, 8(1), 83-9. 2002.

[10] Venugopal, V.*et al.,* "Occupational heat stress profiles in selected workplace in India". *International Journal of Environmental Research and Public Health*, 13, 89. 2016.

[11] Yi, W.*et al*., "Effectiveness of a newly designed construction uniform for heat strain attenuation in a hot and humid environment". *Applied Ergonomics*, 58, 555-565,2017.

[12] Rowlinson, S.*et al.,* "Management of climatic heat stress risk in construction: A review of practices, methodologies, and future research". *Accident Analysis and Prevention*, 66, 187-198,2014.

[13] Lundgren, K.*et al*., "Effects of heat stress on working populations when facing climate change". *Industrial Health*, 51, 3-15,2013.

[14] Golbabaei, F.*et al*., "Investigation of heat stress and heat strain in outdoor workers: A case study in Iran". *Journal of Paramedical Sciences*, 7(4), 4978,2016.

[15] McLellan, T. M.,*et al*., "Encapsulated environment". *Comprehensive Physiology*, 3, 1363-1391.(2013)

[16] Stoecklin-Marois, M.,et al.,"Heat-related illness knowledge and practices among California hired farm workers in the MICASA study". *Industrial Health*, 51, 47-55,2013.

[17] Lucas, R. A.*et al.,* "Excessive occupational heat exposure: a significant ergonomic challenge and health risk for current and future workers". *Extreme Physiology & Medicine*, 3.1, 14,2014)

[18] Ashley, C. D. *et al*., "Heat strain at the critical WBGT and the effects of gender, clothing and metabolic rate". *Journal of Industrial Ergonomics*, 38, 640-644, 2008.

[19] De Almeida, Ronaldo André Castelo dos, *et al*. "Thermal comfort and personal protective equipment (PPE)." *Work* 41.Supplement 1: 4979-4982, 2012.