

Effect of occupation-related heat stress exposure on productivity among sugarcane workers in Thailand¹

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1. Supplementary material
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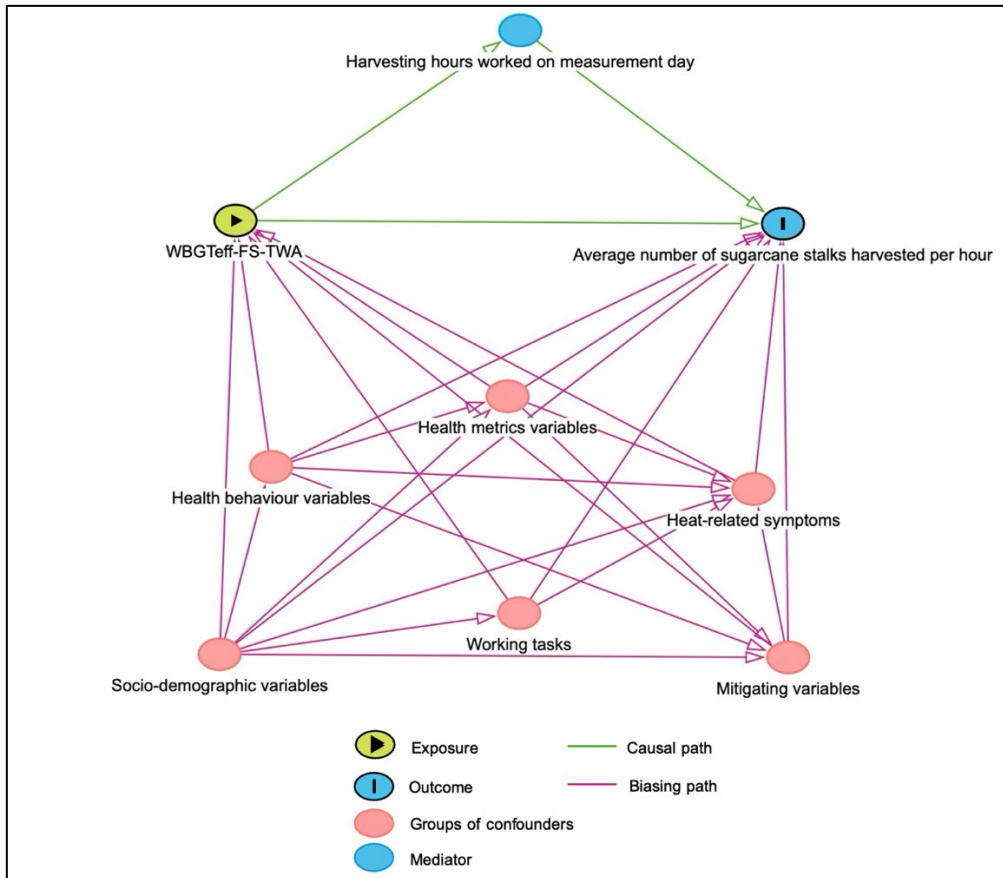


Figure S1 A Directed acyclic graph (DAG) showing the hypothetical causal relationship between the primary explanatory variable (a full work shift time-weighted average effective WBGT or WBGT_{eff}-FS-TWA) and the outcome variable (average number of sugarcane stalks harvested per hour) along with groups of confounders and the mediator

Demographic variable group: gender, age, education, and work experience; **health metrics variable group:** BMI and medical conditions; **health behaviour variable group:** alcohol drinking, smoking, caffeine intake, and last night's sleep duration; **mitigating variable group:** total duration breaks and total fluid intake at work; **working task group:** harvesting approach and harvesting method; **heat-related symptoms;** **mediating variable:** harvesting hours worked on the day of measurement

