Effects of hydration practices on the severity of heat-related illness among municipal workers during a heat wave phenomenon

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ABSTRACT

Introduction: The continue rise in temperatures due to climate change increases the risk of heat-related illness (HRI) among outdoor workers. This study aims to evaluate the effects of hydration practices on the severity of HRI during a heat wave episode among municipal workers in Negeri Sembilan.

Method: A cross-sectional study was performed in March and April 2016. The outdoor temperatures were measured using the wet-bulb globe temperature (WBGT) tool. The participants completed a self-administered questionnaire containing sociodemographic factors prior to work shift; while working profile, hydration practices, and HRI symptoms at the end of work shift. The hydration status of the respondents was assessed by direct observation of their urine colour. Multiple logistic regression was performed to ascertain the effects of age, working profile, hydration practice, history of previous HRI, and hydration status on the likelihood that outdoor workers having moderate to severe HRI.

Results: A total of 320 respondents completed the questionnaire. The mean (standard deviation) outdoor workplace temperature was 30.5°C (SD 0.53°C). The percentage of respondents who experienced moderate to severe HRI was 44.1%. The likelihood that outdoor workers experienced moderate to severe HRI symptoms was associated with irregular fluid intake [odds ratio (OR): 16.11, 95% confidence interval (95%CI): 4.11; 63.20]; consumption of non-plain water (OR: 5.92, 95%CI: 2.79; 12.56); dehydration (OR: 3.32, 95%CI: 1.92; 5.74); and increasing outdoor workplace temperature (OR: 1.85, 95%CI: 1.09; 3.11).

Conclusion: Irregular drinking pattern and non-plain fluid intake was found to have a large effect on HRI severity among outdoor workers exposed high temperatures during a heat wave phenomenon.

KEY WORDS:
heat-related illness, hydration practice, outdoor work place temperature, climate change

INTRODUCTION

Staying adequately hydrated is key to maintain good health. Many outdoor workers have no choice but to work in the hot sun. High workplace temperatures and high metabolic rate activities can exert additional pathological loads on the thermoregulatory system, making them more prone to experience heat-related illness (HRI), especially those who lack acclimatisation capability.[1] This unwanted but preventable illness vary from minor health effects to life-threatening medical emergencies, i.e., from fatigue and heat rashes to heat cramps, heat syncope, heat exhaustion and heat stroke.

To date, HRI research has been expanding from identifying the risk factors and the resulting impact on physical health and work performance up to the development of mitigation plans for people, such as athletes,[2] military personnel,[3] and outdoor workers.[4] Unique individual risk factors correlated with a higher intolerance to heat, such as age, current medication usage, previous history of HRI,[5] obesity and skin disorders were identified.[4] Guidelines on behavioural practices related to high workplace temperatures as simple as providing cold water to employees at work to prevent dehydration have been suggested to employers.[6] However, individual behavioural practices aimed at maintaining hydration in the face of high workplace temperatures through methods such as regular fluid consumption and considering the type of fluid intake have been understudied. Thus, the present study aims to evaluate the effects of individual hydration practices (i.e., regularity and type of fluid consumed) on the severity of HRI among municipal workers. This study is unique because it was done during a heat wave phenomenon in one of the hottest State in Peninsular Malaysia i.e., Negeri Sembilan, Malaysia in 2016. Furthermore, this study applied objective measurement for outdoor workplace temperature (i.e., wet-bulb globe temperature, WBGT) and dehydration status (colour of urine) to ensure adequacy of hydration status.

MATERIALS AND METHODS

Study design and sampling

This cross-sectional study took place in eight different zones

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in a district in Negeri Sembilan from 29 March 2016 to 8 April 2016 at the end of the El Niño phenomenon in Malaysia. The recorded average recorded ambient temperature was 32.84°C (range: 28.05°C-38.76°C).[7] A total of 340 (out of the 2,000 workers) outdoor workers from a private company contracted by Municipal Council, who were involved in sweeping, cleaning drainage, and cutting grass along the roadsides were selected. The minimal calculated sample size was 300 respondents after considering three factors such as given population size, prevalence of heat related illnesses and 5% accuracy. Workers were selected using a computer-generated random number system from a list of the names of all workers. The inclusion criteria were: Malaysian, age 18-year and above, had worked for at least six months in the company and worked an 8-hour shift per day. Workers who were not proficient in Malay or English or had been on leave for more than two days in previous two weeks before the start of the study were excluded.

