



Trend and geographic analysis of the prevalence of dengue in Taiwan, 2010–2015



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SUMMARY

Background: Dengue is the most rapidly spreading disease caused by a mosquito-borne virus in the world. The incidence of dengue globally has increased 30-fold in the last 50 years. Understanding the prevalence of dengue and its longitudinal trends can improve prevention and control strategies. This study assessed the trends in prevalence of dengue in Taiwan by population characteristics and geographical region.

Methods: Dengue and population data for the years 2010–2015 were obtained from the public statistics databases of the Taiwan Centers for Disease Control and Department of Statistics, Taiwan Ministry of Interior. Yearly prevalence rates of dengue were calculated by age group, sex, and administrative area within five geographic regions (northern, mid-western, southern, and eastern regions, and outer islands).

Results: The national prevalence rate of dengue decreased gradually from 8 to 4 per 100 000 population between 2010 and 2013, but it increased substantially in 2014 and 2015 to 67 and 187 per 100 000 population, respectively. There was no significant difference in prevalence rate between males and females. People aged 60–69 years had a significantly higher prevalence rate than those in the other age groups during 2010–2014, and people aged over 70 years had the highest rate in 2015 (309 per 100 000 population). The southern region had the highest yearly dengue prevalence rate (the rate decreased from 23 to 9 per 100 000 population between 2010 and 2013, but increased to 220 and 616 per 100 000 population in 2014 and 2015, respectively). Three unexpected outbreaks of dengue were observed during the study period: the first outbreak occurred in Penghu County in 2011 (prevalence rate 101 per 100 000 population), the second in Kaohsiung City in 2014 (prevalence rate 540 per 100 000 population), and the third in Tainan City in 2015 (prevalence rate 1208 per 100 000 population).

Conclusions: More efforts are still needed to prevent and control dengue in Taiwan. The government should direct resources and interventions to southern Taiwan, which has a tropical climate and a high population density, and should target older people who are more likely to be infected. Strategies are also needed to respond quickly to unexpected incidents to prevent dengue outbreaks.

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1. Introduction

Dengue is an endemic disease with frequently occurring outbreaks in the Southeast Asia, Western Pacific, Latin America, Africa, and Eastern Mediterranean regions.^{1,2} Dengue is transmitted by the bite of *Aedes* mosquitoes infected with the dengue virus

(DENV) and can develop into a potentially lethal condition called severe dengue.³ World Health Organization (WHO) estimates suggest that the incidence of dengue has increased 30-fold globally over the last 50 years, and around 50–100 million infections occur annually worldwide.^{4,5}

Dengue commonly occurs in tropical and sub-tropical climates worldwide, mostly in urban and semi-urban areas.⁶ DENV can be divided into four serotypes (DENV 1, 2, 3, and 4), each of which confers partial cross-protective immunity to the other serotypes in humans.⁷ According to previous studies in Taiwan, most of the

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severe manifestations of dengue infection occur among older people or patients experiencing a secondary DENV infection that has a different serotype from the previous one;^{1,8,9} infection with type 2 DENV, in particular, has been associated with severe dengue illness such as dengue hemorrhagic fever (DHF).⁷ In Southeast Asia, most cases are asymptomatic; only 24% of infected persons show clinical symptoms.⁸ Severe dengue (DHF) is a leading cause of serious illness and death among children in some countries.¹⁰ Currently there is no specific treatment for dengue, but early detection and access to proper medical care lower fatality rates.^{5,11}

The reported case mortality of dengue varies from country to country. On average, the mortality is 1–5%, but it has been reported to be as high as 73% in Colombia.⁵ For governments, dengue represents a substantial economic burden.^{4,12,13} Some studies have suggested that the annual cost attributable to dengue treatment is about US\$2.1 billion in America and \$950 million in Southeast Asia.^{4,13} The economic burden is likely influenced by the prevalence of dengue and disease severity.

Taiwan faces dengue outbreaks in the summer every year. A previous study in Taiwan found that most dengue patients during the years 2002–2007 were adults, with dengue fever peaking in the 50–54 years age range and severe dengue peaking in the 60–64 years age range.⁸ Another study found that older people were at a high risk of dengue-related mortality in Kaohsiung in Taiwan during the years 2003–2009.⁹

A better understanding of the prevalence of dengue and its recent trends can inform improvements in prevention and control strategies. The aim of this study was to assess the trends in prevalence of dengue in Taiwan by population characteristics (sex and age) and geographical region for the period 2010–2015.

