Climatic Factors Affecting Dengue Haemorrhagic Fever Incidence in Southern Thailand

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Abstract

This study investigated the climatic factors associated with dengue haemorrhagic fever (DHF) incidence in southern Thailand. The climatic factors comprised rainfall, rainy days, relative humidity and maximum, minimum and mean temperatures. Pearson's correlation coefficient was used to explore the primary association between the DHF incidence and all climatic factors. Step-wise regression technique was then used to fit the statistical model. The result indicated that the mean temperature, rainfall and relative humidity were associated with the DHF incidence in the areas bordering on the Andaman Sea, while minimum temperature, rainy days and relative humidity were associated with the DHF incidence on the Gulf of Thailand side of the southern peninsula.

Keywords: Dengue haemorrhagic fever, temperature, rainfall, relative humidity, Thailand.

Introduction

Dengue haemorrhagic fever (DHF) is one of the most serious public health problem in Thailand as well as in many other tropical countries around the world. The disease affects hundreds of millions of people every year[1,2]. Dengue virus is transmitted by the mosquito *Aedes aegypti* adapted to living near areas of human habitation[3,4]. Dengue transmission occurs throughout the year in endemic tropical areas, but there exists a distinct cyclical pattern associated with the rainy season[1]. In tropical and sub-tropical regions, temperature and rainfall levels enable adult vectors to remain active throughout the year[5]. This contributes to a continuous transmission cycle that makes the disease endemic.

The transmission of dengue viruses is climatic sensitive for several reasons. First, temperature changes affect vector-borne disease transmission and epidemic potential by altering the vector's reproductive rate, biting rate, the extrinsic incubation period of the pathogen, by shifting a vector's geographical range or distribution and increasing or decreasing vector-pathogen-host interaction and thereby affecting host susceptibility[6]. Second, precipitation affects adult female mosquito density. An increase in the amount of rainfall leads to an increase in available breeding sites which, in turn, leads to an increase in the number of mosquitoes. An increase in the number of adult female mosquitoes increases the odds of a mosquito obtaining a pathogen and transmitting it to a second sensitive host[7]. Third, a distinct

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seasonal pattern in DHF outbreaks is evident in most places. In tropical regions where monsoon weather patterns predominate, DHF hospitalisation rates increase during the rainy season and decrease several months after the cessation of the rains[8,9]. This decline may be related to a decrease in mosquito biting activity, a decrease in longevity of female mosquitoes, or both.

In Thailand where the vector life-cycle is highly domiciliary, temperature and humidity conditions during the rainy season favour the survival of infected mosquitoes[10]. There has been an upward trend in the incidence of DHF, an acute and severe form of dengue virus infection, since the first DHF epidemic outbreak in 1958[11], with a cumulative total of 1 369 542 DHF cases in 2001. The Bureau of Epidemiology (2000) reported that there had been several regular outbreaks in Thailand. From 1992 to 2002, the Southern Epidemiology Department reported 42 692 cases of DHF in southern Thailand, with 123 deaths. This indicates that DHF is a major health risk in southern Thailand. Most studies on dengue[12-15] have been done in the central part of Thailand where the climate differs significantly from that of the southern region of the country. Only one study has been undertaken to define the relationship between climatic factors and DHF in southern Thailand[16]. However, that study was limited in scope as the data, which were collected from only four out of 14 southern provinces, might not be representative of all southern Thailand.

The impact of climatic factors on DHF in Thailand is probably the least understood[17-20]. The aim of this study was to investigate the relationship between climatic factors and the incidence of DHF in southern Thailand and to compare the differential effects of climatic factors on the incidence of DHF in the areas bordering on the Andaman Sea and those on the Gulf of Thailand side of the peninsula.

