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Risk factors associated with heat-related illness among sugarcane farmers in Thailand

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Abstract: Heatstroke is defined as severe symptoms of heat-related illness, which could lead to death. Sugarcane farmers are at high risk of heatstroke under extremely hot outdoor working conditions. We explored the prevalence of heat-related illness symptoms and risk factors related to heat-related illness among sugarcane farmers working in the summer. We conducted a cross-sectional study using questionnaire interviews among 200 sugarcane farmers in Kamphaeng Phet Province, Thailand. The questionnaire addressed demographics, heat-related symptoms experienced during summer at work, and occupational factors. Bioelectrical impedance analysis was used to assess body mass index and body fat percentage. Watson formula equations were used to estimate total body water. The prevalence of heat-related illness symptoms was 48%; symptoms included heavy sweating, weakness/fatigue, dizziness, muscle cramps, headache, and vertigo. Factors associated with heat-related illness included women and clothing. Sugarcane farmers wearing two-layer shirts had a higher risk of heat-related illness. Farmers with fluid intake 3.1–5.0 liters per day had a 79% lower risk of heat-related illness. Our findings demonstrated that sugarcane farmers are at risk of heat-related illness. We confirmed that working conditions, including wearing proper clothing and water-drinking habits, can reduce this risk.

Key words: Risk factor, Heat-related illness, Women, Heatstroke, Fluid intake, Sugarcane farmer, Thailand

Introduction

Heat exposure will increase health problems among farmers in Thailand because global temperatures are expected to rise as the global climate changes[1]. The Thai Meteorological Department reports that the annual maximum temperature is increased by 1.9°C, and the average annual temperatures in Thailand are increased by 0.9°C. There is an increase in warm temperatures during the day and at night in Thailand[2]. The Southeast Asia START (System for Analysis, Research and Training) Regional Centre (SEA STARTRC) estimates that the nighttime temperature will become warmer than the current daytime temperature by 2045– 2065[3]. The World Health Organization (WHO) has

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reported that annual temperatures in Thailand are predicted to increase by approximately 4.3°C between 1990 and 2100[4, 5]. The number of heatwave days is expected to increase by approximately 210 days by the year 2100[4]. All of Thailand will have an extended summertime by the end of the 21st century[6, 7]. When exposed to heat, body heat gain is produced owing to the combination of environmental heat (weather-related) and internal body heat (workload-related) generated from metabolic processes[8]. Extreme and prolonged exposure to heat can lead to a high core body temperature because thermoregulation is overwhelmed by increased heat production with impaired heat loss, resulting in adverse health impacts[9].

Heat-related illnesses have acute health impacts that range from minor to major symptoms and conditions. Minor heat-related illnesses comprise heat edema, heat rash, heat cramps, heat syncope, and heat exhaustion. The most serious outcome of heat exposure is heatstroke, which can lead to death[10, 11]. High ambient temperatures are associated with increased heat-related symptoms and illness[12]. Similarly, exposure to extreme heat in the workplace is related to increased heat-related illness[13].

With such strong evidence, heat-related mortality is predicted to increase by 14%–29% by 2100[5], with over 50% of deaths occurring among farmers[4]. According to the Bureau of Occupational and Environmental Diseases (BOED) Thailand, the annual rates of heat-related illness from 2015 to 2018 were 1.95, 4.12, 0.17, and 0.12 per 100,000 population, respectively[14].

Most of those affected were farmers because these workers are exposed to heat in full sunlight and have a heavy workload throughout their working lifetime[14]. Likewise, a previous study among Thai sugarcane cutters demonstrated that working in the extreme heat with a heavy workload is associated with heat-related illness symptoms[15].

Sugarcane farmers are an essential workforce for the economy of Thailand, the fourth largest sugarcane producer globally, accounting for 8.10% of the world's sugar production. In 2019, Thailand accounted for approximately 16.95% of global sugar export volume, valued at 2.97 billion USD, with approximately 1 million sugarcane farmers[16]. Although sugarcane and other farmers are at high risk of heat-related illness, regulatory standards regarding heat stress are not applicable to farmers. Remarkably, BOED data are only available for the prevalence of heat-related illness, which were collected in interviews with patients during health care visits[17]. In the same way, studies are limited regarding the potential risk factors of heat-related illness in farmers, such as personal risk factors, clothing, rest, acclimatization, and education[17]. Therefore, in the present study, we focused on personal risk factors and clothing associated with heat-related illness symptoms experienced by sugarcane farmers during the summer while working in Kamphaeng Phet Province, Thailand.