Measures

A self-administered questionnaire was used to collect data on sociodemographic factors (e.g., age, gender, education level, duration of service, and race), current medication usage, alcohol intake, history of previous HRI, were answered prior to outdoor work activity while type of work (sweeping, cleaning drainage, and cutting grass at the roadside), hydration practices (i.e., regularity and type of fluid intake), and HRI symptoms typically experienced during the day were answered after finished work for the day. All items in the questionnaire were translated from English to Malay using the traditional Brislin method.[8] HRI symptoms were measured using the validated Heat Illness Symptom Index[9] containing 11 symptoms such as thirst, tiredness, cramps, nausea, dizziness, vomiting, confusion, muscle weakness, heat sensation, chills, and giddiness which are measured using a five-point Likert scale according to severity: 1 = none, 2 = light, 3 = moderate, 4 = severe, and 5 = very severe. In our study, Cronbach's alpha of eleven HRI symptoms was 0.83. Hydration status was assessed at the end of a work shift based on the direct observation of the colour of urine using a standard validated urine colour scale of eight points based on previous literature.[10] Each respondent's urine colour was compared with urine colour chart in Figure 1. Those urine colours given four-point and more were defined as having dehydration.

The type of work was categorised as sweeping, cleaning drainage and cutting grass at the roadside. Hydration practices throughout the work shift were assessed by the regularity and type of fluid consumed. The regularity of fluid intake was classified according to consumption either at regular intervals (i.e., every 30 minutes or one hour) or irregular timing (based on feeling of thirst or only during rest time). For accuracy purposes, researcher assisted the respondents type of fluid and volume intake. The type of fluid taken was assessed by asking each respondent about what they habitually drank during their work shift. Options included plain water, soft drink, cordial, tea/coffee, or isotonic drink. The volume of fluid drank by each respondent was assessed by asking about the amount of fluid intake in comparison to a cup (250 ml), glass (330 ml), and bottle (500 ml) shown by the researcher. Body mass index were calculated based on measured weight in kilograms divided by height in meters squared.

In this study, the 3M™ QUESTemp™ 34 WBGT meter (3M Company, St. Paul, MN, USA) was used to assess outdoor workplace temperature based on the recorded wet-bulb globe temperature that takes into account the temperature, humidity, wind speed, sun angle, and cloud cover (solar radiation). The measurement method was based on the ISO 7243:1989 as reported in previous literature.[11] A tripod was used to maintain the meter's location at 1.1 metres above ground level to represent the workplace temperature at a level above the waists of respondents within a 100-m radius of the working area. The radius area coverage was halved to what was suggested by the Malaysia meteorological expert to ensure accuracy (personal communication, 2016). Care was taken to ensure the instrument was not placed near a heat source or in the shade. The WBGT was set to take measurements at every 15 minutes during the eight-hour shift, from 8:00 am until 4:00 pm. The first reading was taken after 10 minutes of starting the instrument to stabilise its sensors based on equipment's manual. The WBGT data was downloaded into a computer using the 3M™ Detection Management Software (3M Company, St. Paul, MN, USA). The downloaded data were then checked by the first author for completeness and the WBGT values collected during stabilisation of the sensors were excluded. The data were then extracted into Microsoft Excel for further analysis.

Ethical statement

Ethical approval was obtained from the research ethics committee of the National University of Malaysia (reference no. UKM PPI/111/8/JEP-2016-171). Written informed consent was obtained from all of the respondents prior to the survey. All data obtained were collected and stored in an anonymous format.

