Outbreak, Surveillance and Investigation Reports
Field Epidemiology Training Program, Bureau of Epidemiology
Department of Disease Control, Ministry of Public Health, Thailand
Tel: +6625901734-5, Fax: +6625918581, Email: osireditor@osirjournal.net, http://www.osirjournal.net

Situation of Heat-related Illness in Thailand, and the Proposing of Heat Warning System

Supharerk Thawillarp[1,*], Thammawijaya P[1], Praekunnatham H[1], Siriruttanapruk S[2]

1 Field Epidemiology Training Program, Bureau of Epidemiology, Department of Disease Control, Ministry of Public Health, Thailand

2 Department of Disease Control, Ministry of Public Health, Thailand

*Corresponding author, email address: raynus.blueray@gmail.com

Abstract

Many countries in the world experienced heat waves. While the impact of heat on health was well documented in developed countries, there were very few studies of heat-related illnesses (HRI) in tropical countries. Our aim was to describe HRI in Thailand and examine usefulness of the National Health Reporting System in Ministry of Public Health to track HRI during 2010-2013. A descriptive study examined the relationship between hospital visit with ICD-10 codes of T67-679 (effects of heat and light) and temperature from the Meteorological Department. Among 3,963 HRI visits with nine deaths, median age was 43 years (IQR 22-61) with the highest incidence rate 3.8, 2.3 and 1.6 per 100,000 person-year for 65 and above, 55-65 and 45-55 age groups respectively. Male-to-female ratio was 1:1.7. Occupations included skilled agricultural workers (35.7%), odd job persons (15.1%) and students (13.5%). Northern region reported the highest incidence rate (9.3 per 100,000 person-year). This was the first countrywide study describing HRI in Thailand and has been presented to the policy levels. This data could be used to establish a sentinel surveillance and formalize a heat warning collaboration with the Meteorological Department.

Keywords: heat-related illness, climate change, heat stroke, Thailand

Introduction

Nowadays, morbidity and mortality attributable to heat related illnesses (HRI) has been increasing around the world while five of the most deadliest heat waves occurred in this century,[1] including the 2003 European heat wave[2] which claimed about 70,000 lives, 56,000 deaths in Russia during 2010, 10,000 deaths in United States during 1988, 3,418 deaths in Europe during 2006 and 2,541 deaths in India during 1998[3].[1] Although the impact of heat on health was well documented in developed countries, very few studies has focused in tropical climates countries.[4]

A thermoregulation system keeps core body temperature between 36.6-37.0°C. When thermoregulation is overcome by high ambient temperature, heat exhaustion can occur from excessive loss of water and electrolytes through sweating. Later, confusion, seizure, multiorgan failure and death may occur. This stage is called heat stroke. HRI is classified as heat stroke, heat exhaustion, heat rash and heat cramp.

Thailand is a tropical country in Southeast Asia with most people working as farmers in the agriculture industry.[5] There are three seasons in Thailand, rainy (mid-May to mid-October), winter (mid-October to mid-February) and summer (mid-February to mid-May).[6] The highest temperatures occur in April (average 34.5°C), with the lowest in December (average 23.5°C). The country has a single climate and time zone.

There are two reports of HRI in Thailand which were descriptive studies examining certain population such as soldiers who were admitted to a military hospital and school-aged children from grades 1-6 in Bangkok.[7-8] However, the overall national HRI prevalence and risk factors were still unknown.

Thailand has never experienced a heat wave.[9] Existing surveillance systems reported HRI in occupational and military settings. Illness of patients visiting public health facilities are reported through the National Health Reporting System (NHRS). However, the HRI situation was not aware or reported by the Ministry of Public Health (MOPH) as additional data extraction was time-consuming and expensive. This study aimed to describe HRI in Thailand and examine the usefulness of utilizing the NHRS for HRI.

Methods

We conducted a descriptive study using official health service utilization data from NHRS under the Bureau of Policy and Strategy, MOPH.

Study Population

The NHRS captures official health data from every public health care unit such as hospitals and health centers, except for the capital city of Thailand, Bangkok. These data are managed by the Bureau of Policy and Strategy. A separate reporting system is utilized in Bangkok which was integrated into the NHRS later and not available for this study.

Health centers in Thailand are small public clinics located in rural areas that provide only basic primary care and often lack capacity to offer laboratory services or admit patients overnight. Staff in health centers typically consist of non-medical health personnel (registered nurses, nurse's aides) who diagnose and treat patients. Bed capacity in public hospitals can range from 500 to 1,000, and offer specialists and sub-specialist services.

Data Sources

All health care visits are assigned a diagnosis codes using International Classification of Disease – 10 codes (ICD-10) by staff in health care units at health centers or hospitals. The staff in health care units electronically submit health services utilization data monthly to MOPH. These data are collected, cleaned and maintained by the Bureau of Policy and Strategy.

