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The Impact of Heat on Health and Productivity Among Sugarcane Workers In Kampong Cham, Cambodia

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ABSTRACT

Introduction: The increase in environmental temperature has become a problem to the farmer populations in countries vulnerable to climate change including Cambodia. **Objective**: To investigate the impact of heat stress on health and productivity among sugarcane workers in Kampong Cham, Cambodia. **Method**: The subjects were made up of 110 sugarcane workers which represented the typical sugarcane workers in Cambodia. Variables measured were environmental heat exposure (WBGT), physiological changes (blood pressure, heart rate, core body temperature), heat-related symptoms and productivity. QUESTEMP°34 Wet Bulb Globe Temperature (WBGT) monitor and Lascar Data Logger were used to measure the environmental heat exposure (°C) and relative humidity (%). Blood pressure and heart rate were measured using an Omron T-3 Automatic Blood Pressure Monitor while core body temperature was measured using an Omron Mc-510 Gentle Temperature Ear Thermometer. A questionnaire that has been translated into Cambodian language (Khmer) was used to obtain background information on heat exposure at work, the effects of heat, coping mechanism and heat-related symptoms from the workers. The productivity of workers was recorded by a tally counter in terms of the number of sugarcane bundles that were loaded by the workers into a truck. **Results:** The mean environmental heat exposure was 30.12 °C and the mean relative humidity was 58.9%. The sugarcane workers were exposed to high environmental heat exposure according to American Conference and Governmental Industrial Hygiene (ACGIH) standard as the heat stress index levels for each day in the sugarcane farm areas were above the Threshold Limit Value (TLV) of ACGIH (27.5°C). There was a significant difference in physiological changes during working and resting periods of workers. However, out of all variables, only core body temperature of males (0.037) and heart rate of females (0.043) during working period were correlated with environmental heat exposure with a weak negative correlation. Most of the workers reported heat exhaustion (87.2%), tiredness (86.4%), headache (61.8%) and muscle cramps (60.0%). Male workers had higher productivity than female workers. The productivity of workers was significantly decreased as environmental heat increased. **Conclusion**: This study suggests that high environmental heat exposure could reduce productivity of Cambodian sugarcane workers, but it had no effects to their physiological changes.

Keywords: *Heat stress; physiological changes; heat-related symptoms; productivity; Cambodia*

1. Introduction

The Intergovernmental Panel on Climate Change (IPCC) predicted that the global temperature would raise about 2.4°C -6.4°C during the twenty-first century. The broad increase in global temperatures would bring benefits in some areas such as decrease of mortality of cold exposure, and improved agricultural output in cold places like Russia and Canada, but overall it would bring much more negative health impacts especially in tropical developing countries such as increasing heat stress and mortality and morbidity of some infectious diseases (IPCC, 2007). The increasing trend of temperature in the environment indicates that the workers are exposed to the higher potential of heat stress.

Heat stress is one of the factors that had direct effects on workers which then give huge implications in health, economic, social and well being. In a recent study, a total of 423 heat related death among agricultural workers were reported in United States from 1992-2006 (CDC, 2008). In Taiwan, a total of 22 death were officially attributed to excessive heat from 2006-2007 (Department of Health of Taiwan, 2009). This phenomenon is a serious concern since lot of research have shown that heat stress affects the health and productivity of workers. The increasing heat exposure is likely to create occupational health risks and to have a significant impact on the productivity of many workers, unless effective preventive measures reducing the occupational heat stress are implemented (Kjellstorm et al., 2009).

Kampong Cham is one of the largest town located in eastern Cambodia, 124 km from Phnom Penh. The population is comprised of 80% farmers, 1% craftsmen, 14 % service providers and 5% engaged in other businesses (Council for the Development of Cambodia, 2013). Sugarcane industry is one of the important agricultural sectors that contribute to the economic growth of Cambodia instead of producing a fundamental food for their own country. Increasing temperature in the environment has become an arising problem to the farmer populations in Cambodia because of the impact of heat stress towards their health and productivity. A comprehensive study and research need to be done in order to assess heat stress impacts on health and productivity of the sugarcane workers. Therefore, the aim of this research is to investigate the impacts of heat stress on health and productivity of the sugarcane workers in Cambodia, an important aspect of the health effects caused by environmental heat (Figure 1).