Table S1 Descriptions of all models used for data analysis in this study

Model	Description	The purpose of each model
Unadjusted model	Constant + WBGT_{eff}-FS-TWA	To understand the effect of WBGT_{eff}-FS-TWA.
Adjusted model	Constant + WBGT_{eff}-FS-TWA + confounding variables	To understand the effect of WBGT_{eff}-FS-TWA while adjusting for identified confounders
Adjusted model with the interaction term	Constant + WBGT_{eff}-FS-TWA + confounding variables + interaction variable (gender and WBGT_{eff}-FS-TWA)	To investigate whether gender modifies the effect of WBGT_{eff}-FS-TWA on the outcome variable
Adjusted model with the potential mediator	Constant + WBGT_{eff}-FS-TWA + confounding variables + mediating variable	To determine if there is a mediating effect of hours worked during the measurement day.

Table S2 Additional models exploring the effect of specific groups of confounders in a step-by-step process and a fully adjusted model with the potential mediator, examining the effects of WBGT_{eff}-FT-TWA on the average number of sugarcane stalks per hour (unit: stalks per harvesting hour)

Explanatory variable	Model	Model description	β (95% CI)
WBGT_{eff}-FS-TWA	0	unadjusted	-9.57 (-17.14, -2.01)
	1	adjusted for socio-demographic variables	-9.91 (-17.58, -2.25)
	2	adjusted for socio-demographic variables, and health metrics variables	-9.43 (-17.18, -1.68)
	3	adjusted for socio-demographic variables, health metrics variables, and health behaviour variables	-9.70 (-17.49, -1.91)
	4	adjusted for socio-demographic variables, health metrics variables, health behaviour variables, and mitigating variables	-9.96 (-17.72, -2.20)
	5	adjusted for socio-demographic variables, health metrics variables, health behaviour variables, mitigating variables, and working variable	-11.96 (-19.01, -4.92)
	6	adjusted for socio-demographic variables, health metrics variables, health behaviour variables, mitigating variables, the working variable, and heat-related symptoms	-8.59 (-16.19, -0.99)
	7	adjusted for socio-demographic variables, health metrics variables, health behaviour variables, mitigating variables, the working variables, heat-related symptoms, and the mediating variable	-8.85 (-16.36, -1.34)

WBGT_{eff}-FS-TWA = full work shift time-weighted average effective Wet Bulb Globe Temperature

***Demographic variable group:* gender, age, education, and work experience; *health metrics variable group:* BMI and medical conditions; *health behaviour variable group:* alcohol drinking, smoking, caffeine intake, and last night's sleep duration; *mitigating variable group:* total duration breaks and total fluid intake at work; *working task group:* harvesting approach and harvesting method; *heat-related symptoms;* *mediating variable:* harvesting hours worked on the day of measurement**

Table S3 β (95% CI) from the adjusted model of number of sugarcane stalks per harvesting hour associated with WBGT_{eff}-FA-TWA

Explanatory variable	Category	n	β (95% CI)
WBGT_{eff}-FA-TWA (°C)		28	-8.59 (-16.19, -0.99)
		7	
Gender	Female	12	-23.71 (-68.12, 20.70)
		6	
	Male	16	
		1	
Age (years)	≥ 50	85	34.35 (-26.30, 95.00)
	40-49	82	37.85 (-21.84, 97.55)
	30-39	63	20.18 (-40.32, 80.68)
	< 30	57	
Education	$\geq$ High school	30	10.52 (-54.82, 75.86)
	Middle school	63	40.67 (-11.69, 93.04)
	$\leq$ Primary school	19	
		4	
Work experience (years)	> 10	58	20.30 (-32.89, 73.50)
	5.01-10	78	46.08 (-0.18, 92.34)
	≤ 5	15	
		1	
BMI	Obese I	76	30.12 (-18.67, 78.90)
	Overweight	36	-21.57 (-81.02, 37.88)
	Underweight	35	-35.37 (-98.59, 27.85)
	Normal weight	14	
		0	
Medical conditions	Yes	54	-10.59 (-63.56, 42.38)
	No	23	
		3	
Alcohol drinking	Yes	14	27.78 (-13.16, 68.72)
		5	
	No	14	
		2	
Smoking	Yes	13	-8.13 (-54.20, 37.94)
		4	
	No	15	
		3	
Caffeine intake	Yes	27	79.30 (-17.50, 176.09)
		5	
	No	12	
Last night sleep duration (hours)		28	0.42 (-15.05, 15.88)
		7	
Total duration breaks (hours)		28	-13.04 (-37.75, 11.68)
		7	
Total fluid intake at work (litres)		28	21.96 (10.68, 33.25)
		7	
Harvesting approach	Group with 3 people	15	-93.43 (-188.87, 2.01)
	Group with 2 people	10	-52.89 (-96.62, -9.15)
		1	