Statistical analysis

The HRI severity categorisation system used herein was developed by a person-item map distribution, which was generated by using the Rasch measurement model. The thirst item was chosen as the cut-off at the logit value of -2.18 to further categorise the heat illness screening index into the two categories of light, and moderate to severe, respectively. Additional details have been published elsewhere.[12] Further, descriptive, and multiple logistic regression analyses were conducted using IBM SPSS version 23. In the multiple logistic regression, the light, and moderate to severe HRI categories were coded as 0 and 1, respectively. Prior to interpreting the regression analysis, statistical fit assumptions (e.g., Hosmer and Lemeshow test, table of classification, receiver operating characteristic or ROC); interaction; and multicollinearity were checked. An odd ratio (OR) value of more than 4.3 was regarded as indicating a large effect size.[13]

RESULTS

Respondent characteristics

A total of 320 respondents were recruited. The characteristics of the participants between light HRI and moderate-severe HRI is shown in Table I. The mean age (standard deviation, SD) of the respondents was 43 years (SD 9.49 years) and the

Table I: Respondent Characteristics

Respondents Characteristics	Heat-related Illness Severity			
	Moderate to severe severe (n=141)	Light (n=179)	Test	p value
Outdoor workplace temperature in °C, mean (SD)	30.65 (0.53)	30.61 (0.53)	t= 0.80	0.422
Age group, n (%)				
Less than 50 years old	88 (38.6)	140 (61.4)	χ^2 =9.61	0.002
50 and above years old	53 (57.6)	39 (42.4)		
Gender, n (%)				
Male	74 (50.0)	74 (50.0)	χ^2 =3.94	0.047
Female	67 (39.0)	105 (61.0)		
Race, n (%)				
Indian	88 (40.7)	128 (59.3)	χ^2 =2.98	0.085
Non-Indian	53 (51.0)	51 (49.0)		
Education level, n (%)				
No formal education	8 (40.0)	12 (60.0)	χ^2 =3.57	0.168
Primary education	61 (50.8)	59 (49.2)		
Secondary education	72 (40.0)	108 (60.0)		
History of previous heat illness, n (%)				
Yes	83 (54.6)	69 (45.4)	χ^2 =13.06	<0.001
No	58 (34.5)	110 (65.5)		
History of medical illness, n (%)				
Yes	47 (48.0)	51 (52.0)	χ^2 =0.87	0.351
No	94 (42.3)	128 (57.7)		
History of medication intake, n (%)				
Yes	53 (50.5)	52 (49.5)	χ^2 =2.61	0.106
No	88 (40.9)	127 (59.1)		
Alcohol intake, n (%)				
Yes	3 (50.0)	3 (50.0)	Fisher exact	0.540
No	138 (43.9)	176 (56.1)		
Type of work, n (%)				
Sweeping roadside	105 (45.3)	127 (54.7)	χ^2 =5.45	0.065
Grass cutting	24 (52.2)	22 (47.8)		
Drain cleaning	12 (28.6)	30 (71.4)		
Body mass index category, n (%)				
Underweight	10 (50.0)	10 (50.0)	χ^2 =1.24	0.743
Normal	27 (43.5)	35 (56.5)		
Overweight	50 (47.2)	56 (52.8)		
Obese	54 (40.9)	78 (59.1)		

Table II: Hydration Practices on Light and Moderate to Severe HRI among Outdoor Workers

Variables	Simple Logistic Regression					Multiple Logistic Regression				
	^{b}Coefficient	OR	95% CI for OR		p value	b Coefficient	ORa	95% CI for ORa		p value
			Lower	Upper				Lower	Upper	
History of previous HRI	0.80	2.22	1.42	3.48	0.001	0.81	2.25	1.31	3.86	0.003
Hydration practices:										
Irregular fluid intake	2.28	9.77	2.92	32.69	<0.001	2.78	16.11	4.11	63.20	<0.001
Non plain water	1.68	5.38	2.85	10.13	<0.001	1.78	5.92	2.79	12.56	<0.001
Dehydrated	1.34	3.83	2.40	6.12	<0.001	1.20	3.32	1.92	5.74	<0.001
Working profile										
Sweeping roadside	0.61	1.84	0.91	3.73	0.088	1.01	2.75	1.16	6.48	0.021
Grass cutting	0.89	2.43	1.02	5.83	0.046	1.00	2.71	0.95	7.71	0.062
Workplace temperature	0.19	1.21	0.80	1.83	0.377	0.61	1.85	1.09	3.11	0.022
Age 50 years and above	0.75	2.12	1.30	3.47	0.003	1.02	2.76	1.52	5.03	0.001