2. Materials and Method

2.1. Study Design

A cross-sectional study was designed to investigate the impact of heat stress on health and productivity of the sugarcane workers in Kampong Cham, Cambodia. The study was carried out for 6 days started from 21 to 26 of January 2015. Convenient sampling was carried out in getting the respondents. The workers available and gave consent during the data collections were included in the study. Further screening was made on the workers that fulfills the inclusion criteria.

This study received permission from Research ethics committee, Universiti Putra Malaysia (Ref: UPM/TNCPI/RMC/1.4.18.1/JKEUPM/F2, 08/05/2015) and National Ethics Committee for health research (Ref: 0268NECHR, 11/09/2014) under Ministry of Health of the Royal Government of Cambodia. All aspects were carried out according to the ethical requirements by these Ethical Committee groups. A detailed briefing session was conducted among the workers to answer their uncertainty of the purpose of this study. Followed by consent letter distribution to the workers who volunteer to participant in this study.

2.2. Study Population

The target population of this study was sugarcane workers in Kampong Cham Province, Cambodia. Kampong Cham was chosen because 80% of the population comprised of farmers in the sugarcane industry (Council for the Development of Cambodia, 2013).The subjects were 110 sugarcane workers which comprised of 63 males and 47 females in range of 20 to 60 years old. They represented the typical sugarcane workers in Kampong Cham, Cambodia.

2.3. Environmental heat exposure

Wet Bulb Globe Temperature (WBGT) model QUESTEMP°34 and Lascar Data Logger were used to measure the environmental heat (°C) and relative humidity (%) at the sugarcane farm area. The data from WBGT monitor was used to evaluate the heat stress index experienced by the workers as the WBGT monitor was the most sophisticated instruments to evaluate heat exposure and has been proved to be very successful in monitoring heat stress (ACGIH, 1999).

To evaluate the heat stress experienced by the workers, the metabolic workload of workers at different activities were estimated to enable the heat stress index (WBGT) comparison. The American Conference of Governmental Industrial Hygienist (ACGIH) method for estimating metabolic rate was used. The heat stress index was compared with the Threshold Limit Value (TLV) for permissible heat exposure as set by American Conference and Governmental Industrial Hygiene (ACGIH, 1992).