Subjects and Methods

Participants

This study was conducted in Kamphaeng Phet Province, Thailand's main sugarcane-growing province[18] from 15 March to 11 April in 2021. Participants in this study included 200 sugarcane farmers who worked during the growing season. The study period was during the summer (mid-February to mid-May), when the highest temperatures occur in Thailand, especially in March and April[19, 20]. All participants in the study were at least 20 years of age without a medical history of kidney disease, cardiovascular disease, or cancer. The farmers worked outdoors, with overlapped time between 10 am to 3 pm (started working between 8 am and 5 pm). We excluded sugarcane farmers who worked from 8 am to 10 am and from 3 pm to 5 pm. Participation was voluntary, and written informed consent was obtained from each subject. The Human Research Ethics Committee of Mahidol University approved the study protocol (MUPH 2021-014).

Questionnaire

The participants were interviewed using a questionnaire. The questionnaire was divided into three parts: information on demographics, heat-related symptoms experienced during summer at work, and occupational factors. The first part included questions regarding demographic characteristics: sex, age, weight, height, underlying diseases, and lifestyle behaviors (alcohol consumption, caffeine intake, smoking, sleep duration, and afternoon napping). The second part included questions addressing 15 heat-related symptoms. All participants were asked whether they had experienced each symptom during the summer at work; responses were "never", "sometimes", or "regularly" (at least once per week). For data analysis, "sometimes" and "regularly" were grouped into one variable, denoted "ever"[15]. The third part of the questionnaire addressed occupational factors, including heat exposure duration per day, work clothing ensembles, and fluid intake per day. This questionnaire has been previously used among salt production workers in Thailand and has acceptable reliability, with a kappa of 1.00[21].

Body composition analysis

Body composition was assessed using bioelectrical impedance analysis (Omron HBF 375)[22] including body mass index (BMI) and body fat percentage (BF%). Total body water (TBW) was estimated using the Watson formula equations, which are normally used in clinical practice:[23–25]

Male TBW = 2.447 − (0.09156 × age) + (0.1074 × height) + (0.3362 × weight)

Female TBW = −2.097 + (0.1069 × height) + (0.2466 × weight)

%TWB = TBW/weight × 100

For data analysis, BF% was divided into "normal" and "obese". Obesity was defined using the BF% cutoff (> 25% for men and > 35% for women)[26], which revealed a high prevalence of obesity. Total water percentage included "normal" (55%–60% in men and 50%–55% in women) and "lower limit" (< 55%–60% in men and < 50%–55% in women) in the analysis[27].

Heat-related illness symptoms

Heat-related illness symptoms (outcome variable) include weakness/fatigue, dizziness, muscle cramps, heavy sweating, vertigo, nausea, vomiting, headache, fainting, and irritability[28]. If a participant reported "ever" having two or more symptoms with heavy sweating or dizziness[18,29], they were defined as having heat-related illness in this study.

Data analysis

We used SPSS statistical software version 18 (SPSS Inc., Chicago, IL, USA) for the data analysis. Descriptive statistics were used to determine frequency distribution, percentage, and mean ± standard deviation. The effects of potential risk factors on heat-related illness symptoms with adjusted odds ratios (ORs) were assessed using multivariate logistic regression. Potential predictors of heat-related illness were selected using univariate logistic regression with a *p*-value of < 0.05 and < 0.001, including sex, duration of heat exposure, afternoon napping, fluid intake, work shirt, and work pants. We used a Spearman correlation matrix to determine multicollinearity in relationships (r>0.6) between independent variables to avoid an unstable and inaccurate logistic regression model; the results revealed no significant correlations between independent variables (r<0.6). These variables were entered into the multivariate logistic regression model using the enter method. Adjusted ORs with 95% confidence intervals (CIs) at a significance level of 0.05 were used to determine associations between risk variables and heat-related illness symptoms.