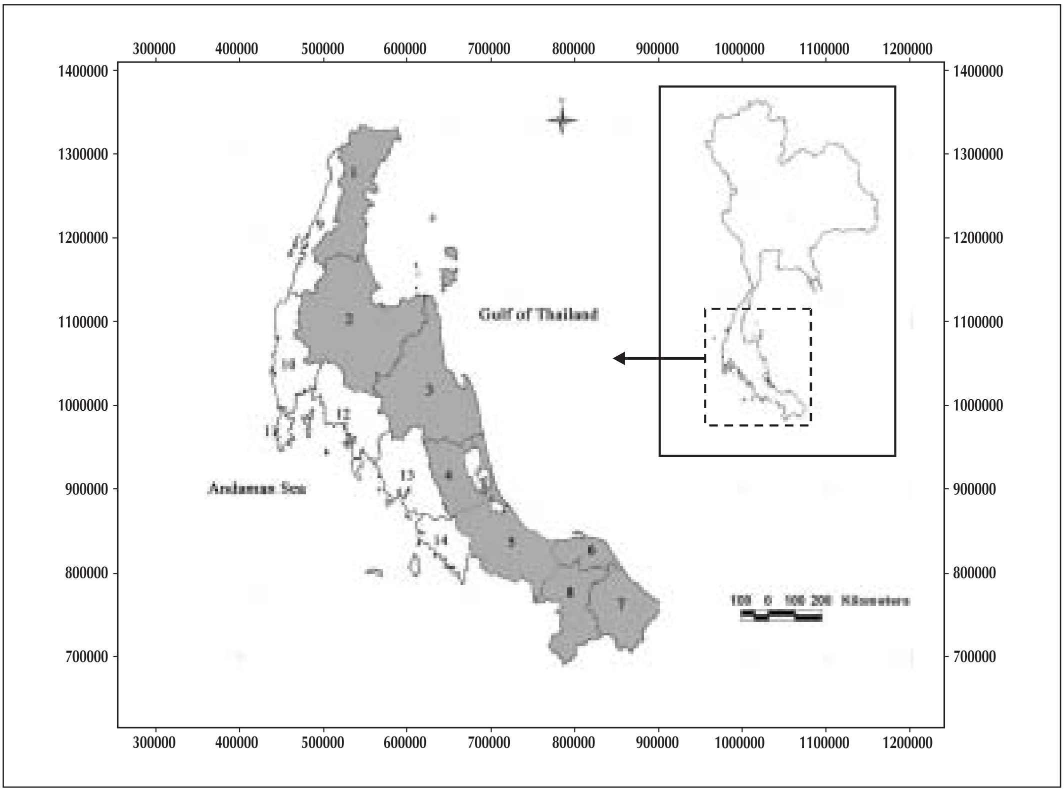
Materials and Methods

Southern Thailand is located at 5° 37' – 11° 42' N, 98° 22' – 102° 05′E and covers 70 715.2 km^2. It is bordered on the eastern side by the Gulf of Thailand and on the western side by the Andaman Sea. There are many hills and mountains bordered by the seas. Southern Thailand is composed of 14 provinces (Figure 1). The climate is equatorial and humid, high temperature of over 20 °C, and relative humidity of 80% throughout the year[11]. The wettest period of the year is from August to September on the Andaman Sea side and from November to January on the Gulf of Thailand side of the southern peninsula.

Climatic data for southern Thailand over the period 1993–2002 was provided by the Climatology Division of the Meteorological Department. The monthly DHF incidence data over the same period were collected by the Centre of Epidemiological Information, Bureau of Epidemiology, Ministry of Public Health. Climatic data comprised monthly rainfall, rainy days, maximum temperature, minimum temperature, mean temperature and relative humidity.

All variables were tested for normality using Kolmogorov-Sminov test and transformed when necessary. DHF was logarithmic transformed to achieve normality. Independent t-tests were used to test DHF and monthly climatic factors between the two coasts of southern Thailand. Pearson's correlation coefficient test was used to detect primary association between DHF incidence and climatic factors. The significantly variables correlative to the DHF incidence were then submitted to multiple regression analysis. Stepwise regression technique was employed to explore and identify statistically significant risk indicators.