Heat-related visits in data of the Bureau of Policy and Strategy were identified by the ICD-10 codes of T67-67.9 for effects of heat and light. Data from 1 Jan 2010 to 30 Sep 2013 was obtained.

Health Outcome Variables

Individual records contained age, gender, level of highest completed education, occupation, ICD-10 codes, date of visit and name of health care unit.

Age was grouped into 10-year intervals. Health care units were grouped by official census regions and categorized either as health center or hospital, based on the status reported in MOPH records.

Data Analysis

We employed descriptive statistics and calculated incidence rate and case-fatality rate using number of visit with relevant ICD-10 codes from NHRS database and 2010-2013 provisional census denominators available from National Statistic Organization.[10] Data were analyzed using R version 3.1.2.[11]

Weather Data

Monthly data for 1996-2013 were obtained from the Ministry of Information and Communication Technology and the Meteorological Department in Thailand. Data available included spatial coordinates of weather stations, monthly highest and average temperature, and relative humidity. At least one weather station is located in 63 out of total 76 provinces in Thailand. However, for the other 13 provinces without a weather station, we used the Kriging interpolation with zonal statistic to estimate the monthly temperatures.[12] Heat index was calculated from average highest temperature and relative humidity, and reported in degree Celsius by using Steadman's equation[13] as below.

$$\begin{aligned} HI = & -42.379 + (2.04901523 \times T) + (10.14333127 \times R) \\ & - (0.22475541 \times T \times R) - (6.83783 \times 10^{-3} \times T^2) \\ & - (5.481717 \times 10^{-2} \times R^2) + (1.22874 \times 10^{-3} \times T^2 \times R) \\ & + (8.5282 \times 10^{-4} \times T \times R^2) - (1.99 \times 10^{-6} \times T^2 \times R^2) \end{aligned}$$

HI = Heat index (°C), T = Ambient temperature (°C), R = Relative humidity (%)

Results

During 2010-2013, there were 3,963 HRI visits and nine deaths reported. There were 1.7 visits per 100,000 person-year. Majority of them were Thai (97.9%) and Myanmar (0.7%). Median age was 43 years (interquartile range IQR = 22-61) and male to female ratio was 1:1.7. About 36% of the visits were the most vulnerable persons of those older than 65 years (20.9%) and younger than 14 years (15.3%). The highest visit incidence per 100,000 person-year were 3.8, 2.3 and 1.6 per 100,000 person-year for more than 65, 55-65 and 45-55 age groups respectively. Nearly half of the patients had primary school education, and over a third worked in agricultural, fishery and forestry. Most of the agricultural workers were female (63.7%). Most of the refuse workers and other elementary service workers were odd job persons (persons skilled in various odd jobs and other small tasks). Students also made up 13.5% of the visits. Other types of occupation included free-lance workers, sex workers, service and sale workers, housekeepers, parental supervision and retired government officers (Table 1).

The highest frequency of heat-related visit was in the northeastern census region. Rates in the northern and southern regions (9.3 and 8.7 per 100,000 population) were almost double when compared with that of the other census regions (5.3 and 5.1 per 100,000 population).

Stratifying across census regions revealed that variables were similar, except the fact that young age groups were prevalent in the northeastern region. The central region had the highest proportion of people with no education level (16.8%) and the lowest proportion of skilled agricultural workers (16.5%) when compared to that of the other three regions (Table 2).

Table 1. Characteristics of heat-related illness visits and incidence rate per 100,000 person-year, Ministry of Public Health, Thailand (excluding Bangkok), 2010-2013

	Visit (%)	Incidence rate per 100,000 person-year
Gender		
Male	1,490 (37.6)	
Female	2,471 (62.4)	
Education (n=3,790)		
None	401 (10.6)	
Elementary	352 (9.3)	
Primary	1,804 (47.6)	
Secondary	415 (10.9)	
Diploma and above	202 (5.3)	
Invalid codes	616 (16.3)	
Age (year)		
0-14	607 (15.3)	1.3
0-6	131 (3.3)	0.6
7-14	476 (12.0)	2.1
15-24	482 (12.2)	1.3
25-34	357 (9.0)	0.9
35-44	520 (13.1)	1.2
45-54	599 (15.1)	1.6
55-64	571 (14.4)	2.3
≥ 65	825 (20.9)	3.8
Occupation (n=3,953)		
Skilled agricultural, fishery and forestry workers	1,412 (35.7)	2.6
Market-oriented skilled agricultural, fishery and forestry workers	1411 (35.7)	N/A
Subsistence farmers, fishers, hunters and gatherers	1 (0.0)	N/A
Refuse workers and other elementary service workers	683 (17.3)	4.0
Refuse sorters	1 (0)	
Odd job persons	596 (15.1)	
Messengers, package and luggage porters, and deliverers	2 (0)	
Other elementary service workers	84 (2.2)	N/A
Students	533 (13.5)	1.0
Unemployed	417 (10.5)	N/A
Others	908 (23.0)	N/A
Census regions		
Northern	1,115 (28.1)	9.3
Southern	808 (20.4)	8.7
Northeastern	1,183 (29.9)	5.3
Central (exclude Bangkok)	855 (21.6)	5.1