	Solo	17	
		1	
Harvesting methods	25% burnt, 75% unburnt without leaf removal	6	-16.92 (-158.72, 124.87)
	75% burnt, 25% unburnt with leaf removal	19	-32.97 (-116.12, 50.18)
	Unburnt without leaf removal	43	-92.43 (-152.01, -32.85)
	Unburnt with leaf removal	87	-158.65 (-209.98, -107.32)
	Burnt	13	
		2	
Heat-related symptoms	< 50th percentile (< 6 symptoms)	11	68.36 (11.87, 124.85)
	50th-75th percentile (6-10 symptoms)	10	30.25 (-21.60, 82.11)
	> 75th percentile (>10 symptoms)	8	
		62	

WBGT_{eff}-FS-TWA = full work shift time-weighted average effective Wet Bulb Globe Temperature
β = Beta coefficient

Identification of leverage points

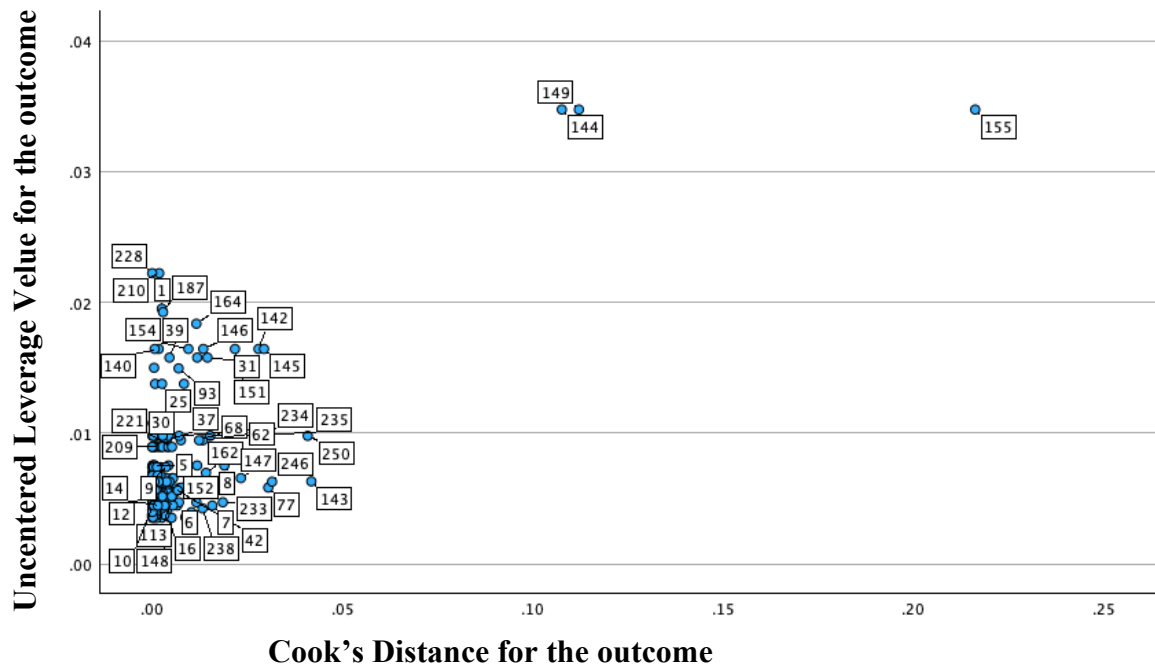


Figure S2 Scatter plot of Cook's distance (X-axis) versus uncentered leverage values for the outcome variable: average number of sugarcane stalks harvested per hour, Each dot represents a participant, with case numbers labelled as identified in SPSS. The plot indicates three potential leverage points: Case 144, Case 149, and Case 155.

