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Epidemiology of imported travelers with dengue fever in Taiwan from 2011 to 2020

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Abstract

We collected data on imported dengue cases between 2011 and 2020 from Taiwan's Centers for Disease Control to determine changes in the case number and importation rate of dengue. We used open data provided by Taiwan's Centers for Disease Control to extract the number of confirmed imported cases of dengue between 2011 and 2020. From 2011 to 2020, 2883 imported cases of dengue were reported in Taiwan. The importation rate was 25.8 to 46.4 per 100,000 inbound travelers from 2011 to 2020, peaking in 2020. Disease incidence varied between sexes, age groups, seasons ($P < .001$), and residence from 2011 to 2020. Numerous dengue cases were imported from Indonesia (548 cases), Vietnam (516 cases), and the Philippines (500). For travelers from Taiwan, the risk ratio of becoming infected by dengue was 31,712 for traveling to the Maldives, 3153 to Cambodia, and 996 to Myanmar. In this study, more serotype 1 and 2 strains were reported by Vietnam, and more serotype 3 and 4 strains were reported by Indonesia. Our data indicate that the rate of imported cases of dengue significantly increased annually from 2011 to 2020 in Taiwan, especially during the COVID-19 pandemic (46.4 per 100,000 inbound travelers).

Abbreviations: CI = confidence interval, OR = odds ratio, RR = risk ratio, TNIDSS = Taiwan National Infectious Disease Statistics System.

Keywords: dengue fever, environment, epidemiology, imported, retrospective study

1. Introduction

Dengue fever is an acute infectious disease caused by the dengue virus,[1,2] which is transmitted to humans by *Aedes* mosquitoes. It causes 10,000 deaths per year[3] and is the largest burden of all arboviral diseases; an estimated 100 million people globally experience symptomatic infections annually.[4] Since 2000, the number of dengue fever cases reported to the World Health Organization has increased by more than 8 fold, from 0.5 million in 2000 to >2.4 million in 2010 and 4.2 million in 2019,[5] with estimates that more than 6.1 billion people may be at risk of dengue fever by 2080.[5]Currently, dengue fever is prevalent in more than 100 countries in Africa, the Americas, the Eastern Mediterranean, Southeast Asia, and the Western Pacific region.[6] The Americas, Southeast Asia, and the Western Pacific region were the most affected, of which Asia accounted for 70% of the global disease burden.[7]

International studies have noted that the transmission cycle of dengue virus between humans and *Aedes* mosquitoes is the main path of transmission,[8] but in West Malaysia and West Africa, the transmission cycle can also involve monkeys; this is known as the forest transmission cycle.[9] Mosquitoes that transmit dengue fever are mainly *Aedes aegypti* and *Aedes albopictus*.[10,11] Studies in the Republic of Trinidad and Tobago and Thailand have discovered that *A aegypti* can transmit dengue virus to the next generation through its eggs, but the positive rate was low (1/158 and 2/100, respectively).[12,13] Dengue virus has also been isolated from male mosquitoes in West African forests, thus demonstrating that dengue virus can be transmitted through eggs. In addition, women infected with dengue fever may vertically transmit dengue virus to the fetus during pregnancy or childbirth, resulting in premature birth, low birth weight, and fetal death.[14] Dengue virus may also be transmitted through infected blood (e.g., blood transfusion, organ transplantation, and needle sharing)[15] or sexual intercourse,[16] but transmission through these methods is extremely rare.

Dengue virus can be divided into 4 serotypes, namely I, II, III, and IV, each of which is infectious and pathogenic.[17] Patients infected with any serotype of dengue virus will have lifelong immunity to that serotype but only transient immunity to other serotypes; thus, reinfection with other serotypes can occur.[18] Clinically, repeated infection with different serotypes of dengue virus can cause different degrees of host response, ranging from mild or insignificant symptoms to typical symptoms such as sudden high fever (≥38°C), headache,

Y-CC and C-PY contributed equally to this work.

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The datasets generated during and/or analyzed during the current study are not publicly available, but are available from the corresponding author on reasonable request.

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pain behind the eyes, muscle pain, arthralgia, and rashes or to warning signs such as lethargy, restlessness, liver enlargement, and severe dengue fever that may lead to severe bleeding or organ damage. Mortality can be as high as 20% without prompt medical treatment.[19]

Taiwan is located at 23°4'N and 121°0'E and has a subtropical climate. The average monthly temperature and relative humidity range from 16°C to 29°C and 75% to 90%, respectively. Taiwan is a developed country with an estimated per capita gross domestic product of US$32,625 in 2022 (see Supplemental Digital Content, http://links.lww.com/MD/O242).[20] Dengue-related cases persist in Taiwan,[21] suggesting that preventive measures to restrict or eliminate the disease have had limited effects. In Taiwan, both local and imported dengue fever cases are reported throughout the year. However, few studies have used big data to explore disease risk associated with imported dengue cases and epidemiological information on the distribution of virus types in Taiwan. To fill this knowledge gap, we used the Taiwan National Infectious Disease Statistics System (TNIDSS)[22] to explore the correlation between the number of imported dengue fever cases from 2011 to 2020 in terms and sex, age, season, residential area, epidemiological characteristics, epidemic trends, environmental factors, and the distribution of virus types.