The number of reported HRI visits increased over the study period. Heat index was the highest in April and May (Figure 1). HRI visits peaked in April and November almost every year, specifically in those provinces with the highest incidence rate per 100,000 person-year located in the northern and southern regions (Figure 2a). During 2010-2013, the national annual average temperature was 27.6°C and maximum temperature was 44°C in the northern region (Figure 2b). On average, humidity in Thailand was 76.1% during the study period while the highest relative humidity was 92% in the southern region. The highest maximum heat index was 50°C in the central region during May.

The overall national average heat index was calculated as 31°C. Areas with the highest heat index were in the central, southern and lower part of northern region in Thailand (Figure 2b). No extreme heat events were recorded during the study period.

While examining HRI visits by health units and census regions, more HRI visits were treated in health centers than hospitals across all census regions (Table 3). Females made up a greater proportion of the HRI visits at health centers compared to that of in hospitals across all census regions.

Table 2. Characteristics of heat-related illness visits by census regions and types of occupation, Ministry of Public Health, Thailand (excluding Bangkok), 2010-2013 (n=3,961)

Variable	Central (%) (n=855)	Northern (%) (n=1,115)	Northeastern (%) (n=1,183)	Southern (%) (n=808)
Number of province	26	17	19	14
Median age (IQR)	43 (23-56)	49 (29.8-62)	35 (16.8-51)	47 (24-63.3)
Age (year)				
0-14	100 (11.7)	132 (11.8)	247 (20.9)	128 (15.8)
0-6	27 (3.2)	29 (2.6)	49 (4.1)	26 (3.2)
7-14	73 (8.5)	103(9.2)	198 (16.8)	102 (12.6)
15-24	120 (14.0)	92 (8.2)	198 (16.8)	72 (8.9)
25-34	88 (10.3)	90 (8.1)	120 (10.1)	59 (7.3)
35-44	115 (13.4)	129 (11.6)	168 (14.2)	108 (13.4)
45-55	150 (17.5)	192 (17.2)	140 (11.8)	117 (14.5)
55-64	110 (12.9)	224 (20.1)	119 (10.1)	118 (14.6)
≥65	172 (20.2)	256 (23.0)	191 (16.1)	206 (25.5)
Gender				
Male	353 (41.3)	417 (37.4)	472 (39.9)	248 (30.7)
Female	502 (58.7)	698 (62.6)	711 (60.1)	560 (69.3)
Education (n=3,790)				
None	135 (16.8)	92 (8.5)	92 (8.1)	82 (10.7)
Elementary	64 (8.0)	164 (15.1)	80 (7.1)	44 (5.7)
Primary	339 (42.2)	505 (46.6)	536 (47.2)	424 (55.2)
Secondary	85 (10.6)	99 (9.1)	155 (13.6)	76 (9.9)
≥ Diploma	32 (4.0)	53 (5.0)	58 (5.1)	59 (7.7)
Invalid codes	148 (18.4)	170 (15.7)	215 (18.9)	83 (10.8)
Occupation (n=3,953)				
Skilled agricultural, fishery and forestry workers	141 (16.5)	413 (37.1)	512 (43.5)	346 (42.9)
Refuse workers and other elementary service workers	242 (28.3)	225 (20.2)	111 (9.4)	105 (13.0)
Students	104 (12.2)	113 (10.2)	217 (18.4)	99 (12.3)
Unemployed	78 (9.1)	107 (9.6)	123 (10.4)	109 (13.5)
Others*	290 (33.9)	255 (22.9)	216 (18.3)	147 (18.3)