Table S4 Comparison of main analysis and sensitivity analysis excluding leverage points, examining the effect of WBGT_{eff}-FS-TWA on the average number of sugarcane stalks harvested per hour (unit: stalks/hour)

Model	Main analysis	Sensitivity analysis		
		Excluded case	Excluded cases	Excluded cases
		No. 155	No. 155 and 149	No. 155, 149, and 144
	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)
Unadjusted model	-9.57 (-17.14, -2.01)	-7.18 (-14.71, 0.36)	-5.30 (-12.87, 2.28)	-3.31 (-10.93, 4.31)
Adjusted model ^a	-8.59 (-16.19, -0.99)	-6.28 (-13.79, 1.23)	-4.38 (-11.88, 3.13)	-3.23 (-10.83, 4.37)

Explanatory variable = full work shift time-weighted average effective Wet Bulb Globe Temperature (WBGT_{eff}-FS-TWA)

^aadjusted for demographic variable group: gender, age, education, and work experience; health metrics variable group: BMI and medical conditions; health behaviour variable group: alcohol drinking, smoking, caffeine intake, and last night's sleep duration; mitigating variable group: total duration breaks and total fluid intake at work; working task group: harvesting approach and harvesting method; and heat-related symptoms

Table S5 β (95% CI) from an adjusted model with interaction effect of number of sugarcane stalks per harvesting hour associated with WBGT_{eff}-FA-TWA

Explanatory variable	Category	n	β (95% CI)
WBGT_{eff}-FA-TWA (°C)		28	-7.81 (-17.15, 1.52)
		7	
Gender	Female	12	40.38 (-404.36,
		6	485.12)
	Male	16	
		1	
Age (years)	≥ 50	85	34.37 (-26.39, 95.13)
	40-49	82	37.44 (-22.42, 97.31)
	30-39	63	19.74 (-40.95, 80.43)
	< 30	57	
Education	$\geq$ High school	30	11.16 (-54.45, 76.77)
	Middle school	63	41.22 (-11.38, 93.82)
	$\leq$ Primary school	19	
		4	
Work experience (years)	> 10	58	19.72 (-33.72, 73.16)
	5.01-10	78	45.97 (-0.39, 92.32)
	≤ 5	15	
		1	
BMI	Obese I	76	30.02 (-18.85, 78.90)
	Overweight	36	-21.86 (-81.45,
			37.73)
	Underweight	35	-35.57 (-98.92,
			27.78)
	Normal weight	14	
		0	
Medical conditions	Yes	54	-11.04 (-64.19,
			42.12)
	No	23	
		3	
Alcohol drinking	Yes	14	27.67 (-13.35, 68.69)
		5	
	No	14	
		2	
Smoking	Yes	13	-8.19 (-54.35, 37.97)
		4	
	No	15	
		3	
Caffeine intake	Yes	27	79.72 (-17.29,
		5	176.73)
	No	12	
Last night sleep duration (hours)		28	0.51 (-14.99, 16.02)
		7	
Total duration breaks (hours)		28	-13.19 (-37.98,
		7	11.59)
Total fluid intake at work (litres)		28	22.10 (10.76, 33.44)
		7	

