Temperature Factor Affecting Dengue Fever Incidence in Southern Taiwan

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ABSTRACT—*This study explored the climatic factors associated with dengue fever incidence in southern Taiwan. The climatic factors comprised maximum and minimum temperatures. Symbolic data analysis was used to explore the primary association between the dengue fever incidence and climatic factors. Linear regression technique was then used to fit the statistical model. Dengue fever data Kaohsiung city in southern Taiwan from January, 2005 to August, 2014 were analysis with linear regression analysis for interval-valued data in this study. The result indicated that the temperature was associated with the dengue fever incidence in southern Taiwan, and the temperature was positive with the dengue fever cases.*

Keywords—Dengue fever, temperature, interval-valued data, symbolic data analysis

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1. INTRODUCTION

Dengue fever is one of the most serious public health problems in Taiwan as well as in many tropical countries around the world. The illness affects many people every year [1]. Dengue fever virus is transmitted by the mosquito of Aedes Aegypti adapted to living near areas of human habitation [2]. Dengue fever transmission occurs throughout the year in endemic tropical areas, but there exists a distinct cyclical pattern associated with the season [1]. In tropical and sub-tropical regions, temperature enable adult vectors to remain active throughout the year [3]. This contributes to a continuous transmission cycle that makes the disease endemic.

The spread of dengue fever viruses is climatic sensitive for several reasons. The changes of temperature 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 [4]. 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. Third, a distinct seasonal pattern in dengue fever outbreaks is evident in most places. In tropical regions where monsoon weather patterns predominate, dengue fever hospitalization rates increase during the rainy season and decrease several months after the cessation of the rains [5]. This decline may be related to a decrease in mosquito biting activity, a decrease in longevity of female mosquitoes, or both.

Taiwan is located in the Pacific Ocean area and is suitable for reproduction of dengue vectors with high temperature and humidity. Taiwan is divided into two zones by the tropic of cancer, and the climate, environment, mosquito species and population density are significantly different [6]. Since the ecological environments between these two areas are different, Southern Taiwan usually has more severe dengue epidemics, especially in 1987 and 1988, including Kaohsiung City, Tainan City and Pingtung County; but there were only few small scales of outbreaks in Northern and Central Taiwan [6]. The most serious dengue outbreak was in 2002, there were 5336 indigenous positive cases in Taiwan and most of them were at the southern side of Tropic of Cancer, and Kaohsiung City alone has 4811 cases in total. For the last 10 years, the ranges of indigenous dengue epidemics in Kaohsiung City were varied every year. Most of these epidemics were not severe, for example, there were 1106, 1183, 532, and 102 indigenous cases from 2010 to 2013, respectively. Besides, in recent years, the types of dengue fever become various in southern Taiwan; 2007 had type I and type II and 2010 had type I and type IV [7]. Therefore, the risk of dengue fever increased gradually in southern Taiwan. Dengue fever has become a major public health issue in Taiwan which affects the quality of life and the health of residents.

The impact of climatic factors on dengue fever in Taiwan is probably the least understood [8]. The aim of this study was to investigate the relationship between climatic factors and the incidence of dengue fever in southern Taiwan and to compare the differential effects of climatic factors on the incidence of dengue fever in Kaohsiung City that is a big city in Southern Taiwan.

2. MATERIALS AND METHODS

Dengue fever data of Kaohsiung city in southern Taiwan from January 2005 to August 2014 were analysis with linear regression analysis for interval-valued data in this study.

2.1. Data collection

Climatic data for southern Taiwan over the period 2005-2014 was provided by the Central Weather Bureau (Taiwan) with Taiwan National Infectious Disease Statistics System [9]. The monthly dengue fever incidence data over the same period were collected by the Ministry of Health and Welfare (Taiwan) with Climate Statistics data base [10]. Climatic data comprised maximum temperature and minimum temperature, and the temperature were interval-valued data.

The variables correlative to the dengue fever incidence were then submitted to linear regression analysis. Symbolic data analysis was employed to explore and identify statistically significant risk indicators.

2.2. Data analysis

Dengue fever data of Kaohsiung city in southern Taiwan from January 2005 to August 2014 were analysis with linear regression analysis for interval-valued data with R 3.1.1 (Package RSDA) [11, 12].