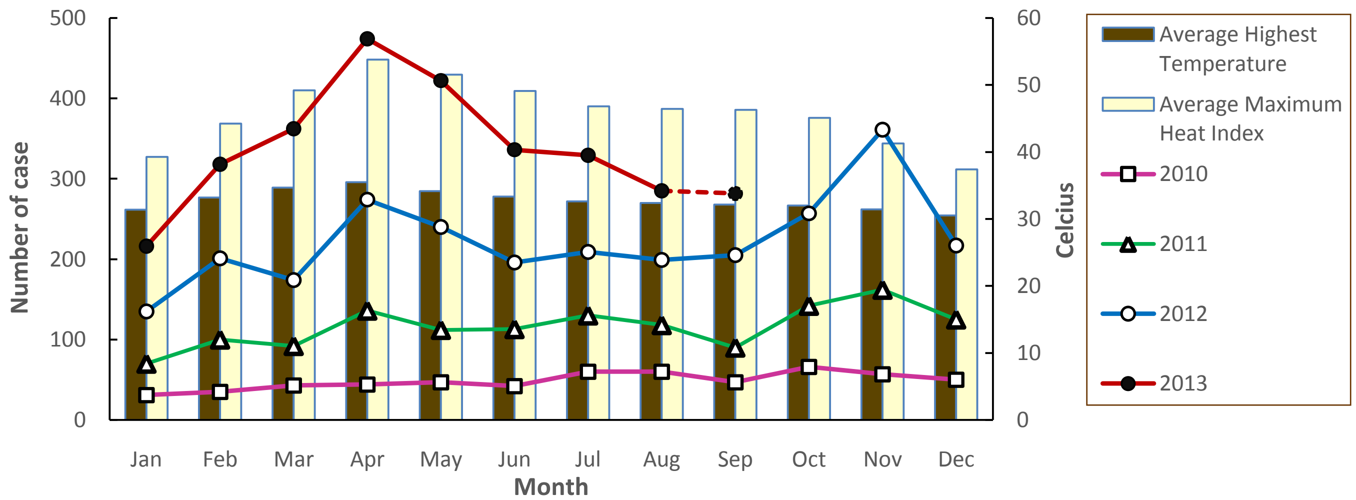

Figure 1. Heat-related illness visits by months, Ministry of Public Health, Thailand (excluding Bangkok), 2010-2013 (n=3,859)

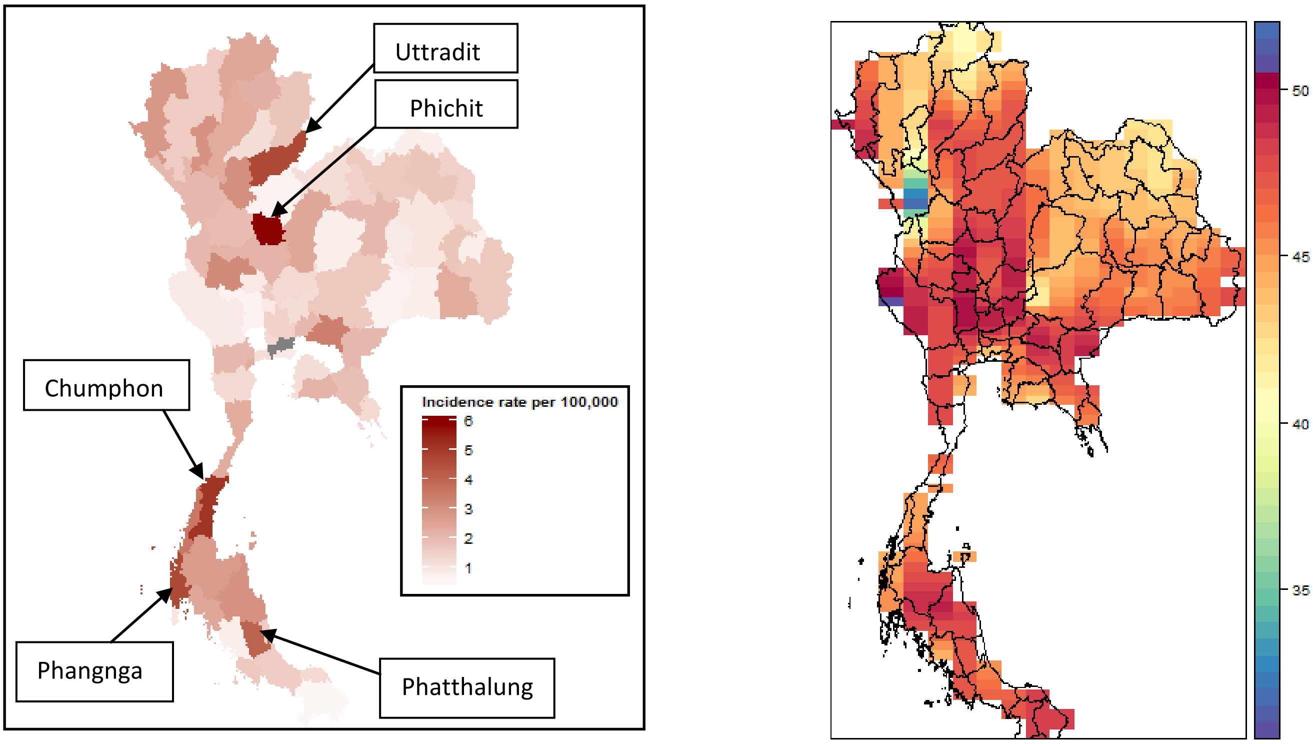

Figure 2. (a) Incidence rate per 100,000 person-year by provinces in Thailand (excluding Bangkok), 2010-2013 (n=3,961) (b) Average maximum heat index (°C) by provinces in Thailand, 2010-2013

Data Quality: HRI Diagnoses, Occupation and Invalid Codes

Staff in health centers diagnosed nearly 60% of all HRI visits as heat stroke (Table 4). Of 1,600 visits of heat stroke diagnosed at health centers, five died, yielding a case fatality rate of 0.3% of all heat stroke visits. In contrast, hospitals reported a variety of HRI without any death (Table 4).