2. Methods

Dengue data reported in the public statistics databases of the Taiwan Centers for Disease Control (CDC) were obtained for the years 2010–2015 (6-year period). The data were monthly numbers of new dengue fever cases (including both outpatient and inpatient settings) by sex and age reported in each administrative division in Taiwan. In addition, yearly population data by region were obtained from the Department of Statistics, Taiwan Ministry of Interior.

Yearly prevalence rates of dengue were calculated by population characteristics (sex and age). The divisions were grouped into five regions: northern, mid-western, southern, and eastern regions, and the outer islands (see Appendix). Divisions were also classified

into urban or rural areas by population density, which was calculated by population number divided by geographic area (km²) for each division. Divisions with a population density higher than 700 people per square kilometer were considered urban areas and those with a density less than 700 people per square kilometer were considered rural areas. Yearly numbers of dengue cases were calculated based on the monthly numbers of new dengue fever cases for each administrative division and geographic region. The prevalence rate was estimated as follows: yearly number of reported dengue fever cases in each region divided by the number of people in the population in the same region.

3. Results

Nationally, the prevalence rate of dengue fever was relatively stable at 8 per 100 000 population in 2010 to 4 per 100 000 population in 2013; however, the rates in 2014 and 2015 were much higher at 67 and 187 per 100 000 population, respectively (Table 1).

The yearly prevalence rates for males and females were similar during the study. People aged 60–69 years generally had the highest yearly prevalence rate, except in 2015 when people aged over 70 years had the highest rate. Children aged 0–9 years had the lowest yearly prevalence rate during the study. There was an approximately 3.6-fold difference in prevalence rate between the age groups in 2015.

Table 2 shows the yearly numbers of cases and population-adjusted prevalence rates of dengue by region and administrative division in Taiwan. Between 2010 and 2014, the prevalence rates in the northern (range 1–2 per 100 000 population), mid-western (1 per 100 000 population), and eastern (range 0–3 per 100 000 population) regions were relatively stable. The rates were slightly higher in 2015, with rates at 4, 4, and 6 per 100 000 population in the northern, mid-western, and eastern regions, respectively. In the northern region, urban areas (Taipei City, New Taipei City, and Taoyuan City) had relatively higher prevalence rates of dengue during 2010–2015 compared with rural areas (e.g., Yilan County, Hsinchu County, and Miaoli County). In 2015, the mean prevalence rate in urban areas within the northern region was 4.35 per 100 000 population, while it was 3.64 in rural areas, reflecting a 1.19-fold difference between them. Similar patterns were seen in the mid-western and eastern regions. Figure 1 shows prevalence rates of dengue by region over time. Figure 2 illustrates the yearly prevalence rates of dengue by administrative division over time.

Table 1

Yearly numbers of cases and population-adjusted prevalence rates of dengue by population characteristics in Taiwan, 2010–2015

	Year											
	2010		2011		2012		2013		2014		2015	
	Case number	Prevalence rate (per 100 000 population)	Case number	Prevalence rate (per 100 000 population)	Case number	Prevalence rate (per 100 000 population)	Case number	Prevalence rate (per 100 000 population)	Case number	Prevalence rate (per 100 000 population)	Case number	Prevalence rate (per 100 000 population)
Sex												
Total	1888	8	1700	7	1477	6	857	4	15 705	67	43 832	187
Male	932	8	855	7	746	6	430	4	7827	67	21 838	186
Female	956	8	845	7	731	6	427	4	7878	67	21 994	187
Age group, years												
Total	1888	8	1700	7	1477	6	857	4	15 705	67	43 832	187
0–9	61	3	59	3	31	2	23	1	585	29	1732	85
10–19	157	5	148	5	125	4	79	3	1572	57	4242	160
20–29	284	8	214	6	217	7	134	4	2044	64	5653	177
30–39	302	8	285	7	233	6	167	4	2450	62	6172	157
40–49	290	8	296	8	228	6	118	3	2433	67	5541	153
50–59	370	11	341	10	320	9	142	4	2924	82	7488	208
60–69	226	13	226	12	184	9	121	6	2398	104	6950	278
>70	198	11	131	7	139	8	73	4	1299	67	6054	309