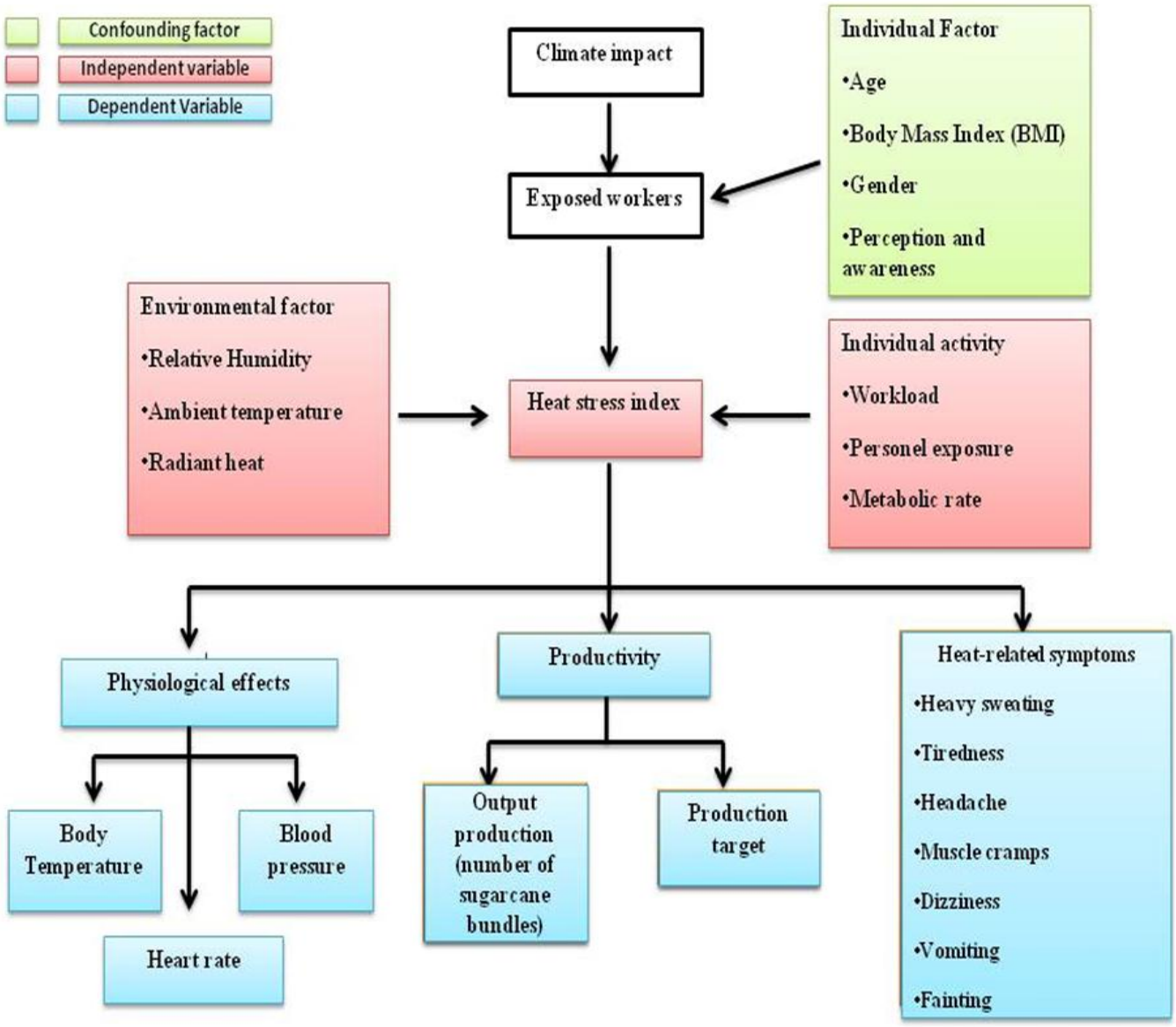

Figure 1. The conceptual framework of the research

2.4. Physiological changes

For the physiological changes, blood pressure, heart rate and core body temperature of the workers were measured. Blood pressure and heart rate were measured using Omron T-3 Automatic Blood Pressure Monitor while core body temperature was measured using Omron Mc-510 Gentle Temperature Ear Thermometer. The blood pressure, heart rate, core body temperature were first recorded during their working period. The workers were selected after working at least for 30 min. They were asked to resume their work after the measurement of their physiological changes was done. In a real situation, the workers would take a
rest after working so hard or in case of extreme temperature. The blood pressure, heart rate and core body temperature were measured again for the same workers after they rested about 5-10 min. The data of physiological changes were later compared between during working and resting period.

2.5. Heat concerns and Heat related symptoms

A questionnaire containing the working information, heat exposure at work, effects of heat on work, coping mechanism and Heat-related symptoms was used in the interviews (adopted from the HOTHAPS questionnaire). The questionnaire has been translated into Cambodian language (Khmer) and interviewed by Cambodian research collaborators in their local Khmer language.

2.6. Productivity

A total of 6 groups were selected at the same type of work at different environmental heat levels. A new area was selected each day and all sugarcane workers in the working farm were counted as a group (10-12 per group). The productivity of workers was measured in terms of the number of sugarcane bundles loaded into a truck. Observational technique were conducted to observe the production output of sugarcane workers in bundles during working hours.