Harvesting approach	Group with 3 people	15	-94.74 (-190.78, 1.30)
	Group with 2 people	10	-52.76 (-96.59, -8.94)
	Solo	17	
Harvesting methods	25% burnt, 75% unburnt without leaf removal	6	-15.95 (-158.15, 126.26)
	75% burnt, 25% unburnt with leaf removal	19	-33.39 (-116.74, 49.96)
	Unburnt without leaf removal	43	-92.79 (-152.53, -33.05)
	Unburnt with leaf removal	87	-158.57 (-209.99, -107.14)
	Burnt	13	
		2	
Heat-related symptoms	< 50th percentile (< 6 symptoms)	11	68.65 (12.03, 125.28)
	50th-75th percentile (6-10 symptoms)	10	29.95 (-22.04, 81.94)
	> 75th percentile (>10 symptoms)	8	
		62	
Interaction between WBGT_{eff}-FS-TWA and Gender		28	-2.03 (-16.07, 12.01)
		7	

WBGT_{eff}-FS-TWA = full work shift time-weighted average effective Wet Bulb Globe Temperature

β = Beta coefficient

Table S6 β (95% CI) from the adjusted model of number of sugarcane stalks per harvesting hour associated with WBGT_{meas}-FA-TWA (Ambient WBGT)

Explanatory variable	Category	n	β (95% CI)
WBGT_{meas}-FS-TWA (°C)		28	-6.73 (-14.53, 1.07)
		7	
Gender	Female	12	-27.09 (-71.72, 17.54)
		6	
	Male	16	
		1	
Age (years)	≥ 50	85	35.60 (-25.18, 96.38)
	40-49	82	37.89 (-21.92, 97.69)
	30-39	63	21.19 (-39.48, 81.87)
	< 30	57	
Education	$\geq$ High school	30	8.66 (-56.83, 74.16)
	Middle school	63	36.29 (-16.60, 89.17)
	$\leq$ Primary school	19	
		4	
Work experience (years)	> 10	58	22.61 (-30.85, 76.07)
	5.01-10	78	46.17 (-0.18, 92.52)
	≤ 5	15	
		1	
BMI	Obese I	76	32.21 (-16.70, 81.12)
	Overweight	36	-18.91 (-78.68, 40.85)
	Underweight	35	-31.95 (-95.43, 31.53)
	Normal weight	14	
		0	
Medical conditions	Yes	54	-10.76 (-63.83, 42.32)
	No	23	
		3	
Alcohol drinking	Yes	14	25.51 (-15.59, 66.61)
		5	
	No	14	
		2	
Smoking	Yes	13	-6.02 (-52.27, 40.23)
		4	
	No	15	
		3	
Caffeine intake	Yes	27	82.18 (-14.91, 179.26)
		5	
	No	12	
Last night sleep duration (hours)		28	-0.61 (-16.18, 14.97)
		7	
Total duration breaks (hours)		28	-15.02 (-39.87, 9.84)
		7	
Total fluid intake at work (litres)		28	22.32 (11.02, 33.61)
		7	
Harvesting approach	Group with 3 people	15	-90.78 (-186.54, 4.98)
	Group with 2 people	10	-53.74 (-97.56, -9.92)
		1	

	Solo	17	
		1	
Harvesting methods	25% burnt, 75% unburnt without leaf removal	6	-12.60 (-154.80, 129.60)
	75% burnt, 25% unburnt with leaf removal	19	-33.69 (-116.97, 49.59)
	Unburnt without leaf removal	43	-91.68 (-151.40, -31.96)
	Unburnt with leaf removal	87	-157.93 (-209.42, -106.44)
	Burnt	13	
		2	
Heat-related symptoms	< 50th percentile (< 6 symptoms)	11	70.95 (14.31, 127.59)
	50th-75th percentile (6-10 symptoms)	10	30.69 (-21.28, 82.66)
	> 75th percentile (>10 symptoms)	62	
Number of shirt	1 layer	65	49.62 (0.54, 98.70)
	≥ 2 layers	22	
		2	

WBGT_{meas}-FS-TWA = full work shift time-weighted average measured Wet Bulb Globe Temperature (Ambient WBGT)
β = Beta coefficient