Results

Demographic characteristics

Table 1 shows the demographic characteristics of the 200 sugarcane farmers in this study. The overall prevalence of heat-related illness symptoms was 48.0% (96/200). The enrolled sugarcane farmers included 79 men (39.5%) and 121 women (60.5%). The prevalence of heat-related illness symptoms among male and female sugarcane farmers was 30.4% and 59.5%, respectively. The mean age of farmers was 54.9 ± 10.1 years, with heat-related illness and no heat-related illness symptoms were 53.8 ± 10.6 years and 55.9 ± 9.6 years, respectively. The average duration of work experience was 20.1 ± 11.3 years, among farmers with heat-related illness symptoms (19.4 ± 10.6 years) was less than that in farmers with no heat-related illness symptoms (20.8 ± 11.9 years). Most of the farmers (32.5%) had a BMI between 25.0–29.9 kg/m^2. Farmers with heat-related illness symptoms had obesity, including 34.4% with class I obesity (BMI 25.0–29.9 kg/m^2), 24.0% with class II obesity (BMI >30.0 kg/m^2), and without these symptoms (30.8%) with class I obesity. Approximately 78.5% of farmers demonstrated a BF% indicative of obesity. The prevalence of heat-related illness symptoms and no heat-related illness symptoms were 79.2% and 77.9%, respectively. Most of the farmers showed a normal level of total body water percentage (61.0%). Approximately 45.8% of farmers with heat-related illness symptoms had a total body water percentage lower than the limit, and 67.0% with no heat-related illness symptoms had a normal level. Almost 60.0% of farmers were never a drinker. Farmers with heat-related illness symptoms consumed more alcohol than among those without those symptoms (25.0% vs. 20.0%). Most farmers (71.0%) consumed caffeine, had heat-related illness symptoms (75.0%), and without these symptoms (67.3%). Most of the farmers were non-smokers (78.0%), the prevalence of heat-related illness symptoms and no heat-related illness symptoms were 81.3% and 75.0%, respectively. Approximately 56.0% of farmers reported 7–8 hours of sleep per night, 56.3% showed heat-related illness symptoms, and 55.8% without these symptoms. About 75.0% of farmers with heat-related illness symptoms and 61.5% of those with no heat-related illness symptoms were exposed to heat for more than 5 hours per day. Most farmers (59.6%) took an afternoon nap; specifically, 51.1% had heat-related illness symptoms, and 49.0% had no symptoms. Half of the farmers had a fluid intake of 1–3 liters per day

Table 1. Demographic characteristics

Variables	Total (N=200)	HI (N=96)	No HI (N=104)	OR	95% CI	*p*-value
Heat-related illness						
Men, n (%)	79.0 (39.5)	24.0 (30.4)	55.0 (69.6)	1		
Women, n (%)	121.0 (60.5)	72.0 (59.5)	49.0 (40.5)	3.37	1.85–6.14	< 0.001**
Age (years), mean (SD)	54.9 (10.1)	53.8 (10.6)	55.9 (9.6)	0.98	0.95–1.01	0.160
Work experience (years), mean (SD)	20.1 (11.3)	19.4 (10.6)	20.8 (11.9)	0.99	0.97–1.01	0.378
BMI (kg/m^2)						
<18.5 (underweight), n (%)	7.0 (3.5)	3.0 (3.1)	4.0 (3.8)	0.92	0.19–4.56	0.919
18.5–22.9 (normal), n (%)	49.0 (24.5)	22.0 (22.9)	27.0 (26.0)	1		
23.0–24.9 (overweight), n (%)	42.0 (21.0)	15.0 (15.6)	27.0 (26.0)	0.68	0.29–1.59	0.375
25.0–29.9 (obese I), n (%)	65.0 (32.5)	33.0 (34.4)	32.0 (30.8)	1.27	0.60–2.66	0.535
≥30 (obese II), n (%)	37.0 (18.5)	23.0 (24.0)	14.0 (13.5)	2.02	0.84–4.82	0.114
Fat (%)						
Normal, n (%)	43 (21.5)	20 (20.8)	23 (22.1)	1		
Obese, n (%)	157 (78.5)	76 (79.2)	81 (77.9)	1.08	0.55–2.12	0.826
Total body water (%)						
Normal, n (%)	122 (61.0)	52 (54.2)	70 (67.3)	1		
Lower limit, n (%)	78 (39.0)	44 (45.8)	34 (32.7)	1.74	0.98–3.09	0.058
Alcohol consumption						
Never drinker, n (%)	134.0 (67.0)	62.0 (64.6)	72.0 (69.2)	1		
Former drinker, n (%)	20.0 (10.0)	9.0 (9.4)	11.0 (10.6)	0.95	0.37–2.44	0.915
Current drinker, n (%)	46.0 (23.0)	25.0 (26.0)	21.0 (20.2)	1.38	0.71–2.71	0.345
Caffeine intake						
No, n (%)	58.0 (29.0)	24.0 (25.0)	34.0 (32.7)	1		
Yes, n (%)	142.0 (71.0)	72.0 (75.0)	70.0 (67.3)	1.46	0.79–2.70	0.232
Smoking						
Never smoker, n (%)	156.0 (78.0)	78.0 (81.3)	78.0 (75.0)	1		
Former smoker, n (%)	14.0 (7.0)	7.0 (7.3)	7.0 (6.7)	1.00	0.34–2.99	1.000
Current smoker, n (%)	30.0 (15.0)	11.0 (11.5)	19.0 (18.3)	0.58	0.26–1.30	0.184
Hours of sleep (hours/day)						
< 7, n (%)	24 (12.0)	10 (10.4)	14 (13.5)	0.71	0.28–1.84	0.487
7–8, n (%)	112 (56.0)	54 (56.3)	58 (55.8)	0.93	0.50–1.72	0.820
>8, n (%)	64 (32.0)	32 (33.3)	32 (30.8)	1		
Duration of heat exposure (hours/day)						
Mean (SD)	5.7 (2.2)	5.8 (2.1)	5.5 (2.3)			
<5, n (%)	64.0 (32.0)	24.0 (25.0)	40.0 (38.5)	1		
≥5, n (%)	136.0 (68.0)	72.0 (75.0)	64.0 (61.5)	1.88	1.02–3.44	0.043*
Afternoon napping (minutes/day)						
No napping, n (%)	110.0 (55.3)	47.0 (49.0)	63.0 (60.6)	1		
Napping, n (%)	90.0 (45.0)	49.0 (51.1)	41.0 (39.4)			
30–60 minutes, n (%)	61.0 (30.5)	30.0 (31.3)	31.0 (29.8)	1.29	0.69–2.43	0.417
>60 minutes, n (%)	29.0 (14.6)	19.0 (19.8)	10.0 (9.6)	2.55	1.08–5.98	0.032*
Fluid intake (liters/day)						
1.0–3.0, n (%)	73.0 (36.5)	47.0 (49.0)	26.0 (25.0)	0.90	0.36–2.30	0.832
3.1–5.0, n (%)	100.0 (50.0)	31.0 (32.3)	69.0 (66.3)	0.23	0.09–0.56	0.001*
>5.0, n (%)	27.0 (13.5)	18.0 (18.8)	9.0 (8.7)	1		