The output productivity of workers were manually counted and the data were recorded using the productivity form adopted from HOTHAPS. During the study period, the workers were not told about the planned analysis to ensure that the workers load the bundles according to their usual capacity per group. The results were tabulated based on average environmental heat exposed by the workers and the average sugarcane bundles loaded per person during the working period. The coping mechanism such as move to cooler environments, take a shower bath and take a rest were also recorded.

2.7. Statistical data analyses

All statistical data analyses were employed by statistical package for social sciences (SPSS) version 20.0 for windows (IBM Corporation, New York, United States).. Paired samples t-test was applied to verify the significant differences in physiological changes of workers during working and resting period. Moreover, Spearman's rho correlation test was used to determine the correlation between physiological changes of workers and heat stress index (WBGT) based on their gender. Spearman's rho correlation test was applied to determine the correlation between the productivity of workers with heat stress index. Concurrently, linear regression analysis was employed to determine an equation of the straight lines between the productivity and heat stress index. General linear model data analysis was applied to determine the relationship between age, gender, BMI, WBGT, type of work and working hours with productivity of workers. Significance was considered in circumstance where $p < 0.05$.

3. Results

The summary of age, standing height (cm), body weight (kg), body mass index and employment period of the workers are presented in Table 1. The mean age for male workers in this study was 37 while that for female workers was 35. The result from t-test shows that there was a significant difference in height ($p = 0.004$) and body weight ($p < 0.001$) between male and female workers. However, the mean BMI for both male and female workers were in a normal category. The mean employment period for male workers was 14 years while that for female workers was 12 years.

Table 2 shows the reading of heat stress index (WBGT) and humidity (%) measured using WBGT monitor and Lascar Data Logger for a period of 6 days. There was a significant difference in heat stress index ($p < 0.001$) and relative humidity ($p = 0.004$) between WBGT monitor and Data Logger.

Therefore, the reading from WBGT monitor was used to evaluate the heat stress experienced by the workers as the WBGT monitor has been proved to be very successful in monitoring heat stress (ACGIH, 1999). The results from WBGT monitor shows the reading of heat stress index value for each day in the sugarcane farm was above the Threshold Limit Value (TLV) for heat exposure as stated in ACGIH standard. The highest reading of heat stress index value in the sugarcane farm was 31.1°C and the lowest reading was 29.1°C.

Table 1. Background information of workers and comparison between gender.

Variable	Male = 63		Female = 47		t	p
	Median	Mean ± SD	Median	Mean ± SD		
Age (y)	35.00	37.19±10.22	39.00	35.57±10.66	-1.025	0.305
Body weight (kg)	56.00	57.54±7.06	53.00	53.57±8.00	-2.804	0.004
Height (cm)	165.00	164.97±5.62	158.00	156.47±5.43	-0.65	< 0.001
BMI	21.09	21.118±2.33	21.30	21.30±3.03	-1.145	0.252
Employed Time (y)	13.00	14.48±9.88	12.00	12.36±8.22	-0.801	0.423

Table 2. Heat stress index (WBGT) and humidity (%) value by using WBGT monitor and Data Logger

	Heat stress index (WBGT °C)				Humidity (%)			
Day	WBGT monitor	Data Logger	t	p	WBGT monitor	Data Logger	t	p
1	29.1*	26.4	6.66	< 0.001	59.5	66.4	-3.80	0.004
2	29.3*	26.7			63.5	69.7		
3	31.0*	27.1			56.2	70.6		
4	29.8*	27.5			56.5	65.3		
5	30.4*	26.9			51	67.6		
6	31.1*	28.3			66.7	69.5		

** Measured heat stress index is above the recommended ACGIH TLV of 27.*

Table 3 shows the descriptive data analysis and the results of paired samples t-test for physiological changes of workers during working and resting period. The results demonstrated that the mean(SD) for all physiological changes variable were within the normal range for both male and female workers. However, the diastolic blood pressure was detected below the normal ranges during resting for both male 79.68±9.569 and female 79.04±8.993 workers. The p-value from paired sample t-test was less than 0.001 for all the physiological change variables. Thus, there was a significant difference in physiological changes of workers during working and resting period.