Centre method from an optimization standpoint [11, 12]. In this method, the estimate of the parameters β is based only on the midpoint of the intervals according to the criterion considered. Let E={$e_1,\ldots,e_n$} be a set of examples that are described by p+1 interval-valued variables Y, $X_1,\ldots,X_p$. Each example is represented as an interval quantitative feature vector $z_i=(x_i, y_i)$, $xi=(x_{i1},\ldots,x_{ip})$, where $x_{ij}=[a_{ij},b_{ij}]\in\hat{s}=\{[a,]:a,b\in R,a\le b\}$ (j=1,…,p) and $y_i=[y_{Li},y_{Ui}]\in\hat{s}$ are, respectively, the observed values of X_j and Y.

Let us consider $X_1,\ldots,X_p$ related to Y according to the linear regression relationship:

$$y_{Li}=\beta_0+\beta_1 a_{i1}+\cdots+\beta_p a_{ip}+\varepsilon_{Li}$$

$$y_{Ui}=\beta_0+\beta_1 b_{i1}+\cdots+\beta_p b_{ip}+\varepsilon_{Ui} \quad (1)$$

From (1), we will denote the sum of the squares of deviations in this first approach by

$$S_{cm}=\sum_{i=1}^{n}(\in_{Li}+\in_{Ui})^2=\sum_{i=1}^{n}(y_{Li}-\beta_0-\beta_1\alpha_{i1}-\cdots\beta_p\alpha_{ip}+y_{Ui}-\beta_0-\beta_1 b_{i1}-\cdots\beta_p b_{ip})^2 \quad (2)$$

which represents the sum of the square of the sum of the lower and upper boundary errors.

Lima Neto and De Carvalho present the estimates of the vector of parameters β in matrix notation for the center method [11], which can be rewritten in the simplest form as

$$y^C=X^C\beta+\varepsilon^C \quad (3)$$

where $y^C=(y_1^C,\cdots y_n^C)^T$, $X^C=((x_1^C)^T,\cdots(x_n^C)^T)^T$, $(x_i^C)^T=(1,x_{i1}^C,\ldots x_{ip}^C)$ (i=1,…,n), $\beta=(\beta_0,\ldots\beta_p)^T$, $\varepsilon^C=(\varepsilon_1^C,\ldots,\varepsilon_n^C)^T$, $x^c_{ij}=(a_{ij},\ldots, b_{ij})/2$ and $x^c_j=(a_{Li},\ldots, b_{Ui})/2$.

If X_c has full rank $p+1\le n$, the least square estimate of β in Eq. (3) is given by

$$\hat{\beta}=((X^C)^T X^C)^{-1}(X^C)^T y^C \quad (4)$$

Given a new example e, described by z=(x, y), where $x=(x_1,\ldots,x_p)$ with $x_j=[a_i, b_j]$ (j=1,…,p), the value $y=[y_L, y_U]$ of Y will be predicted by $\hat{y}=[\hat{y}_L,\hat{y}_U]$ as follows:

$$\hat{y}_L=(x_L)^T\hat{\beta} \text{ and } \hat{y}_U=(x_U)^T\hat{\beta} \quad (5)$$

where $(x_L)^T=(1,a_1,\cdots,a_p)$, $(x_U)^T=(1,b_1,\cdots,b_p)$

The determination coefficient (R^2) represents a goodness-of-fit measure commonly used in regression analysis to capture the adjustment quality of a model. The determination coefficient (R^2) for the CM method is easily established as

$$R_{cm}^2 = \frac{\sum_{i=1}^{n}(\hat{y}_i^C - \bar{y}^C)^2}{\sum_{i=1}^{n}(y_i^C - \bar{y}^C)^2} \quad (6)$$

However, note that $2y^C = (y_L + y_U)$. Thus, the expression (6) can be replaced by

$$R_{cm}^2 = \frac{\sum_{i=1}^{n}((\hat{y}_{Li} + \hat{y}_{Ui}) - (\bar{y}_{Li} + \bar{y}_{Ui}))^2}{\sum_{i=1}^{n}((y_{Li} + y_{Ui}) - (\bar{y}_{Li} + \bar{y}_{Ui}))^2} \quad (7)$$

3. RESULTS

Dengue fever data of Kaohsiung city in southern Taiwan from January, 2005 to August, 2014 were analysis with linear regression analysis for interval-valued data in this study. The characteristics of the research data was as Table 1. Dengue fever cases in 2010, 2011 and 2014 were above 1000. The minimum of temperature were 8.7^{o}C, and the maximum of temperature were 36.4^{o}C.