Table 2

Yearly numbers of cases and population-adjusted prevalence rates of dengue by region and administrative division in Taiwan, 2010–2015

Region	Urban/rural	Year											
		2010		2011		2012		2013		2014		2015	
		Case number	Prevalence rate (per 100 000 population)	Case number	Prevalence rate (per 100 000 population)	Case number	Prevalence rate (per 100 000 population)	Case number	Prevalence rate (per 100 000 population)	Case number	Prevalence rate (per 100 000 population)	Case number	Prevalence rate (per 100 000 population)
National		1888	8	1700	7	1477	6	857	4	15 705	67	43 832	187
Northern		196	2	119	1	135	1	173	2	168	2	474	4
Taipei City	Urban	59	2	53	2	41	2	64	2	68	3	157	6
Keelung City	Urban	3	1	3	1	1	0	2	1	1	0	9	2
New Taipei City	Urban	74	2	30	1	43	1	34	1	54	1	146	4
Yilan County	Rural	3	1	2	0	7	2	2	0	1	0	9	2
Hsinchu City	Urban	2	0	1	0	2	0	4	1	5	1	26	6
Taoyuan City	Urban	39	2	24	1	30	1	46	2	27	1	79	4
Hsinchu County	Rural	9	2	2	0	6	1	15	3	7	1	34	6
Miaoli County	Rural	7	1	4	1	5	1	6	1	5	1	14	2
Mid-western		49	1	33	1	40	1	39	1	60	1	191	4
Taichung City	Urban	35	1	22	1	24	1	23	1	47	2	127	5
Changhua County	Urban	9	1	7	1	12	1	9	1	9	1	51	4
Nantou County	Rural	5	1	4	1	4	1	7	1	4	1	13	3
Southern		1639	23	1449	21	1297	18	640	9	15 442	220	43 113	616
Tainan City	Urban	505	27	112	6	754	40	50	3	175	9	22 778	1208
Chiayi City	Urban	4	1	1	0	1	0	0	0	7	1	25	9
Yunlin County	Rural	5	1	2	0	5	1	5	1	11	2	28	4
Chiayi County	Rural	9	2	3	1	1	0	3	1	6	2	38	7
Kaohsiung City	Urban	1099	40	1182	43	531	19	103	4	15 015	540	19 830	714
Pingtung County	Rural	17	2	149	17	5	1	479	56	228	27	414	49
Eastern		3	1	0	0	3	1	3	1	19	3	33	6
Hualien County	Rural	2	1	0	0	1	0	3	1	3	1	16	5
Taitung County	Rural	1	0	0	0	2	1	0	0	16	7	17	8
Outer Islands		1	0	99	47	2	1	2	1	16	7	21	8
Kinmen County	Urban	1	1	1	1	0	0	0	0	0	0	4	3
Lienchiang County	Urban	0	0	0	0	0	0	0	0	0	0	1	8
Penghu County	Urban	0	0	98	101	2	2	2	2	16	16	16	16

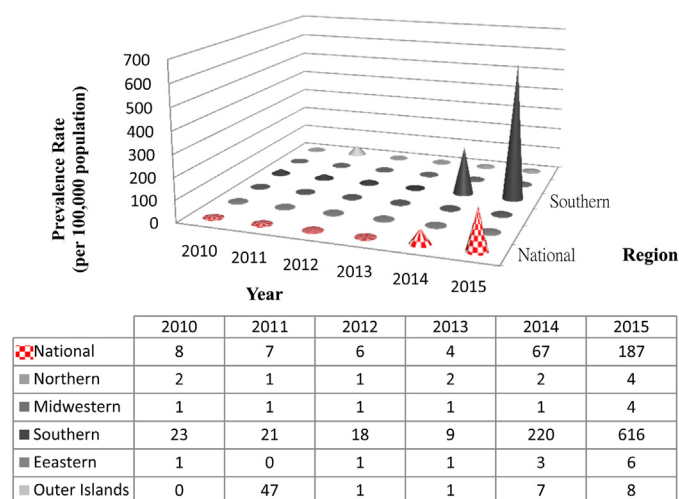


Figure 1. Trend in numbers of reported dengue fever cases per 100 000 population by region in Taiwan over time.