Figure 1. ***Map of administrative boundaries of 14 provinces of southern Thailand (Shaded area (no. 1-8) represents eight provinces at the Gulf of Thailand while the non-shaded area (no. 9-14) represents six provinces at the Andaman Sea)***



Results

DHF incidence rates in southern Thailand varied from 0–192.73 per 100 000 population. The highest incidence of the disease was observed in July 1995 in Trang Province on the Andaman Sea side with 192.73 cases per 100 000 population. DHF incidence rate was 9.91±17.42 with the median 3.09 (Figure 2). Rainfall varied from 0–1213.20 mm. Rainy days were 14.22±7.06 days per month with the range of 0–31 days. Relative humidity were 79.89±3.39% with the range of 72.4–86.0%. Maximum, minimum, and mean temperatures varied from 29.40–40.30, 13.00–26.60 and 23.90–31.20 °C respectively.

The DHF incidence rates and climatic factors differed among 14 provinces in southern Thailand (Table 1). The DHF incidence rate and climatic factors on the Andaman Sea side differed from those on the Gulf of Thailand side in all categories (Table 2). The DHF incidence per 100 000 population on the Andaman Sea side was lower than that for the Gulf of Thailand side (Table 2). Rainy days, rainfall, mean, maximum temperature and relative humidity on the Andaman Sea side were higher than those on the Gulf of Thailand side. However, the minimum temperature was lower on the Andaman Sea side than on the Gulf of Thailand side (Table 2).

Figure 2. ***Average monthly DHF incidence on the Andaman Sea side and the Gulf of Thailand side of southern Thailand during 1993-2002***

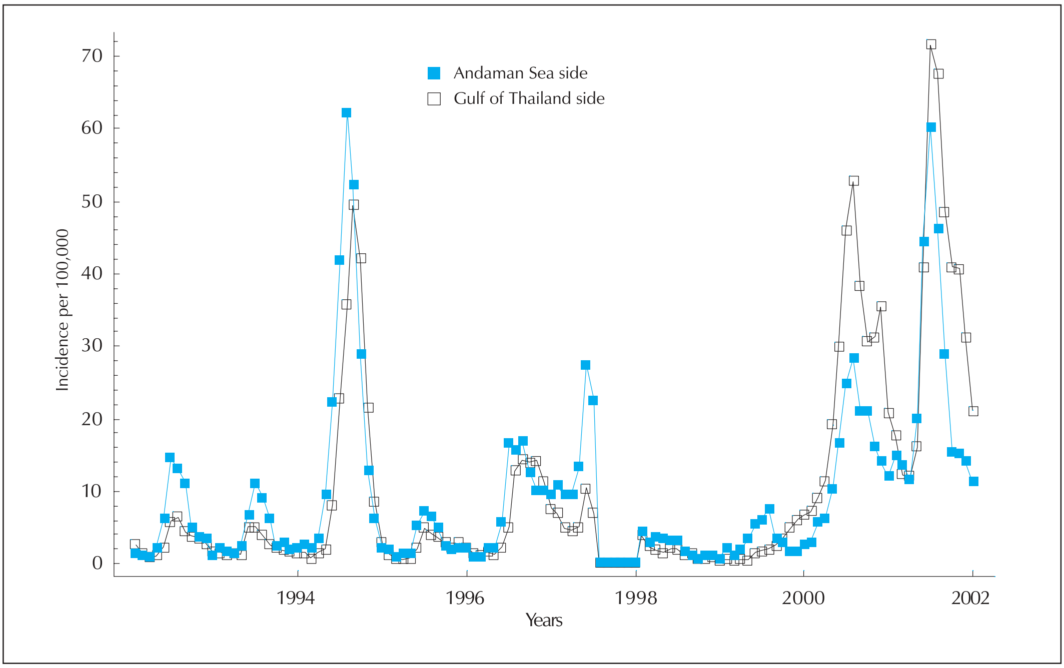


Table 1. *Mean (±SD) of DHF incidence rates and climatic factors in 14 provinces of southern Thailand*