Table 4 shows the Spearman's rho correlation test to determine the correlation between physiological changes of workers with heat stress index (WBGT) based on their gender. Females heart rate (0.043) and males core body temperature (0.037) during working period was significantly associated with heat stress index. The results also shows the r-value for all physiological changes variables were less than 0.3 which means there was a weak correlation between physiological changes of workers with heat stress index (WBGT). The systolic and diastolic blood pressure during working and resting period for males and core body temperature during working period for females showed non-significant positive correlation whereas, the remaining variables were found have non-significant negative association with heat stress index.

Table 5 shows the heat related symptoms reported by the workers. The highest reported symptoms was heavy sweating which is accounted for 87.2% followed by tiredness 86.4%, headache 61.8%, muscle cramps 60.0% , dizziness 40.9%, vomiting 17.3% and the lowest heat related symptoms reported by the workers was fainting which is 1.8%.

Table 6 shows the data on heat concerns and awareness about heat stress among the sugarcane workers. Majority of the workers were not comfortable with their workplace temperature and have a problem with heat stress. The most applied method to cope with heat while working was moving to a cooler environment. The highest effects of heat stress to their work was that they need more time to complete their work.

Table 7 shows the Spearman rho test to determine the correlation between the productivity of workers with heat stress index (WBGT). The r value was -0.974 which indicates a strong negative correlation between productivity of workers with heat stress index (WBGT). Table 8 shows linear regression analysis to determine an equation of the straight lines between the two variables. The equation obtained was: Productivity = 224.43 – 6.596 (WBGT), which means for every unit increase in degree of heat exposure, productivity was expected to be decreased by 6.596 unit.

Hence, there was a correlation between productivity of workers with heat stress index (WBGT).

Table 9 shows the general linear model data analysis to determine the relationship between selected factors with productivity of workers. Analytical results, revealed that age, BMI, type of work and working hours per day were not significant. After dropping the insignificant variable one-at-a-time, only gender and WBGT were significant predictors of productivity whose p-value was <0.001 and 0.014 respectively. The parametric values were provided in table 10. The equation was as follows: productivity = 177.996 - 2.187(gender) -5.288 (WBGT). Thus, for a given temperature, the productivity of females was -2.187 lower than males.

4. Discussion

This study highlighted the health and productivity experienced by the agricultural workers when exposed to high level of heat. A total of 110 workers comprises of 63 male and 47 female involved in sugarcane farms have been recruited to fulfil this study requirement. The age of participants ranged from 20 to 60 years old. The mean age for male workers was 37 while female was 35. All of the workers were Cambodian people (Khmer). Most of them came from a poor socioeconomic backgrounds and have to work hard for their family. The work was heavy labour and very stressful as they exposed to direct heat source from the sun. The mean Body Mass Index (BMI) for both male and female workers were categorised as normal BMI. All of the workers worked for more than 3 months in sugarcane farm as the mean employed time for male workers were 14 years and female 12 years.

The data from WBGT monitor shows that the average environmental heat exposure in the sugarcane farm were exceeded the limit of American conference of Governmental Industrial Hygiene (ACGIH) standard which is 27.5°C for heavy workload and 28.5°C for moderate workload. The highest heat stress index (WBGT) was 31.1°C whereas the lowest one was 29.1°C. The results shows that the sugarcane workers in Kampong Cham province were exposed to impermissible environmental heat exposure according to ACGIH standard during their work.

There was a significant difference in heart rate during working and resting among the workers. Sahu et al. (2013) revealed that the heart rate of workers increased during working and the heart rate recovery was fast at low temperature.

The highest value of average heart rate measured was 85 bpm and 80 bpm for male and female workers respectively during working which was lower than daily average heart rate 110 bpm moderate workload suggested by Zenz et al. (1994).