Between 2010 and 2013, the prevalence rates in the southern region were relatively higher than in the other regions (range 9–23 per 100 000 population) except the outer islands in 2011. In particular, the prevalence rates were substantially higher in 2014 (220 per 100 000 population, which was a 24-fold difference compared with 2013) and 2015 (616 per 100 000 population, which was a 68-fold difference compared with 2013). The high rate in the southern region was the main driver of the high national rate for these years. In the southern region, urban areas overall had much higher dengue rates than rural areas during 2010–2015. In 2015, the mean prevalence rate in urban areas within the southern region was 864 per 100 000 population, while it was 23 in rural areas, reflecting a 37-fold difference between them. An exception was Chiayi City; although an urban area, it had a relatively low dengue rate (9 per 100 000 population) as it is geographically surrounded by Chiayi County, which is a rural area. In contrast, Pingtung County, a rural area by population density, had relatively higher prevalence rates in 2011, 2013, 2014, and 2015. In 2015, the prevalence rate in Tainan City (1208 per 100 000 population) was the highest, followed by that in Kaohsiung City (714 per 100 000 population) and Pingtung County (49 per 100 000 population).

The dengue prevalence rate in the outer islands was unexpectedly high in 2011 (47 per 100 000 population). This represented an approximately two-fold higher prevalence than the southern region and 47-fold higher prevalence than in other regions. In particular, a high prevalence rate was found in Penghu County (an urban area with a population density of 827 people/km²): 98 dengue cases, or 101 per 100 000 population. The prevalence rates in the outer islands were also notable in 2014 (7 per 100 000 population) and 2015 (8 per 100 000 population) due to cases occurring in Penghu County (16 per 100 000 population).

Overall, there were three unexpected outbreaks of dengue during the study period. The first outbreak occurred in the outer islands in 2011 (prevalence rate 47 per 100 000 population; Table 2). In particular, Penghu County had a prevalence rate of 101 per 100 000 population in 2011; otherwise there were only between 0 and 16 per 100 000 population cases in this county during the years 2010–2015. The second outbreak of dengue occurred in the southern region in 2014, with a prevalence rate of 220 per 100 000 population; prevalence rates ranged from 9 to 23 per 100 000 population between 2010 and 2013. Kaohsiung City

saw 15 015 cases reported during the outbreak, compared to only 103–1182 per year between 2010 and 2013. The third outbreak of dengue occurred again in the southern region in 2015 with a prevalence rate of 616 per 100 000 population. The urban areas Tainan City and Kaohsiung City were particularly affected, with 22 778 cases (1208 per 100 000 population) and 19 830 cases (714 per 100 000 population) reported, respectively.

4. Discussion

This study assessed the trend in prevalence of dengue in Taiwan. The strengths of the study include the use of recent data: the most recent years (up to 2015) were examined. These data have not yet been reported in published articles. Furthermore, population-adjusted dengue prevalence rates are reported by sex, age group, and geographic region. Understanding the prevalence of dengue and its longitudinal trends can inform how prevention and control strategies might best be targeted.

The epidemiology of dengue in Taiwan differs from that in other countries of Southeast Asia. In most parts of Southeast Asia, the majority of dengue cases are found in children.⁸ This study and previous studies on dengue in Taiwan found that the majority of dengue-affected people were older, and the prevalence rate appeared to increase with increasing age. The possible reasons for this might be that during dengue outbreaks, young children spend most of the daytime in enclosed air-conditioned environments (e.g., their homes, day care centers, and schools) and therefore are less likely to be exposed to mosquitoes.⁹ On the other hand, reporting of dengue may be more likely among older people with chronic diseases who may more often visit the doctor and therefore are more likely to have an existing dengue infection detected, especially if they have a severe infection.¹⁴

The southern region had the highest yearly dengue prevalence rate over time, and it was 166-fold and 145-fold higher than in the other regions in Taiwan in 2014 and 2015, respectively. Based on the subgroup analysis of administrative divisions within the southern region, it was found that Tainan City, Kaohsiung City, and Pingtung County had the highest dengue prevalence rates during the study period. These results suggest that, in general, urban areas located in the southern region in Taiwan have the highest prevalence rates, possibly due to a combination of factors including a high population density (which may influence the dengue prevalence rate^{15,16}), the tropical climate, and the presence of *Aedes aegypti* mosquitoes. Although Pingtung County is a rural area, it had relatively high dengue rates due to its geographical location (the southern-most division in Taiwan with a typical tropical climate).