Backward LR method was applied. Multicolinearity and interaction term were checked and not found. Hosmer-Lemeshow test was not significant, table of classification is 71.9% and area under the curve (80.8%) was applied to check model fitness. OR= odd ratio, ORa = adjusted odd ratio, adjusted r^2= 0.375

average number of months in service was 51 months. The majority of the respondents were females (53.8%), aged between 40 and 49 years (37.8%), Indians (67.5%), had at least a secondary level of education (56.3%), and were sweeping at the roadside (72.5%). All respondents wore shirts (either long- or short-sleeved), long pants and close-toed shoes. The mean (SD) of water intake during working hours was 2,150ml (SD 933ml). Majority of respondents drank plain water (80.6%), at irregular times (89.4%) and had adequate hydration (56.6%).

Outdoor workplace temperatures

The mean WBGT value was 30.50°C (SD 0.53°C) throughout the eight-hour work shift for all eight days. The maximum WBGT value recorded during the study period was 34.06°C, which was on the first day of monitoring at 1.30 p.m.; conversely, the minimum WBGT value recorded was 26.42°C, which was observed on the third day at 8:00 a.m. There was a significant difference in the mean value when compared with the recorded mean proxy value for the same El Niño month (t=86.52, p<0.001). Overall, the trend of mean WBGT

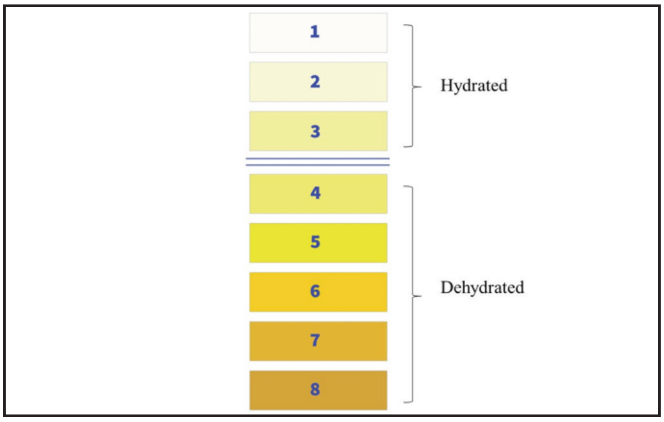

Fig. 1: Urine colour chart.

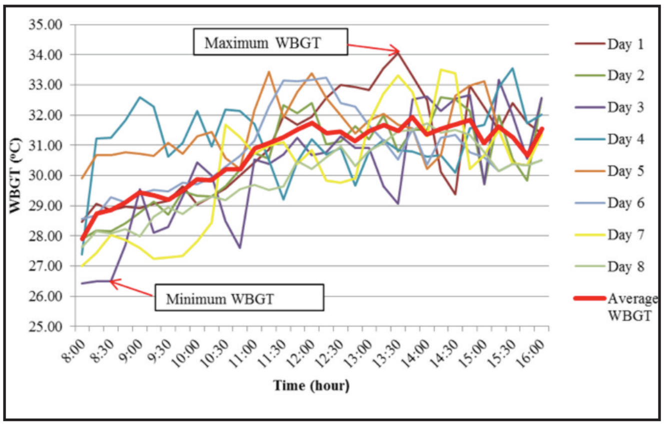

Fig. 2: WBGT reading during the study period.

value showed an increase from early morning towards the evening. Mean WBGT values were 29.10°C, 31.01°C and 31.39°C at 8 am to 10 am, 10.30 am to 1 pm, and 2 pm to 4 pm, respectively.

Hydration practices and HRI severity

The percentage of respondents who experienced moderate to severe HRI was 44.1%. The model explained 37.5% of the variance in HRI severity and correctly classified 71.9% of participants in the moderate to severe HRI category. The likelihood that outdoor workers experienced moderate to severe HRI symptoms was associated with irregular fluid intake [OR: 16.11, 95% confidence interval (95%CI): 4.11; 63.20]; consumption of non-plain water (OR: 5.92, 95%CI: 2.79; 12.56); dehydration (OR: 3.32, 95%CI: 1.92; 5.74); and increasing outdoor workplace temperature (OR: 1.85, 95%CI: 1.09; 3.11), with age, working profile, and previous history of HRI as controlled variables. Hydration practices such as irregular fluid intake and the drinking of non-plain water had a large effect size on the degree of HRI severity experienced by the respondents.