	$\overline{X} \pm SD$		*t* test
	Andaman Sea side	**Gulf of Thailand side**	
Incidence (per 100 000)	9.53±16.96	10.20±17.76	t_{1430}=3.027**
Rainy days (days)	15.41±7.97	13.32±6.15	t_{1309}=5.850**
Rainfall (mm)	204.03±215.14	183.92±177.76	t_{1373}=5.692**
Relative humidity (%)	80.85±5.80	79.19±4.17	t_{1244}=6.504**
Temperature (°C)			
Mean	27.51±0.90	27.33±1.01	t_{1630}=3.818**
Maximum	34.51±1.41	33.72±1.82	t_{1676}=10.020**
Minimum	22.03±1.48	22.21±1.57	t_{1678}=–2.338*

On the Andaman Sea side, the significant variables were mean temperature (t_{597}=7.77, P<0.001), relative humidity (t_{597}=2.73, P<0.001) and rainfall (t_{597}=3.55, P<0.01). Therefore, the selected regression model was $y_1=-6.522+0.338x_{11}+0.180x_{14}+0.147x_{16}$ (R^2=0.15, $F_{3,594}$=26.11, P<0.001).

On the Gulf of Thailand side, the significant variables were minimum temperature (t_{862}=3.16, P<0.01), rainy days (t_{862}=4.03, P<0.001) and relative humidity (t_{862}=–3.73, P<0.001). Therefore, the selected regression model was $y_2=0.072x_{23}+0.015x_{25}-0.017x_{26}$ (R^2=0.34, $F_{3,838}$=144.85, P<0.001).

Table 2. *DHF incidence rates and climatic factors of southern Thailand*

Province	$\overline{X} \pm SD$						
	Incidence (per 100 000)	Rainy days (day)	Rainfall (mm)	Relative humidity (%)	Temperature (°C)		
					Mean	Max	Min
Gulf of Thailand side							
Chumphon	8.41±12.52	13.9±7.2	170±136	76.6±3.7	27.0±1.1	34.5±1.5	21.5±2.4
Suratthani	11.53±20.51	12.8±6.7	136±115	81.1±3.5	26.8±0.9	34.6±1.5	21.2±1.5
Phattalung	10.83±20.27	13.0±5.4	174±149	79.0±3.3	28.0±0.9	32.0±1.5	24.0±1.1
Nakhonsithammarat	10.81±19.61	14.0±5.8	219±210	81.0±3.7	27.0±1.0	34.0±1.9	22.0±1.4
Songkhla	12.72±19.53	13.2±6.5	182±200	78.6±3.7	27.8±0.9	33.7±2.0	23.1±0.9
Pattani	7.83±15.28	12.0±6.3	170±177	81.0±3.3	27.0±0.9	34.0±1.4	22.0±1.3
Yala	13.14±19.15	12.7±4.4	180±111	74.6±3.0	27.7±0.9	32.8±1.6	22.6±0.6
Narathiwat	6.31±12.02	14.2±6.3	240±257	82.2±2.8	27.1±0.9	33.8±1.8	22.0±0.9
Andaman Sea side							
Ranong	10.88±14.54	16.6±9.7	358±338	79.7±6.2	27.2±0.9	34.6±1.7	22.0±1.7
Phungnga	8.07±17.43	18.0±8.2	321±250	84.0±4.2	27.0±0.8	34.0±1.4	21.0±1.6
Phuket	7.48±8.59	15.0±7.6	186±131	77.0±5.0	28.0±0.8	34.0±1.2	23.0±0.8
Krabi	13.03±16.27	13.0±7.1	189±150	82.4±5.2	28.0±0.9	34.5±1.3	22.6±1.2
Trang	12.81±27.04	15.0±7.1	191±125	83.0±5.4	27.0±0.8	35.0±1.4	21.0±1.3
Satun	4.89±10.04	16.0±7.1	196±131	80.0±5.6	28.0±0.7	34.0±1.2	22.0±1.2