There are two common types of *Aedes* mosquito in Taiwan: *A. aegypti* and *Aedes albopictus*, and they have different habitual behaviors.^{15–18} *A. aegypti* is responsible for most dengue epidemics because the human is the only host for *A. aegypti*, whereas *A. albopictus* can feed on humans and animals.^{19,20} *A. aegypti* is mainly active indoors,^{21,22} while *A. albopictus* is mainly active outdoors.^{18,22,23} *A. aegypti* breeds predominantly in urban areas, while *A. albopictus* exists more frequently in rural areas.^{18,24} In addition, *A. aegypti* appears only in the south of the Tropic of Cancer regions, i.e. north of Chiayi County and Hualien County regions in Taiwan, while *A. albopictus* is typically distributed in the north of the Tropic of Cancer regions.¹⁸ Consistent with previous studies,¹⁸ it was found that dengue outbreaks occur mainly in southern Taiwan where *A. aegypti* is found; these outbreaks rarely occur in central, northern, and eastern Taiwan where only *A. albopictus* is found.^{1,25}

Three outbreaks of dengue were observed of the 6-year study period. The exact reasons for these outbreaks are not known. In terms of the first outbreak, which occurred in Penghu County in

2011, dengue was likely transmitted by people coming from other neighboring regions with higher prevalence rates of dengue compared with other divisions, especially from Kaohsiung City and Pingtung County. For instance, it could have been imported by travelers, because Penghu is a small sightseeing island and is geographically near Kaohsiung City and Pingtung County located on the main island. After the outbreak, dengue rates in Kaohsiung City, Pingtung County, and Penghu County dropped back substantially in 2012 and 2013.

The second outbreak occurred in Kaohsiung City in 2014. This outbreak might have been due to the natural gas explosion incident in Kaohsiung City on August 1, 2014. In addition, the summer in Kaohsiung City in 2014 had record-setting high temperatures and heavy rains.²⁶ While there were already hundreds of dengue cases reported before the gas explosion, the incident likely exacerbated dengue rates. After the explosion, stagnant pools of rainwater would have appeared in many of the destroyed buildings, creating an ideal environment for *Aedes*

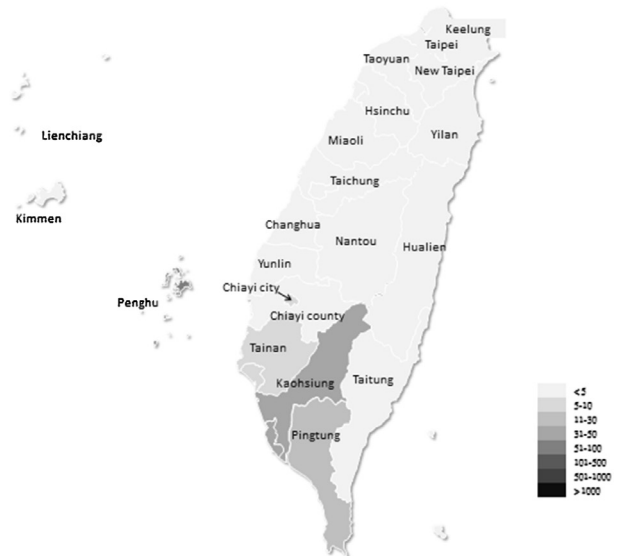
mosquitoes.^{27–30} With regard to the third outbreak in 2015, Tainan City was the original division of the outbreak and it had the highest prevalence rate of dengue. The reasons for this outbreak may include geographical location, high population density, inhabitation of *A. aegypti*, and inadequate control of dengue outbreaks. After the initial stage of this outbreak in Tainan City, the case number and prevalence rates also increased in Kaohsiung City due to the spread of DENV from its neighbor, Tainan City.