* Significant at $p<0.05$; ** $p<0.001$.

Univariate logistic regression analyses.

HI, heat-related illness; OR, odds ratio; CI, confidence interval; SD, standard deviation; BMI, body mass index.

Table 2. List of work clothes

Variables	Total (N=200)	HI (N=96)	No HI (N=104)	OR	95% CI	p-value
Work clothes: shirt						
One-layer: Long-sleeved cotton shirt or long-sleeved cotton/polyester blend T-shirt	62.0 (31.0)	13.0 (13.5)	49.0 (47.1)	1		
Two-layer: Long-sleeved cotton shirt and long-sleeved cotton/polyester blend T-shirt	33.0 (16.5)	22.0 (22.9)	11.0 (10.6)	7.54	2.92–19.44	< 0.001**
Two-layer: Short-sleeved cotton/polyester blend T-shirt and long-sleeved cotton shirt or long-sleeved cotton/polyester blend T-shirt	105.0 (52.5)	61.0 (63.5)	44.0 (42.3)	5.23	2.23–10.78	< 0.001**
Work clothes: pants						
One-layer: cotton/polyester blend pants	99.0 (49.5)	44.0 (45.8)	55.0 (52.9)	1		
One-layer: polyester pants	39.0 (19.5)	14.0 (14.6)	25.0 (24.0)	0.70	0.33–1.50	0.361
One-layer: jean pants	20.0 (10.0)	11.0 (11.5)	9.0 (8.7)	1.53	0.58–4.01	0.390
Two-layer: cotton/polyester blend shorts and polyester pants or cotton/polyester blend pants	42.0 (21.0)	27.0 (28.1)	15.0 (14.4)	2.25	1.07–4.74	0.033*
Full face mask						
Not used	29.0 (14.5)	11.0 (11.5)	18.0 (17.3)	1		
Used full face mask	171.0 (85.5)	85.0 (88.5)	86.0 (82.7)	1.62	0.72–3.63	0.243
Head protection						
No hat	7.0 (3.5)	1.0 (1.0)	6.0 (5.8)	1		
Used a hat	193.0 (96.5)	95.0 (99.0)	98.0 (94.2)	5.82	0.69–49.23	0.106

HI, heat-related illness; OR, odds ratio; CI, confidence interval.
* Significant at $p<0.05$; ** $p<0.001$.
Univariate logistic regression analyses.

during the summer at work, with nearly 50.0% of farmers experiencing heat-related illness symptoms and 25.0% experiencing no such symptoms.