DISCUSSION

This study aimed to demonstrate the effects size of hydration practices on HRI severity among outdoor workers in Negeri Sembilan. In this investigation, hydration practices (i.e., regularity of drinking and type of drink chosen), working profile, and hydration status were significant associated with HRI severity, consistent with the findings of other studies.[14-18] Drinking non-plain water such as caffeinated, sweetened, or carbonated drinks contributed to a higher risk of experiencing HRI. Caffeinated beverages were repeatedly proven to increase core temperature,[19-21] notably as much as 0.3°C for every 2.9mg/kg caffeine.[17] Caffeinated drinks also have a diuretic effect, which will further increase the loss of water and electrolytes.[14] Sweetened drinks affect the body's rehydration rate and the capability of the heat loss mechanism, particularly when the carbohydrate content exceeds normal plasma osmolarity (290mosmol/kg), which results in a slower fluid absorption into the plasma.[22,23] Carbonated beverages were also found to increase the metabolic rate, which subsequently increases the body's core temperature.[16,23,24]

Although plain water is tasteless and possibly inferior to low-to-moderate carbohydrate-electrolyte (CHO-E) beverages in terms of fluid replacement,[23,25] it is a good option in maintaining the well-being of the workers. Water was found to have a similar effectiveness to that of low-concentration CHO-E drinks (e.g., Gatorade; The Gatorade Company, Chicago, IL, USA) in controlling core temperature, heart rate, and stroke volume during activities performed in higher-heat conditions.[22,24] The consumption of water was also proven to be sufficient to rehydrate a person who is not severely dehydrated when an isotonic solution is not available.[26] Therefore, the selection of plain water during work activity among outdoor workers needs to be encouraged, especially when there is limited access to low-concentration CHO-E beverages.

This study showed that regular drinking is important to avoid moderate and severe HRI experiences. Drinking only when feeling thirsty or during breaks may result in the body not able to maintain good hydration.[16,27] Relying on the thirst sensation to trigger the action of taking a drink in a hot environment resulted in ineffective rehydration, as thirst is a poor indicator of body fluid loss. The sensation of thirst will only be felt after 1% to 2% of body fluid loss,[28] or approximately three to four litre of body fluid loss among workers involved in heavy manual work.[29] Conversely drinking to quench thirst was found to be more beneficial among athletes who are involved in short activities such as sports,[30] but not in workers participating in longer physical work in a hot environment.

Regular drinking of water in the workplace was found to be beneficial in maintaining hydration throughout the working hours and on perceived exertion reduction.[23,27] A reduction in perceived exertion was found to ensure better adaptability to the surrounding hot environment and to limit the risks of HRI.[23] To the best of our knowledge, the consumption of at least 250 mL of fluid every 20 minutes in workers who are exposed to heat index between 39°C and 46°C is the best practice.[31,32] A previous study showed that the rehydration strategy of drinking water at least 30 minutes before the start work and the consumption of a further 250ml of liquid every 30 minutes to 45 minutes lead to the prevention of HRI among workers exposed to heat.[33] Similar to athletes running in a marathon, outdoor workers should be advised to have a personal drink pack readily accessible when doing heavy work to prevent dehydration.

This investigation demonstrated that dehydration will predict HRI, similarly reported in previous studies.[12-14,28] This is due to the effects of an elevated core temperature and a reduction in heat loss mechanism that are secondary to dehydration. Excessive sweat rates as high as 0.3l/hr to 1.5l/hr was observed among workers under heat stress, which may result in dehydration and subsequently can reduce blood volume and compromise cardiovascular function.[16] The reduction of blood volume will result in an adverse impact on cardiac output, leading to less effective heat loss function due to circulation to the skin.[34] Every 1% body weight loss due to dehydration causes an increase in the heart rate of 10 beats/minute and a rise in the core temperature of 0.1°C to 0.2°C depending on the activity being performed and the surrounding environmental conditions.[23,34] Ensuring optimum hydration status prior to the work shift is very important in preventing workers from having HRI. Workers who begin their work shift in a dehydrated state (urine specific gravity value >1.022) under a heat stress environment had a higher risk of experiencing HRI due to more severe dehydration at the end of their shift as compared with those who started their shift in a hydrated state.[16]