This study had some limitations. First, data from the Taiwan CDC dengue database were used; thus information was available only for dengue cases that had been reported. If dengue-infected individuals did not visit clinics or other medical institutions, this infection information would not have been captured in the CDC database. The study may, therefore, have underestimated the dengue prevalence. Nonetheless, because dengue is a communicable disease and physicians are required to report suspected dengue cases to the Taiwan CDC, it is likely that the database captured the majority of identified dengue cases. Second, the CDC

2010



2011



2012



2013

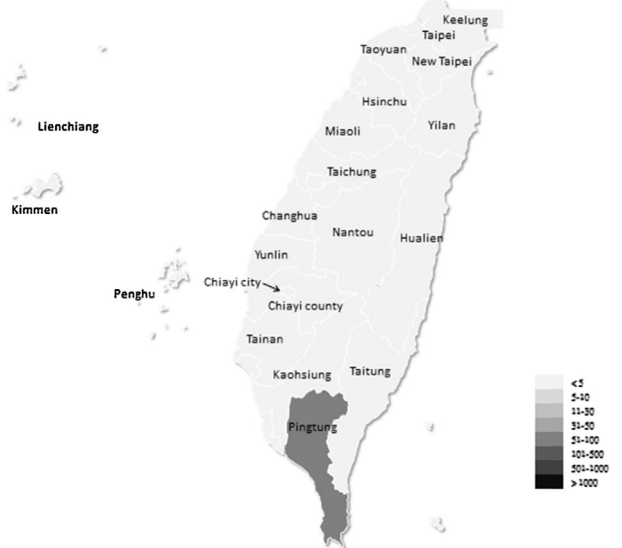


Figure 2. Yearly numbers of dengue fever cases per 100 000 population by administrative division in Taiwan.

2014

2015

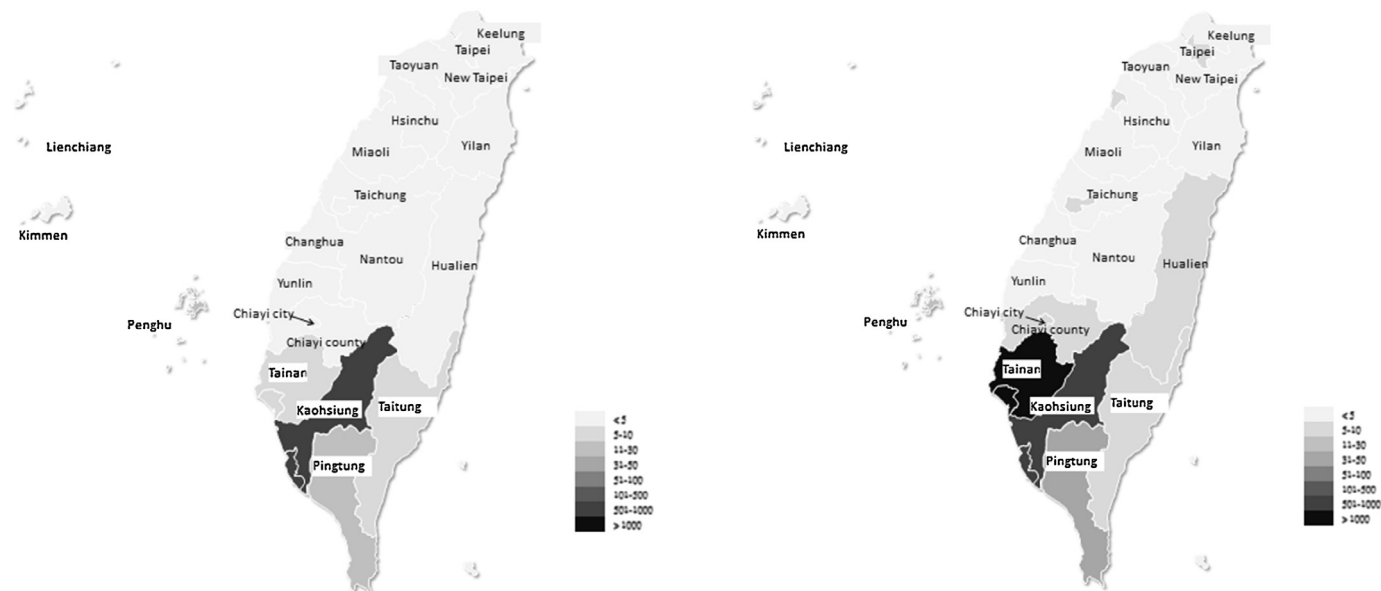


Figure 2. (Continued).

public statistics database does not contain information on the more detailed geographic distribution of cases in each administrative division (for indirectly grouping areas into city, urban, and rural areas), outcomes of cases, dengue serotypes, and entomology data relating to mosquito surveillance in each region. Thus, the dengue cases and their outcomes could not be analyzed further (e.g., by dengue serotype) in this study. Third, the origin of the dengue outbreaks is unknown. It is assumed that the outbreaks initiated in the regions (administrative divisions) with the highest numbers of cases and prevalence rates.