In September 2011, we noted refuse workers and elementary service workers visited for HRI as the first time, and decrease in HRI visits among skilled agricultural workers (Figure 3). Invalid and missing educational codes were noted from all reporting regions and hospitals (Tables 2-3). Overall, education variable had the highest proportion of invalid codes, increased from 8.6% in 2010 to 22.8% in 2013.

Discussion

This was the first study to examine human health impact of environmental heat throughout Thailand, excluding Bangkok. Frequency of HRI visits increased with a few deaths. Incidence rates were varied across geographical regions and could not be fully explained by temperature. Majority of visits were female, and agricultural and elementary workers.

Majority of female identified among agricultural workers was the opposite finding to most of other HRI studies[14]. This was interesting given the fact that male farmers were two times more than female farmers in Thailand[15]. Previous literature noted that females might have less tolerance to heat exposure[16]. Other reason could be the time they spent outside for working, including informal work often intertwined with their household duties and awareness of HRI signs and symptoms.

Maximum heat index is the strongest weather parameters with positive correlation to HRI[17,18]. Despite that, heat index alone could not explain the increasing trends and seasonal patterns of HRI over the study period since temperature and heat index trends remained stable and the HRI rate went up while the temperature went lower in the early winter. Cultural activity might explain this phenomenon as several studies found occurrence of HRI among mass gatherings and festivals[19,20]. Thai people generally gather in summer for the tradition of New Year festival and also planting. Harvesting begins in winter and the intensity of the labor might explain the second HRI peak in November.

Another consideration of the HRI visit pattern could be variability of the ambient temperature. The northeastern region, despite having the highest agriculture activity[21], reported the low HRI rates. The northern and southern regions reported the first and the second highest rates even though these regions had less agricultural activity than the northeastern region. However, the northern and southern regions Did experience the higher temperature variability as well.[22]

Table 3. Characteristics of heat-related illness visits by census regions and types of health care unit, Ministry of Public Health, Thailand (excluding Bangkok), 2010-2013

	Central		Northern		Northeastern		Southern	
	Health Center (%)	Hospital (%)	Health Center (%)	Hospital (%)	Health Center (%)	Hospital (%)	Health Center (%)	Hospital (%)
Total units	2,566	301	2,239	218	3,474	334	1,515	175
Total visits	540	283	858	245	742	405	673	109
Median age (IQR)	47 (28-60)	44 (24-61)	49 (27-61)	49 (28.8-61)	32 (14-53)	39 (18-57)	50 (28-66)	48 (25-65)
Age (year)								
0-14	60 (11.1)	32 (11.3)	102 (11.9)	28 (11.4)	189 (25.5)	53 (13.1)	96 (14.3)	22 (20.2)
0-6	17 (3.2)	8 (2.8)	22 (2.6)	6 (2.5)	41 (5.5)	7 (1.8)	24 (3.6)	2 (1.8)
7-14	43 (7.9)	24 (8.5)	80 (9.3)	22 (8.9)	148 (20.0)	46 (11.3)	72 (10.7)	20 (18.4)
15-24	63 (11.7)	55 (19.4)	58 (6.7)	34 (13.9)	117 (15.8)	72 (17.8)	47 (7.0)	20 (18.4)
25-34	51 (9.4)	34 (12.0)	65 (7.6)	24 (9.8)	65 (8.7)	50 (12.3)	46 (6.8)	11 10.1)
35-44	74 (13.7)	39 (13.8)	101 (11.8)	26 (10.6)	96 (12.9)	68 (16.8)	91 (13.5)	13 (11.9)
45-54	104 (19.2)	41(14.5)	147 (17.1)	42 (17.2)	84 (11.3)	53 (13.1)	103 (15.3)	12 (11.0)
55-64	84 (15.6)	21 (7.4)	182 (21.2)	39 (15.9)	77 (10.4)	38 (9.4)	105 (15.6)	12 (11.0)
≥ 65	103 (19.3)	61 (21.6)	203 (23.7)	52 (21.2)	114 (15.4)	71 (17.5)	185 (27.5)	19 (17.4)
Gender								
Male	212 (39.3)	131 (46.3)	293 (34.2)	118 (48.2)	280 (37.7)	177 (43.7)	186 (27.6)	53 (48.6)
Female	328 (60.7)	152 (53.7)	565 (65.9)	127 (51.8)	462 (62.3)	228 (56.3)	487 (72.4)	56 (51.4)
Education								
None	77 (14.8)	56(22.2)	67 (7.9)	24 (10.7)	52 (7.2)	38 (10.2)	66 (10.2)	14 (14.3)
Elementary	55 (10.6)	6 (2.4)	151 (17.8)	13 (5.8)	64 (8.8)	15 (4.0)	38 (5.9)	4 (4.1)
Primary	285 (54.8)	46 (18.3)	456 (53.8)	41 (18.3)	436 (60.0)	84 (22.5)	399 (61.6)	13 (13.3)
Secondary	55 (10.6)	22 (8.7)	73 (8.6)	25 (11.2)	96 (13.2)	55 (14.7)	66 (10.2)	8 (8.2)
Diploma and above	19 (3.6)	10 (4.0)	34 (4.1)	18 (8.0)	30 (4.1)	21 (5.6)	50 (7.7)	6 (6.1)
Invalid codes	29 (5.6)	112 (44.4)	66 (7.8)	103 (46.0)	49 (6.7)	161 (43.0)	29 (4.4)	53 (54.0)