Clothing ensembles for work

The clothing ensembles for work among sugarcane farmers are summarized in Table 2. During summer at work, the type of shirt worn while working was significantly related to heat-related illness symptoms. Approximately 63.5% of farmers with heat-related illness symptoms and 42.3% of farmers with no such symptoms wore a two-layer shirt. Most farmers in both groups wore one-layer cotton/polyester blend pants, accounting for 45.8% of farmers with heat-related illness and 52.9% of farmers with no heat-related illness symptoms. Wearing two-layer pants, including cotton/polyester blend shorts and polyester pants or cotton/polyester blend pants, was associated with heat-related illness symptoms. Wearing a full-face mask and head protection showed no significant relationship with heat-related illness symptoms in both groups.

Prevalence of heat-related illness symptoms

Table 3 shows the number of sugarcane farmers who indicated that they experienced each heat-related illness symptom while working in the summer. The symptoms reported by more than 50% of sugarcane farmers included heavy sweating (81.0%), weakness/fatigue (71.5%), dizziness (60.0%), muscle cramps (55.5%), headache (52.0%), and vertigo (51.5%).

Risk factors associated with heat-related illness among sugarcane farmers

Univariate logistic regression analysis revealed factors significantly associated with heat-related illness in sugarcane farmers (Tables 1 and 2). Women were more likely to experience heat-related illness than men (OR = 3.37, 95% CI: 1.85–6.141). Sugarcane farmers exposed to heat for more than 5 hours per day had a greater risk of heat-related illness than those exposed to heat for fewer than 5 hours per day (OR = 1.88, 95% CI: 1.02–3.44). Farmers who took an

Table 3. Prevalence of heat-related illness symptoms while working in summer (N=200)

Symptoms	n	%
Heavy sweating	163	81.5
Weakness/fatigue	143	71.5
Dizziness	120	60.0
Muscle cramps	111	55.5
Headache	104	52.0
Vertigo	103	51.5
Rash on skin	81	40.5
Irritability	72	36.0
Nausea	37	18.5
Dry and cracking skin	33	16.5
Vomiting	30	15.0
Swelling hands and feet	21	10.5
Blisters on skin	18	9.0
Fainting	8	4.0
Other abnormal symptom	15	7.5

afternoon nap of more than 60 minutes were more likely to experience heat-related illness than non-nappers (OR = 2.55, 95% CI: 1.08–5.98); napping for ≤ 60 minutes was not associated with heat-related illness (OR = 1.29, 95% CI: 0.69–2.63). The odds of experiencing heat-related illness were 77% lower for farmers with a fluid intake of 3.1–5.0 liters per day (OR = 0.23, 95% CI: 0.09–0.56). Farmers who wore two long-sleeved shirts (OR = 7.54, 95% CI: 2.92–19.44) or a short- with a long-sleeved shirt (OR = 5.23, 95% CI: 2.23–10.78) were more likely to experience heat-related illness than farmers who wore one long-sleeved shirt. Moreover, wearing two-layer pants made of all types of fabric was associated with a greater risk of heat-related illness than wearing single-layer cotton/polyester blend pants (OR = 2.25, 95% CI: 1.07–4.74).

In multivariate logistic regression analysis, factors associated with heat-related illness in univariate logistic regression analyses (Table 4) were entered into the model after multicollinearity analysis, including sex, duration of heat exposure, afternoon napping, fluid intake, work shirt, and work pants. Women had a 2.37-times greater risk of heat-related illness than men (adjusted OR = 2.37, 95% CI: 1.11–5.04). The odds of heat-related illness were 79% lower for farmers with a fluid intake of 3.1–5.0 liters per day (adjusted OR = 0.21, 95% CI: 0.07–0.60). Farmers who wore a two-layer shirt (a long-sleeved cotton shirt and a long-sleeved cotton/polyester blend T-shirt) were 5.24 times more likely to have heat-related illness than farmers who wore a one-layer shirt (a long-sleeved cotton shirt or a long-sleeved cotton/polyester blend T-shirt), with adjusted OR = 5.24, 95% CI: 1.69–16.24. Farmers who wore a short-sleeved cotton/polyester blend T-shirt and a long-sleeved cotton shirt or a long-sleeved cotton/polyester blend T-shirt were 3.61 times more likely to have a heat-related illness than farmers who wore a one-layer shirt (adjusted OR = 3.61, 95% CI: 1.52–8.53). Duration of heat exposure, afternoon napping, and work pants were not related to heat-related illness.