These results suggest that more efforts are still needed for dengue prevention and control, particularly for older people and in the southern region of Taiwan, especially highly populated areas. Strategies are also needed to respond quickly to unexpected incidents, such as the gas explosion in Kaohsiung City, to prevent dengue outbreaks. Prevention strategies for mosquito breeding and other environmental policies should be strengthened (e.g., use of mosquito nets, repellent, cleaning up stagnant water).

It is important to note that Taiwan has begun working with the USA in developing the world's first dengue vaccine for older people.³¹ The dengue vaccine developed by the US National Institutes of Health has entered into clinical trials in the USA, Brazil, Thailand, and Bangladesh.^{32,33} The trial findings suggest that the vaccine confers 50–100% protection from all four serotypes of DENV.^{34–36} In addition, early in 2016 the vaccine entered a phase 3 trial in Brazil, and just recently the vaccine entered a phase 1 trial in the USA for people aged 50 years and above. Due to the huge outbreak of dengue in Taiwan in 2015, which posed an increased threat to older people, the government of Taiwan is fully supporting a clinical trial of the dengue vaccine for 250 older people in Taiwan.³¹ The research data generated from this clinical trial will be extremely valuable and Taiwan intends to make such data public to help contribute to global disease prevention. Once the vaccine becomes available in Taiwan, populations with risk factors should be the priority; risk factors include older age group, living in southern Taiwan (especially in urban areas like Kaohsiung City and Tainan City), patients experiencing a secondary DENV infection that has a different serotype from the previous one, and health care professionals working in hospitals.

In conclusion, dengue commonly occurs in Taiwan and other countries in the tropical region. This study examined the trends and the prevalence of dengue in Taiwan over the past 6 years. Based on these results, urban areas located in the southern region of Taiwan have the highest prevalence rates due to high population density, the tropical climate, and the presence of *A. aegypti* mosquitoes. Older people are more likely to be infected compared with younger children. Factors that may indirectly contribute to dengue infections include natural disasters, travelers, and unhygienic environments. More effective and efficient strategies for dengue control and prevention are needed in Taiwan.

Funding and data sharing: This study received no funding. We obtained 2010–2015 dengue and population data from public statistics databases of the Taiwan Centers for Disease Control and Department of Statistics, Taiwan Ministry of Interior. The authors had full access to all of the data in the study and had final responsibility for the decision to submit for publication.

Conflict of interest: All authors declare no competing interests.

Appendix

Classification of regions in this study

Region	Population	Area (km ²)	Population density (km ²)	Urban/rural
National	23 492 074	34 996	671	
Northern	11 151 470	8886	1255	
Taipei City	2 704 810	261	10 369	Urban
Keelung City	372 105	130	2854	Urban
New Taipei City	3 970 644	1981	2004	Urban
Yilan County	458 117	2117	216	Rural
Hsinchu City	434 060	103	4228	Urban
Taoyuan City	2 105 780	1180	1785	Urban
Hsinchu County	542 042	1370	396	Rural
Miaoli County	563 912	1744	323	Rural
Mid-western	4 543 007	7115	638	
Taichung City	2 744 445	2098	1308	Urban
Changhua County	1 289 072	1043	1235	Urban
Nantou County	509 490	3974	128	Rural
Southern	6 995 550	10 759	650	
Tainan City	1 885 541	2114	892	Urban
Chiayi City	270 366	58	4671	Urban
Yunlin County	699 633	1317	531	Rural

Appendix (Continued)

Region	Population	Area (km ²)	Population density (km ²)	Urban/rural
Chiayi County	519 839	1880	277	Rural
Kaohsiung City	2 778 918	2858	972	Urban
Pingtung County	841 253	2532	332	Rural
Eastern	554 397	7946	70	
Hualien County	331 945	4473	74	Rural
Taitung County	222 452	3473	64	Rural
Outer Islands	247 650	290	853	
Kinmen County	132 799	149	890	Urban
Lienchiang County	12 547	17	723	Urban
Penghu County	102 304	124	827	Urban

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