In this study, the prevalence of moderate to severe HRI among municipal workers was surprisingly high, though our findings were similar to previous studies.[35-37] This similarity is probably a result of the timing of the present study, which was conducted during a time when a higher mean ambient temperature was prevalent due to a heat wave as the result of a clash between the Equinox and the El Niño phenomenon.[38] Peninsular Malaysia experienced a higher mean ambient temperature during the aforementioned period as compared with the same month in the previous year. Some areas, such as Chuping, Alor Setar and Ipoh, recorded highest daily maximum temperatures of between 37°C and 39°C.[7] During the same period, three heat stroke cases were reported across the country, with one death.[39] Although the prevalence found in this study was considered high during such an extreme weather, the impact on workers should not be neglected. Future increases in temperature as projected due to ongoing climate changes will subsequently increase the prevalence of HRI. Thus, more aggressive prevention actions need to be planned.

Based on our study, more time can be allocated to do work (up to 75%) in early morning compared to latter time of the day, i.e., 10.30 am onwards (up to 25% only) after factoring in work metabolic rate and clothing factor. Use of WBGT as an effective tool to calculate adjusted temperature based on four factors (humidity, wind, temperature, and radiant heat) to assess heat hazard exposure[40] among outdoor workers should be done periodically at the organisation level to plan work-rest regime. However, the WBGT and work-rest regime's application for Malaysian workers is still debatable because the values were derived from the US Armed forces and athletics. Physiologically, the studied population may not be similar with Malaysian workers who are exposed to heat regularly. Practically, a simpler tool of digital era such as heat index calculator apps can be used to measure of how an individual really feels when relative humidity is factored in with the actual air temperature. Such information accessible through smart phones that may help supervisor to revise work plan and heat stress prevention strategies in timely manner such as nearby access to water and worker have self-control to decide regularity of water intake breaks. Individual drink pack should be provided if frequent breaks are not possible.

Although a cross-sectional design was not the most ideal method to prove causality, this study was conducted using the best method identified for determining the burden of disease in Malaysia. The use of multiple sources for and types of data, which include objective measurements collected during this study, addresses the common method bias issues commonly associated with the cross-sectional study methodology. The present study used objective measurements such as WBGT values and a urine colour observation scale at the study site rather than ecological data and self-recorded responses, respectively. The categories of HRI identified based on the person-item map technique showed the importance of recognising the high-risk symptoms that may progress to heat stroke if left untreated. This method was superior as compared with that of listing and evaluating the individual symptoms, as individuals with HRI are known to demonstrate progressive symptoms and a person can have multiple symptoms that occur concurrently. In view of the variability inherent in self-pacing activities and the possible association with individual preferences, the workers' activity was challenging to monitor. Self-pacing activity information needs to be obtained with careful attention because some workers may not want it to be recorded and possibly misunderstood, leading to disciplinary action.

Suggested model of hydration practices, dehydration and workplace temperature explained about 40% HRI severity with controlled variables previous history of HRI, working profile and age. In our analysis, other factors such as body mass index (BMI), alcohol intake and history of medical illness and intake of medication were considered but lack of valid contrast probability due to small sampling variability. For example, BMI displayed quite similar in frequency matching for both mild and moderate to severe HRI groups. Hence, the data accidently acted like a controlled variable for the analysis. One other factor that should be considered is healthy worker effect. The sampled workers may experience lower moderate to severe HRI than the general population because they were the one who is healthy enough to work, motivated to continue to work despite the high temperature workplace exposure.

CONCLUSION

In Malaysian outdoor workers under average workplace temperatures of 30.5°C (0.53°C) throughout the eight-hour work shift, about 44% of them experienced moderate to severe HRI. Since both irregular drinking pattern and non-plain fluid intake were found to have large effect size (i.e., odd ratio value of more than 4.3) on HRI severity during heat wave phenomena, more intervention should be focused on individual behavioural practices. This study reinforces the need for worker's participation to safeguard own health by maintaining optimum hydration status pertaining to selection type of water and frequency to drink at workplace.

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