Discussion

In this study, we found that 96 sugarcane farmers experienced heat-related illness symptoms, accounting for 48% of the study sample. Heat-related illness tended to occur more frequently in women. In terms of the differences in hormones, sex does not impact heat-related illness. However, the National Institute for Occupational Safety and Health (NIOSH) recommended standard states that with occupational exposure to heat and hot environments, women's lower absolute muscle mass, higher body fat content, and lower hemoglobin concentration leads to a lower average maximum oxygen consumption during exercise (VO_2 max). The NIOSH report describes many factors that affect core body temperature in men and women of varying body weights, ages, and work capacities who do the same job[30]. Additionally, other sources of variability when individuals work in hot environments include differences in circulatory system capacity, sweat production, and ability to regulate electrolyte balance, each of which may be a large difference. Dietary factors might contribute to differences in thermoregulation[30]. A limitation of our study was control of dietary factors during the study. We found that 80.2% of women had excess BF%, class I obesity (36.4%), and class II obesity (20.7%). Therefore, obesity might be

Table 4. Multivariate analysis of risk factors associated with heat-related illness among sugarcane farmers

Variables	B	SE	Wald	df	OR	95% CI	*p*-value
Sex							
Male	1						
Female	0.86	0.39	4.99	1	2.37	1.11–5.04	0.025*
Duration of heat exposure (hours/day)							
<5	1						
≥5	0.55	0.37	2.25	1	1.74	0.84–3.58	0.134
Afternoon napping							
No napping	1						
≤60-minute nap	0.05	0.39	0.02	1	1.05	0.49–2.26	0.901
>60-minute nap	0.52	0.53	0.97	1	1.68	0.60–4.75	0.325
Fluid intake (liters/day)							
1.0–3.0	−0.11	0.54	0.04	1	0.89	0.31–2.60	0.837
3.1–5.0	−1.57	0.54	8.49	1	0.21	0.07–0.60	0.004*
>5.0	1						
Work clothes: shirt							
One-layer: Long-sleeved cotton shirt or long-sleeved cotton/polyester blend T-shirt	1						
Two-layer: Long-sleeved cotton shirt and long-sleeved cotton/polyester blend T-shirt	1.66	0.58	8.23	1	5.24	1.69–16.24	0.004*
Two-layer: Short-sleeved cotton/polyester blend T-shirt and long-sleeved cotton shirt or long-sleeved cotton/polyester blend T-shirt	1.28	0.44	8.51	1	3.61	1.52–8.53	0.004*
Work clothes: pants							
One-layer: cotton/polyester blend pants	1						
One-layer: polyester pants	0.01	0.48	0.00	1	1.01	0.40–2.58	0.976
One-layer: jean pants	0.51	0.58	0.79	1	1.67	0.54–5.20	0.375
Two-layers: cotton/polyester blend shorts and polyester pants or cotton/polyester blend pants	0.22	0.45	0.25	1	1.25	0.52–3.00	0.614
Cox & Snell R^2				0.262			
Nagelkerke R^2				0.349			

Hosmer–Lemeshow test: χ^2=14.62. * Significant at p<0.05.
SE, standard error; df, degrees of freedom; OR, odds ratio; CI, confidence interval.

involved in sex differences. A person with excess BF% will gain heat faster owing to lower specific heat capacity or impaired sweat gland function[31–33]. Obese individuals produce less self-generated airflow, causing heat loss to decrease. Body fat is added to body mass, increasing heat production. Subcutaneous fat determines the physical insulation level of the body and reduces the direct transfer of heat from muscles to the skin[30–33]. Likewise, a systematic review revealed that women experienced a higher incidence of heat-related illness than men. Longer working time was a risk factor for both men and women, and higher BMI was related to heat-related illness among men. However, the association between these factors and heat-related illness is limited owing to the small number of articles included in that review. Other studies have acknowledged that sex differences in cardiorespiratory fitness, BF%, and surface area-to-mass ratio may account for higher rates of heat intolerance among women[34]. However, a systematic review and meta-analysis found that men have a higher prevalence of heat-related illness than women owing to psychological and behavioral factors[35]. Thus, the higher heat-related illness risk for women than men found in our study might be explained by greater body mass and BF% among female study participants (Table 5).