Remark: missing data 106 records for health care unit and 65 records for education

Table 4. Diagnosis codes of heat-related illnesses reported by health care units, Ministry of Public Health, Thailand (excluding Bangkok), 2010-2013

ICD diagnosis code	Health center		Hospital	
	Visit (%)	Death	Visit (%)	Death
T67 Effects of heat and light	42 (1.5)	0	10 (1.0)	0
T67.5 Heat exhaustion	1 (0)	0	0 (0)	0
T67.0 Heat stroke and sun stroke	1,600 (57.1)	5	198 (19.1)	0
T67.1 Heat syncope	187 (6.7)	1	388 (37.3)	0
T67.2 Heat cramp	340 (12.1)	0	89 (8.6)	0
T67.3 Heat exhaustion, anhidrotic	106 (3.8)	1	6 (0.6)	0
T67.4 Heat exhaustion	39 (1.4)	0	2 (0.2)	0
T67.5 Heat exhaustion, unspecified	80 (2.9)	0	30 (2.9)	0
T67.6 Heat fatigue transient	137 (4.9)	1	228 (21.9)	0
T67.7 Heat edema	198 (7.0)	1	20 (1.9)	0
T67.8 Other effects of heat and light	32 (1.1)	0	27 (2.6)	0
T67.9 Effects of heat and light, unspecified	42 (1.5)	0	41 (3.9)	0
Total	2,804	9	1,039	0

Remark: missing data 109 records for health unit

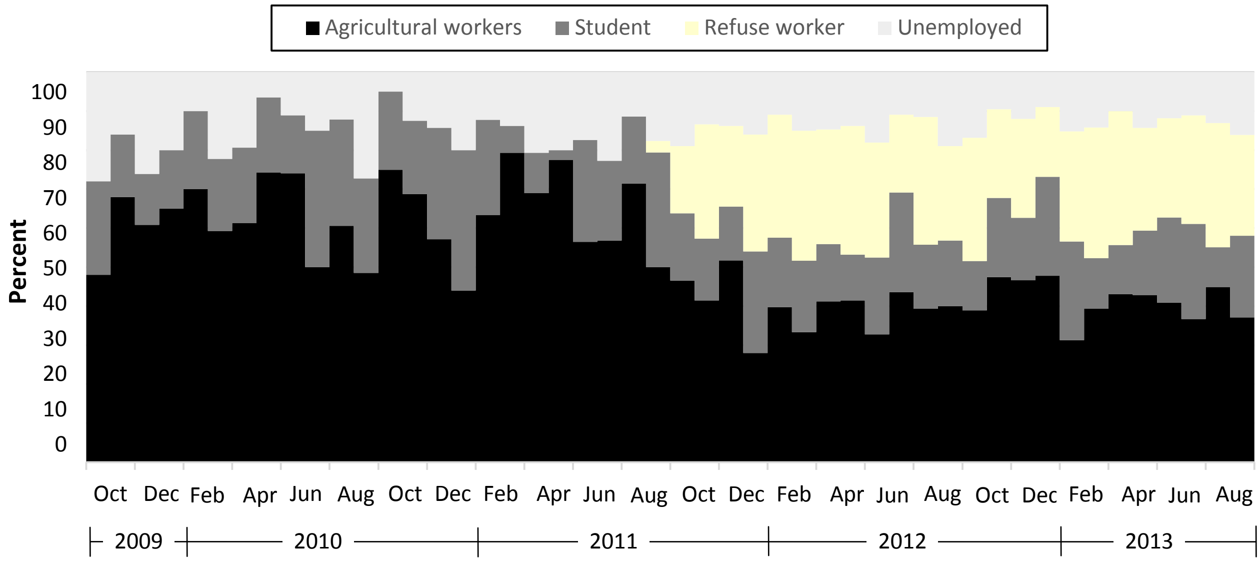

Figure 3. Proportion of heat-related illnesses by most common reported occupation, Thailand (excluding Bangkok), 2010-2013 (n=2,776)

Data Quality

We questioned the accuracy of heat stroke diagnoses in the data set for two reasons. First, heat stroke is a severe disease with very high case fatality rate (10-35%) while the result showed 0.3% which was surprising, especially as most of these were reported from health centers. Secondly, it was likely that staff in health centers had less experience and training to differentiate among various types of HRI such as heat exhaustion and heat fatigue, and might miscode them as heat stroke. Although the heat stroke visits were probably over diagnosed, these diagnoses provided strong evidence that heat contributed significantly to the reason for the patients' visit.