Table 3. The physiological changes data of workers and comparison between during working and resting

Variable	Male = 63				Female = 47			
	Median	Mean±SD	t	p	Median	Mean±SD	t	p
Systolic Blood Pressure								
Resting	128	129.56±13.40	-11.566	<0.001***	120	124.43±15.55	-5.845	<0.001***
Working	138	138.05±14.72			130	134.11±17.46		
Diastolic Blood Pressure								
Resting	80	79.68±9.569	-5.317	<0.001***	79	79.04±8.99	-4.334	<0.001***
Working	84	83.83±9.95			85	83.79±7.68		
Heart Rate								
Resting	74	76.61±10.75	-6.427	<0.001***	80	78.72±11.07	-8.762	<0.001***
Working	80	80.81±11.40			87	85.80±11.19		
Body Temperature								
Resting	35.7	35.53±0.67	-7.815	<0.001***	35.7	35.68±0.46	-3.877	<0.001***
Working	35.9	35.82±0.60			35.9	35.92±0.58		

****p is significant at 0.001*

Table 4. The correlation between physiological changes with heat stress index (WBGT) according to gender

Main variable	Variable	Male = 63		Female = 47	
		r	p	r	p
WBGT	Systolic Blood Pressure				
	Working	0.172	0.177	-0.168	0.26
	Resting	0.225	0.076	-0.024	0.872
	Diastolic Blood Pressure				
	Working	0.101	0.431	-0.247	0.094
	Resting	0.143	0.262	-0.097	0.515
	Heart Rate				
	Working	-0.002	0.989	-0.296	0.043*
	Resting	-0.008	0.948	-0.248	0.092
	Body Temperature				
	Working	-0.263	0.037*	0.15	0.313
	Resting	-0.222	0.08	-0.111	0.458

** p is significant when <0.05*

Table 5. The prevalence of heat related symptoms reported by the workers (n = 110)

Variable	Number reported	Percentage (%)
Heavy Sweating	96	87.2
Tiredness/Weakness	95	86.4
Headache	68	61.8
Muscle Cramps	66	60
Dizziness	45	40.9
Nausea/Vomiting	19	17.3
Fainting	2	1.8

Table 6. Heat concerns reported by workers

Heat concerns	Number reported	Percentage (%)
Comfortable with workplace temperature	2	1.8
Heat stress is a problem	109	99.1
How bad the heat stress		
Bad	88	80
Very bad	17	15.5
Manageable	5	4.5
Coping mechanism from heat exposure		
Move to cooler environment	65	60
Take a rest	39	35.5
Cool shower, bath, or sponge bath	5	4.5
Effects of heat to their work		
Take more time to complete work	58	52.7
Absenteeism	33	30
Less productivity	19	17.3

Table 7. The correlation between productivity of workers with heat stress index (WBGT)

WBGT (°C)	Average per person per bundle	Spearman's rho test	
		r	p
29.1	35	-0.974	<0.001***
29.8	30		
31	20		
29.8	25		
30.4	25		
31.1	20		

****p is significant at 0.001*

Table 8. The parametric value of correlation between productivity of workers with heat stress index (WBGT)

Variable	Unstandardized Coefficients		t	p
	B	Std. Error		
Constant	224.43	6.835	32.829	< 0.001
WBGT	-6.596	0.228	-28.89	< 0.001

Table 9. The relationship between selected factor (age, gender, BMI, WBGT, type of work, working hours) with productivity

Source	df	Mean Square	F	p
Intercept	1	1849.2	117.5	< 0.001
Age	1	23.127	1.47	0.228
Gender	1	98.617	6.27	0.014*
BMI	1	34.664	2.204	0.141
WBGT	1	1532.9	97.46	< 0.001*
Type of work	2	31.479	2.001	0.14
Working hours	1	29.727	1.89	0.172

** significant at p <0.05*

There was a significant difference for core body temperature during working and resting of workers. The highest average value of body core temperature measured in this study was 35.9°C and 35.8°C respectively for both male and female workers during work.

However, the findings demonstrated the average body core temperature of workers were below 38°C as recommended by ACGIH. American conference of Governmental Industrial Hygiene (ACGIH) declared that workers should not be permitted to work when their deep body temperature exceeds 38°C (ACGIH, 2001).