Two layers of clothing are commonly worn among Thai farmers in summer and throughout the year to protect against sunburn, and there seems to be less concern about heat-related illness. Most sugarcane farmers (69%) in our study wore two-layer shirts, with 52.5% wearing a short-sleeved shirt with a long-sleeved shirt and 16.5% wearing two long-sleeved shirts. Two-layer clothing is associated with heat-related illness symptoms. Clothing serves as

Table 5. Difference in demographic characteristics between men and women

Variable	Men	Women	*p*-value
Age (years), mean (SD)	57.0 (10.5)	53.5 (9.7)	0.017 [a*]
Work experience (years), mean (SD)	22.8 (11.8)	18.4 (10.6)	0.007 [a*]
Height (cm), mean (SD)	167.4 (6.6)	156.0 (6.0)	0.000 [a**]
Weight (kg), mean (SD)	69.5 (14.3)	64.2 (12.1)	0.005 [a*]
BMI (kg/m^2), mean (SD)	24.8 (4.6)	26.4 (4.5)	0.017 [a*]
<18.5 (underweight), n (%)	7.0 (8.9)	0.0 (0.0)	0.009 [b*]
18.5–22.9 (normal), n (%)	22.0 (27.8)	27.0 (22.3)	
23.0–24.9 (overweight), n (%)	17.0 (21.5)	25.0 (20.7)	
25.0–29.9 (obese I), n (%)	21.0 (26.6)	44.0 (36.4)	
≥30 (obese II), n (%)	12.0 (15.2)	25.0 (20.7)	
Fat			
Normal, n (%)	19 (24.1)	24 (19.8)	0.478 [b]
Obese, n (%)	60 (75.9)	97 (80.2)	
Total body water (%)			
Normal, n (%)	53 (67.1)	26 (32.9)	0.154 [b]
Lower limit, n (%)	69 (57.0)	52 (43.0)	
Hours of sleep (hours/day), mean (SD)	7.8 (1.5)	7.8 (1.4)	0.994 [b]
Afternoon napping			
No napping, n (%)	41 (51.9)	38 (48.1)	0.476 [b]
Napping, n (%)	69 (57.0)	52 (43.0)	
Duration of heat exposure (hours/day), mean (SD)	5.7 (2.1)	5.6 (2.3)	0.467 [a]
Fluid intake (liters/day), mean (SD)	3.4 (1.9)	3.8 (2.2)	0.155 [a]

*Significant at $p<0.05$; ** $p<0.001$.

[a] Independent *t-test*. [b] Chi-square test.

SD, standard deviation; BMI, body mass index.

insulation between the skin and the environment to protect from heat, cold, and moisture[30]. The main effect of clothing is to interfere with heat exchange between the skin and the environment by dry transfer (convection, conduction, and radiation) and sweat evaporation[36, 37], which can cause physiological stress resulting in heat-related illness and death[37]. If the environmental temperature is higher than the skin temperature, dry heat gain occurs, and when the skin temperature is higher than the environmental temperature, dry heat loss can result[38]. Clothing reduces the efficiency of conduction heat transfer by controlling the body surface, causing a core temperature increase. Clothing is a barrier to wind velocity on convective heat exchange because covection is an effective mechanism of the wind. When exposed to heat, clothing reduces effective radiative heat exchange mechanisms by controlling the skin's surface area. Clothing is resistant to the evaporation of sweat[37, 38]. Our findings showed that wearing a two-layer shirt was related to heat-related illness and wearing two long-sleeved shirts (adjusted OR = 5.24, 95% CI: 1.69–16.24) was associated with greater occurrence of heat-related illness than wearing a short-sleeved shirt and a long-sleeved shirt (adjusted OR = 3.61, 95% CI: 1.52–8.53) at work in summer. These findings result from interference with the heat exchange mechanism, which leads to a high core body temperature and causes heat-related illness. Additionally, women in our study wore two-layer clothing more often than men, which led to their higher risk of heat-related illness (Table 6).

Approximately 3.1–5.0 liters of fluid intake a day among sugarcane farmers is needed to maintain a stable core body temperature. In our study, this level of fluid consumption was related to a 79% lower risk of heat-related illness. The fluid requirements during heat exposure depend on fluid lost in controlling body temperature and maintaining muscle function[39]. The perspiration rate ranges from 1.0–3.5 liters per hour, depending on weight, sweat gland volume and activity, work intensity, climate, and heat acclimatization[40]. The Institute of Medicine recommends adequate water intake of ≥ 3.7 liters per day for men and ≥ 2.7 liters per day for women under normal conditions of diet, physical activity, and climate[41]. A median 15 liters of water per day among sugarcane cutters was found to be less adequate than a median 5 liters of water intake per day in