In addition, the mortality data did not include people who died at home or outside hospitals and might underestimate the number of heat-related deaths.

Limitations

There were several limitations to this study. Our data source collected information from only the public health care units. Private clinics and hospitals are not required to report health data to MOPH. This likely had little impact on our findings as majority of private health units are located in Bangkok which was not included in this study. Although 12% of population resided in Bangkok, one of the previous HRI studies that examined urban cities in Thailand[23] reported more HRI in rural area[24]. Bangkok population was excluded for calculating rates in this study as a separate system is used for reporting in Bangkok, which was not available for our study.

This study use number of visit, instead of number of illness episode, as numerator for calculating incidence rate since unavailability of patient identification in the database. However, HRI is acute disease with very short illness duration and able to recur. It is unlikely that patients will seek care from multiple hospitals, were being recorded as multiple visits and can still get HRI again. Therefore, number of visit should acceptably represent number of illness episode using visit in the calculation and would not substantially overestimate the incidence rate of HRI in this study.

Recommendations

To improve management, outcomes and reporting of HRI, the MOPH should provide training for staff in health centers, including training on diagnosis of heat stroke. The provinces with the highest HRI rates should be targeted during peak seasons using simple reminders or refresher courses.

Public education or health campaigns on HRI signs, symptoms, protection and first aid should be encouraged among agricultural, odd job and elementary service workers because HRI is preventable and treatable even without accessing a health center or hospital. Majority of HRI patients in our study reported having had at least primary school education. Therefore, Thai government could request to include HRI messages in existing projects such as agricultural, water and sanitation hygiene (WASH), health and climate change.

Consideration for a Heat Warning System

Heat warning system is an important intervention to alert citizens for dangerous levels of heat, especially for those working outdoor such as agricultural workers. The exact threshold for Thai heat warning was needed to be examined using human health data and daily weather patterns in the various provinces. The recent deadly heat wave in India demonstrated the need for alerting public on the danger of heat.[25]

Collaboration among the Ministry of Information and Communication Technology, the Meteorological Department and the MOPH was necessary. The Meteorological Department has access to the forecasted weather information and should have the authority to issue and disseminate heat warning to health centers and local NGOs.

Findings of this study initiated discussions on collaboration to conduct a HRI cohort study and establish sentinel surveillance in provinces with high HRI rates. The objectives would be to gather additional essential information which was not collected by the NHRS such as behaviors, locations of HRI and types of activity. Data captured by these projects would be of better quality, more detailed and ultimately more useful to understand HRI risk factors and achieve better data quality in order to define a temperature threshold for Thailand.

Conclusion

This was the first study of national data to report and describe HRI in Thailand. HRI is an important public health issue because during the 3-year study period, the trend appeared to be increasing, and disproportionate number of women and those with low socio-economic status seemed to be affected.

The study findings had been well received by the policy makers, including Deputy Permanent Secretary of MOPH and Director of Bureau of Occupational and Environmental Diseases, and actions had been supported. A sentinel surveillance establishing plan was proposed in collaboration with the Meteorological Department in order to formalize a heat warning system. This study should encourage other tropical countries to explore their available health data to examine if they could identify and track heat-related illnesses in their country as well.

Acknowledgement

We thank staff from data center in Bureau of Epidemiology, programmer team and data center in Bureau of Strategy and Policy in Ministry of Public Health; Dr. Sroisuda Kesornthong, Faculty of Public Health, Thammasart University; Dr. Pongthep Wiwattanadej, Department of Community Medicine, Faculty of Medicine, Chiang Mai University; and staff from Meteorological Department, Ministry of Science and Technology for their contribution and support to make this research successful. We also would like to express our appreciation towards Rebecca S. Noe from Division of Environmental Hazards and Health Effects, National Center for Environmental Health, Centers for Disease Control and Prevention for her editing and suggestions.

Suggested Citation

Thawillarp S, Thammawijaya P, Praekunnatham H, Siriruttanapruk S. Situation of heat-related illness in Thailand, and the proposing of heat warning system. OSIR. 2015 Sep;8(3):15-23. <http://osirjournal.net/issue.php?id=83>.

References

1. Wikipedia. List of natural disasters by death toll. 2015 [cited 2015 Sep 2]. <https://en.wikipedia.org/wiki/List_of_natural_disasters_by_death_toll#Deadliest_heat_waves>.

2. Larsen J. Record heat wave in Europe takes 35,000 lives: far greater losses may lie ahead. 2003 [cited 2015 Jul 26]. <http://www.earth-policy.org/index.php/plan_b_updates/2003/update29>.