Table 1: The characteristics of the research data

	Dengue fever cases			Temperature (^{o}C)
	Sum/Year	Mean/Month	S.D./Month	
2005 Jan.-Dec.	144	12.00	15.82	U[8.7, 34.9]
2006 Jan.-Dec.	956	79.67	100.36	U[11.3, 35.7]
2007 Jan.-Dec.	202	16.83	20.60	U[9.2, 35.4]
2008 Jan.-Dec.	443	36.92	48.67	U[10.2, 35.0]
2009 Jan.-Dec.	773	64.42	102.70	U[9.3, 35.0]
2010 Jan.-Dec.	1106	92.17	122.07	U[10.9, 35.9]
2011 Jan.-Dec.	1183	98.58	143.43	U[11.3, 35.8]
2012 Jan.-Dec.	532	44.33	57.98	U[11.0, 36.4]
2013 Jan.-Dec.	102	8.50	9.74	U[12.0, 35.7]
2014 Jan.-Aug.	1369	171.13	311.23	U[11.1, 34.8]

On the southern Taiwan (Kaohsiung city), the significant variable was temperature (t-value=1.71, P-value=.09). The temperature was positive with the dengue fever cases. Therefore, the selected linear regression analysis for interval-valued data model was y=5.10a_1. Multiple R-squared was .02, and Adjusted R-squared was .02.

Table 2: Regression analysis of temperature factor affecting dengue fever incidence in southern Taiwan

	Estimate	S.D.	t-value	P-value
(Intercept)	-71.55	76.98	-.93	.35
a_1: Temperature	5.10	2.99	1.71	.09

4. DISCUSSION AND CONCLUSION

The results of this study indicate that climatic factors of temperature play an important role in the transmission cycles of dengue fever. The relative importance of these climatic factors varied with geographical areas. The dengue fever case in Kaohsiung city at 2013 was lower than other years, and this could be due to public health policy. This result contradicted the findings of the study by Promprou, Jaroensutasinee, and Jaroensutasinee [13], which concluded that the seasonal patterns of dengue fever incidence on the Andaman Sea side and the Gulf of Thailand side were similar.

Changes in temperature of climate may influence the abundance and distribution of vectors and intermediate hosts [14]. Precipitation is an important factor in the transmission of dengue fever. All mosquitoes have aquatic larval and pupal-stages and therefore require water for breeding [B1]. Precipitation also determines the presence or absence of breeding sites.

Warmer temperatures would increase the transmission rates of dengue fever in various ways. Warmer temperature may allow vectors to survive and reach maturity much faster than at lower temperatures [13]. Moreover, 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 [13]. Ambient temperature had a marked effect on the length of the extrinsic incubation periods of parvoviruses in their vectors. 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. Therefore, the transmission of proviruses 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 in mosquitoes [13]. At 30°C, the duration of dengue virus extrinsic incubation periods is 12 days, compared with only 7 days at 32-35°C [13]. Moreover, a 5-day decrease in the duration of the incubation period can triple the transmission rate of dengue [15]. It was found in this study that the mean and minimum temperatures were positively associated with the transmission of dengue fever in southern Taiwan. As the minimum temperature increased, the transmission rate of dengue fever also increased. It is possible that most of the physiological functions of vectors in this area are subject to optimal minimum temperature.

This study was only focus on temperature factor affecting dengue fever incidence in southern Taiwan. This study didn't focus on the other climate factors (such as rainy days, sunshine days, and relative humidity) affecting dengue fever. Further research can continue to test and verify those. Besides, for the strong effect of public health policy in dengue fever, the effect of policy can be an external factors in future research.

The surveyed samples used in this study were southern Taiwan cases. The cultural background and medical environments for which that cases stand are different from those living in other countries (such as United States, German, United Kingdom…). Further research can continue to test and verify those impacts through extensively interviews with patients.

5. REFERENCES

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