Discussion

The results of this study indicate that climatic factors play an important role in the transmission cycles of DHF. However, the relative importance of these climatic factors varied with geographical areas. The DHF incidence rate on the Andaman Sea side was lower than that on the Gulf of Thailand side. This could be due to high annual precipitation and a higher number of rainy days on the Andaman Sea side during the south-west monsoon season (May-October). This result contradicted the findings of the study by Kanchanapairoj et al.[16], which concluded that the seasonal patterns of DHF incidence on the Andaman Sea side and the Gulf of Thailand side were similar. The difference may possibly be due to the fact that the two studies were specific to different time-spans. Data for the present study were collected during the period 1993–2002, while those for their study covered the period 1978–1997. From 1997 to 2002, several significant outbreaks of DHF were reported in southern Thailand. A second reason may be that the data for the present study were collected from all 14 provinces of southern Thailand, whereas for the earlier study data were derived from only four provinces[16]. It is reasonable to assume that the data used in the present study is more comprehensive and representative of southern Thailand.

Changes in climate may influence the abundance and distribution of vectors and intermediate hosts[21,22]. Precipitation is an important factor in the transmission of DHF. All mosquitoes have aquatic larval and pupal stages and therefore require water for breeding[21,22]. Precipitation also determines the presence or absence of breeding sites[21]. Rainfall events and subsequent floods can lead to outbreaks of DHF mainly by enabling increased breeding of vector mosquitoes[22]. The timing of rainfall is as important as the amount of rain. The pattern of rainfall may also play a part. Extremely heavy rainfall may flush mosquito larvae away from breeding sites or kill them outright[21]. More frequent, lighter rains may replenish existing breeding sites and maintain higher levels of humidity that assist in dispersal and survival of adult mosquitoes[21,22]. In this study, it was found that rainfall and rainy days were two important determinants in DHF transmission in southern Thailand. Rainy days were significantly associated with DHF incidence in both earlier[16] and our studies. According to this earlier study, the number of rainy days was associated with the DHF incidence rate on both sides of the peninsula, but our study showed that rainy days were associated with the DHF incidence rate only on the Gulf of Thailand side. This divergence may be due to the differential data in terms of the scope and timing of data collection for the two studies. The number of rainy days may influence either the life-cycle of a mosquito or viral replication rates since a certain number of rainy days are generally favourable for mosquito development. If the number of rainy days were too low, there would not be enough water for mosquito larvae to complete their development.

Warmer temperatures can increase the transmission rates of DHF in various ways. First, warmer temperature may allow vectors to survive and reach maturity much faster than at lower temperatures[22]. Secondly, warmer temperature may reduce the size of mosquito larvae resulting in smaller adults that have high metabolism rates, require more frequent blood meal and need to lay eggs more often[11,18,21]. Thirdly, ambient temperature has a marked effect on the length of the extrinsic incubation periods (EIPs) of arboviruses in their vectors[21,22]. This means that mosquitoes exposed to higher temperatures after ingestion of virus become infectious more rapidly than mosquitoes of the same species which are exposed to lower temperatures[22]. Therefore, the transmission of arboviruses may increase under warmer conditions as more vector mosquitoes become infectious within their life-span. Higher temperature may reduce the length of viral extrinsic incubation periods (EIPs) in mosquitoes[15,23,24]. At 30 °C, the duration of dengue virus EIPs is 12 days, compared with only 7 days at 32–35 °C[17]. Moreover, a 5-day decrease in the duration of the incubation period can triple the transmission rate of dengue[25]. It was found in this study that the mean and minimum temperatures were positively associated with the transmission of DHF in southern Thailand. As the minimum temperature increased, the transmission rate of DHF also increased. It is possible that most of the physiological functions of vectors in this area are subject to optimal minimum temperature.

Relative humidity influences longevity, mating, dispersal, feeding behaviour and oviposition of mosquitoes and rapid replication of the virus[4,21,26]. At high humidity, mosquitoes generally live longer and disperse further. Therefore, they have a greater chance of feeding on infected people and surviving to transmit the virus to other people. Relative humidity also directly affects the evaporation rates of vector breeding sites. In this study it was found that relative humidity had a positive association with the transmission of DHF on the Andaman Sea side, but a negative association on the Gulf of Thailand side. The disparity may be due to the differences in some climatic factors. The Andaman Sea side has higher temperature, humidity, precipitation, more rainy days and slightly lower minimum temperature than the Gulf of Thailand side of the peninsula.

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