According to World Health Organization (WHO), normal adult blood pressure is defined as a blood pressure of 120 mm Hg when the heart beats (systolic) and a blood pressure of 80 mm Hg when the heart relaxes (diastolic). When systolic blood pressure is equal to or above 140 mm Hg and/or a diastolic blood pressure equal to or above 90 mm Hg , the blood pressure is considered to be raised or high (WHO, 2012). In overall, the systolic blood pressure during working and resting for male and female workers were in the normal range in the present study.

However, the mean for diastolic blood pressure during resting for male 79.68 ± 9.57 and female 79.04 ± 8.99 workers were reported below the normal range which is less than 80 mmHg. Meanwhile, the mean diastolic blood pressure was in the normal range for both male 83.83 ± 9.95 and female 83.79 ± 7.68 workers during work.

There was a significant difference in systolic and diastolic blood pressure during working and resting of workers. Nadia (2009) stated that there was a significant increase in systolic blood pressure before work and after working due to high ambient temperature.

Most of the physiological changes variables have no significant correlation with environmental heat exposure. Out of all variables, only core body temperature of male (0.037) and heart rate of female (0.043) during working were found to have a significant correlation with environmental heat exposure. However, the r-value from Spearman's rho test shows a weak negative correlation between those significant variables.

Previous study reported that there was no significant correlation between physiological changes with environmental heat exposure (Nadia, 2009). Similarly, Goh et al. (2004) found that there was no correlation between heat exposure with the body temperature as well as heart beat. Hence, our study results suggested that the increase in blood presure, heart rate and body temperature of workers during working period were not related to the environmental heat exposure, but due to their physical work activities.

The common symptoms reported from the workers was heavy sweating (87.2%) which may be due to heavy work task performed by the workers. Sweating evaporation is the reaction mechanism developed by our body to transport the interior heat from our body to the outside environment. Our field observation revealed that , most of the workers were heavily sweating while working. Thus, there were possibilities of having heat-related illness among the workers. The lowest heat related symptoms reported by the workers was fainting (1.8%).

This study found that the number of sugarcane bundles loaded by the workers decreased as the environmental heat increased. At higher environmental heat exposure (31.1°C),

the corresponding number of sugarcane bundles loaded by each workers was 20. Meanwhile, at lowest environmental heat exposure (29.1°C), the corresponding number of sugarcane bundles loaded for each workers was 35.

The productivity of workers was expected to decrease by 6.5 bundles for each degree of environmental heat increase. These findings are consistent with those of Sahu et al. (2013) which reported that the work productivity gradually decreased with the increases in heat exposure as well as with the order working hours. Sahu et al. (2013) also found that the work output of workers were decreases approximately 5% in each degree of WBGT increases. There were several factors probably related to the decrease in work productivity among the workers such as age, gender, body mass index (BMI), type of work and working hours. Based on our analysis, only gender (0.014) and environmental heat (< 0.001) were found to have a relationship with productivity of workers. This is due to a difference in physical work output capacity between male and female. The male workers have higher number of sugarcane bundles loaded as compared to the female workers. Higher levels of physical activity are related to greater muscle strength, especially in women and those with lower age (Gómez-Cabello et al., 2014). The amount of sugarcane bundles loaded by female workers were expected to be lower by approximately 2.1 bundles compared to male workers.

5. Conclusion

This study suggests that the sugarcane workers at Kampong Cham area were exposed to high heat stress during this study period. Even though the environmental heat exposure were above the ACGIH's threshold limit value, the physiological changes did not reach unacceptable level of physiological standard. Blood pressure, heart rate and core body temperature were not found to be associated with environmental heat exposure. Interestingly, we found that work output productivity of sugarcane workers decreased as the environmental heat increased. In fact, male workers have high productivity as compared to female workers. Mitigating actions are warrant to improve the productivity of sugarcane workers and minimize the health risks of worker populations.

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