Table 6. Difference in work clothes between men and women

Variables	Men, n (%)	Women, n (%)	*p*-value
Work Clothes: shirt			
One-layer: Long-sleeved cotton shirt or long-sleeved cotton/polyester blend T-shirt	42 (53.2)	20 (16.5)	< 0.001**
Two-layer: Long-sleeved cotton shirt and long-sleeved cotton/polyester blend T-shirt	3 (3.8)	30 (24.8)	
Two-layer: Short-sleeved cotton/polyester blend T-shirt and long-sleeved cotton shirt or long-sleeved cotton/polyester blend T-shirt	34 (43.0)	71 (58.7)	
Work Clothes: pants			
One-layer: cotton/polyester blend pants	33 (41.8)	66 (54.5)	0.001*
One-layer: polyester pants	26 (32.9)	13 (10.7)	
One-layer: jean pants	8 (10.1)	12 (9.9)	
Two-layer: cotton/polyester blend shorts and polyester pants or cotton/polyester blend pants	12 (15.2)	30 (24.8)	
Full face mask			
Not used	16 (20.3)	13 (10.7)	0.062
Used full face mask	63 (79.7)	171 (85.5)	

*Significant at $p<0.05$; ** $p<0.001$; chi-square test.

production workers because the cutters had low urine specific gravity[42]. An average liquid intake of 3.2 liters per day (0.8 liters per hour of work) among sugarcane cutters seems sufficient to maintain body weight and serum osmolality, but large amounts of water are reabsorbed by the kidney[43]. A study among Thai sugarcane workers found that a mean 3.8 liters of fluid intake per shift was insufficient to maintain a constant internal temperature because the workers had urine acidification[15]. Additionally, NIOSH recommends that an equivalent of 6–8 liters of body water can be lost as sweat during a workday, and drinking water or other fluids every 15–20 minutes can replace sweat losses while working under heat stress conditions[30]. The California Occupational Safety and Health Association requirement is intake of 240 milliliters (8 ounces) of water every 15 minutes when working in a hot environment and continuously drinking sufficient amounts of water to reduce the risk of heat-related illness[44]. Working in the summer an average of 5.8 hours a day with fluid intake of 3.1–5.0 liters reduced the heat-related illness risk by 79% among sugarcane farmers in our study. However, these farmers had a 21% increased risk of heat-related illness because of inadequate body water. Therefore, sugarcane farmers should intake approximately 5.6 liters of water in a workday by drinking 240 milliliters of water every 15–20 minutes to prevent dehydration and maintain their core body temperature.

According to the findings of this study, univariate analysis revealed that afternoon napping was associated with heat-related illness, but there was no association in multivariate analysis. Napping in the daytime is common among Thai farmers. A previous study in Saskatchewan found that farmers had excessive daytime napping, which negatively affected their health[45]. Dhand and Sohal suggested that a nap of less than 30 minutes' duration during the day enhances performance and promotes wakefulness and learning ability. Those authors stated that habitually taking frequent and long naps may be associated with higher morbidity and mortality, especially among older people. They showed that daytime naps are associated with sleep inertia after the individual awakens[46]. A study revealed that sleep inertia results in impaired alertness and performance for approximately 30 minutes after awakening from a nap and slows the speed of cognitive tasks, but there are few effects on the accuracy of task performance[47]. The importance of sleep inertia is that the reduction in work productivity occurs not only during the period of the nap itself but also extends for a variable period after awakening from the nap. In our study, we found that farmers who had an afternoon nap of longer than 60 minutes were more likely to experience heat-related illness than non-nappers (OR 195 = 2.55, 95% CI: 1.08–5.98). Therefore, we suspect that long naps might modify the physiological response to heat via sleep inertia. The association of napping during the daytime among Thai farmers with specific working task behaviors should be studied in the future.

Limitations

Several limitations of this study should be mentioned. We began data collection on 15 March 2021, during the COVID-19 pandemic in Thailand; therefore, we experienced problems with time limitations and the number of participants. Urine testing was not conducted, and physiological responses were also not assessed. Future studies are needed that examine the effect of sex differences on heat intolerance and heat-related illness, with a larger number of both women and men.

Conclusion

This study demonstrated that female sex and wearing a two-layer shirt were associated with the occurrence of heat-related illness and that an adequate daily water intake is required when working outdoors in summer to reduce the risk of heat-related illness among sugarcane farmers. These study results may serve as a basis to protect farmers working in hot environments. The present findings should be disseminated to sugarcane farmer associations to improve working conditions among these workers.

Conflicts of Interest

The authors declare no conflicts of interest.

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