3. Varma S. You're experiencing world's 5th deadliest heatwave ever. 2015 May 31 [cited 2015 Sep 22]. <http://timesofindia.indiatimes.com/india/Youre-experiencing-worlds-5th-deadliest-heatwave-ever/articleshow/47485972.cms>.

4. Cadena AJ, Rattanasorn T, Shutidamrong F. USAID Mekong adaptation and resilience vulnerability assessment report. USAID Mekong ARCC; 2014.

5. National Statistic Organization, Thailand Statistic. 2015. Thai [cited 2015 May 7]. <http://service.nso.go.th/nso/nso_center/project/search/result_by_department-th.jsp>.

6. Thai Meteorological Department. The climate of Thailand. 2012 Jan [cited 2015 May 7]. <http://www.tmd.go.th/en/archive/thailand_climate.pdf>.

7. Somboonwong J, Sanganrungsirikul S, Pitayanon C. Heat illness surveillance in schoolboys participating in physical education class in tropical climate: an analytical prospective descriptive study. BMJ Open. 2012 Jul 7;2(4). pii: e000741.

8. Sithinamsuwan P, Piyavechviratana K, Kitthaweesin T, Chusri W, Orrawanhanothai P, Wongsa A, et al. Exertional heatstroke: early recognition and outcome with aggressive

combined cooling -- a 12-year experience. Mil Med. 2009 May;174(5):496-502.

9. Met Office. Heat wave. 2014 [cited 2015 Jun 1]. <http://www.metoffice.gov.uk/learning/learn-about-the-weather/weather-phenomena/heatwave>.

10. R Core Team. R: A language and environment for statistical computing. R Foundation for Statistical Computing. 2014 [cited 2015 May 22]. <http://www.R-project.org/>.

11. Official Statistics Registrations System, Thailand. Population statistics. 2015. Thai [cited 2015 May 20]. <http://stat.dopa.go.th>.

12. Tiengrod P, Wongseree W. A comparison of spatial interpolation methods for surface temperature in Thailand. Proceedings of the International Computer Science and Engineering Conference; 2013 Sep 4-6; Bangkok; Bangkok: ICSEC; 2013. p.179-83.

13. Steadman RG. The assessment of sultriness, part II: effects of wind, extra radiation and barometric pressure on apparent temperature. Appl. Meteor. 1979 Jul;18:874-85.

14. Luber G, Sanchez C, Conklin L. Heat-related deaths - United States, 1999-2003. CDC MMWR. 2006 Jul;55(29):796-8.

15. Cooperative Promotion Department. 2015. Thai [cited 2015 Jul 27]. <http://www.cpd.go.th/cpd/cpdinter/download/ANNUAL_STAT_Farmer_PokPa.pdf>.

16. Druyan A, Makranz C, Moran D, Yanovich R, Epstein Y, Heled Y. Heat tolerance in women--reconsidering the criteria. Aviation Space Environmental Medicine. 2012 Jan;83(1):58-60.

17. Metzger KB, Ito K, Matte TD. Summer heat and mortality in New York City: how hot is too hot? Environmental Health Perspective. 2010 Jan;118(1):80-6.

18. Kent ST, McClure LA, Zaitchik BF, Smith TT, Gohlke JM. Heat waves and health outcomes in Alabama (USA): the importance of heat wave definition. Environmental Health Perspective. 2014 Feb;122(2):151-8.

19. Wetterhall SF, Coulombier DM, Herndon JM, Zaza S, Cantwell JD. Medical care delivery at the 196 Olympic Games. JAMA. 1998 May; 279(18):1463-8.

20. Coletta M, Dewey L, White-Russel M, Powell T, Toney D, Cheek SJ, et al. Surveillance for early detection of disease outbreaks at an outdoor mass gathering -- Virginia, 2005. CDCMMWR. 2006 Jan;55(3):71-4.

21. Royal Command of HM the King. Rice planting in Thailand. Thai [cited 2015 Jun 1]. <http://kanchanapisek.or.th/kp6/sub/book/book.php?book=3&chap=1&page=t3-1-infodetail07.html>.

22. Thai Meteorological Department. Weather, climate, Thailand. 2014. Thai [cited 2015 Jun 2]. <http://www.tmd.go.th/info/info.php?FileID=22>.

23. Soomboonwong J, Sanguanrungsirikul S, Pitayanon C. Heat illness surveillance in schoolboys participating in physical education class in tropical climate: an analytical prospective descriptive study. BMJ. 2012 Jul;2(4):e000741.

24. Tawatsupa B, Lim LLY, Kjellstrom T, SeubsmanSa, Sleigh A. Association between occupational heat stress and kidney disease among 37,816 workers in the Thai cohort study (TCS). J. Epidemiol. 2012;22(3):251-60.

25. Najar N. Indians urged to stay indoors as sweltering heat kills more than 1,300. 2015 [cited 2015 Jun 1]. <http://www.nytimes.com/2015/05/28/world/asia/india-heat-wave-andhra-pradesh-telengana.html?_r=0>.