2. Materials and methods

2.1. Ethics statement

All case data are freely available online, with information regarding imported dengue fever cases found on the Taiwan Centers for Disease Control website.[22] This study was deemed unnecessary for ethics approval according to the Communicable Disease Control Act[23] of Taiwan because of the use of processed data sets without any personal identifiers and did not involve any of the open data sets in such a way that individuals might be identified, where the data are properly anonymized. Although no personal identifiers were involved and no individuals were harmed by the study, institutional research guidelines were followed to ensure scientific soundness.[24,25]

2.2. Data source

We used the TNIDSS public network database,[22] which included all notifiable communicable diseases in categories 1 to 5 (e.g., dengue fever) specified by the Communicable Disease Control Act. The provision of these data has maintained the transparency and currency of Taiwan's disease information. To ensure information security and prevent personal information leaks, the TNIDSS does not store personal information and stores only secondary statistics. These statistics enable the public, researchers, and the press to access current information on dengue fever in Taiwan at any time. Dengue fever was categorized as a category-2 notifiable communicable disease by the central competent authority of Taiwan in 1998. The present study collected the following data from the TNIDSS: date when confirmed cases of dengue fever were reported to the health department, date of symptom onset, date of case confirmation, number of confirmed imported cases, and patients' location, age, and sex. The database does not contain patients' medical histories, signs, and symptoms. Furthermore, this study indicated that imported cases of dengue fever entered in Taiwan by any means of transport.

2.3. Clinical conditions

Clinical conditions are as follows. Sudden fever ≥38°C accompanied by any 2 of the following symptoms: headache/pain behind the eyes/muscle pain/arthralgia/bone pain; rash; leukopenia; nausea/vomiting; positive tourniquet test; and any warning sign (e.g., abdominal pain and tenderness, persistent vomiting, ascites or pleural effusion, mucosal bleeding, drowsiness/restlessness, liver enlargement 2 cm below the rib, and hematocrit increase with rapid decline in platelet count).[26]

2.4. Examination conditions

A patient with any of the following test results is considered to have a positive test result: dengue virus is isolated and identified from clinical specimen (blood); nucleic acid test of the clinical specimen is positive; serological antigen (referring to nonstructural protein 1 of dengue virus) is positive; positive dengue virus-specific immunoglobulin M or G antibody in the acute phase serum (or initial test) is found; and dengue virus-specific immunoglobulin M or G antibody has a positive conversion or a ≥4-fold increase in the paired serum (recovery and acute phases).[26]

2.5. Definition of dengue notified case

Those who meet the clinical conditions.[26]

2.6. Definition of dengue confirmed case

Those who meet the first, second, third, or fifth item of the definition of positive test results are considered a confirmed case of dengue. Clinicians can also use the patient's epidemiological conditions (e.g., having positive dengue fever cases near home or range of activities and having a history of travel to dengue fever-endemic areas) to assist in the diagnosis of dengue fever.[26] This study merely stating what criteria meet a confirmed case where the "confirmed" status must have been done at the individual level by public health officials.

2.7. Data analysis and statistical methods

The research structure of this study is based on a retrospective historical study of all the local dengue cases from 2011 to 2020. We determined the number of dengue fever cases from 2011 to 2020 and examined the differences and trends in the distribution of their epidemiological characteristics. We used the numbers for categorical variables to present their epidemiological features and dengue infections (including viral serotype types I, II, III, and IV) in each year, respectively. Chi-square tests or Fisher exact tests (while any expected numbers in cells were <5) were used to examine the differences in the distributions of the categorical variables. To estimate the effect of different features of epidemiology (e.g., men vs women, <20 vs ≥20 years old, spring vs nonspring, northern residency vs nonnorthern residency) and viral serotypes (e.g., dengue viral serootype I vs other dengue viral serotypes) on the risk of different calendar years (e.g., in 2011 vs other years [a sum of the numbers of other years]), the logistic model was estimated with odds ratios (ORs) and 95% confidence intervals. A 2-tailed P value <.05 was considered statistically significant. All statistical analyses were performed using SPSS v21 (IBM; Asia Analytics Taiwan, Taipei, Taiwan).

3. Results

From 2011 to 2020, 2883 imported cases of dengue were reported in Taiwan. A detailed flowchart is shown in Figure 1. Table 1 presents the patients' sociodemographic characteristics. The mean age was 39.9 years (standard deviation = 13.3), and the median age was 40 years (range: 3–70 years). Most patients (2559/2883, 89%) were older than 20 years of age.

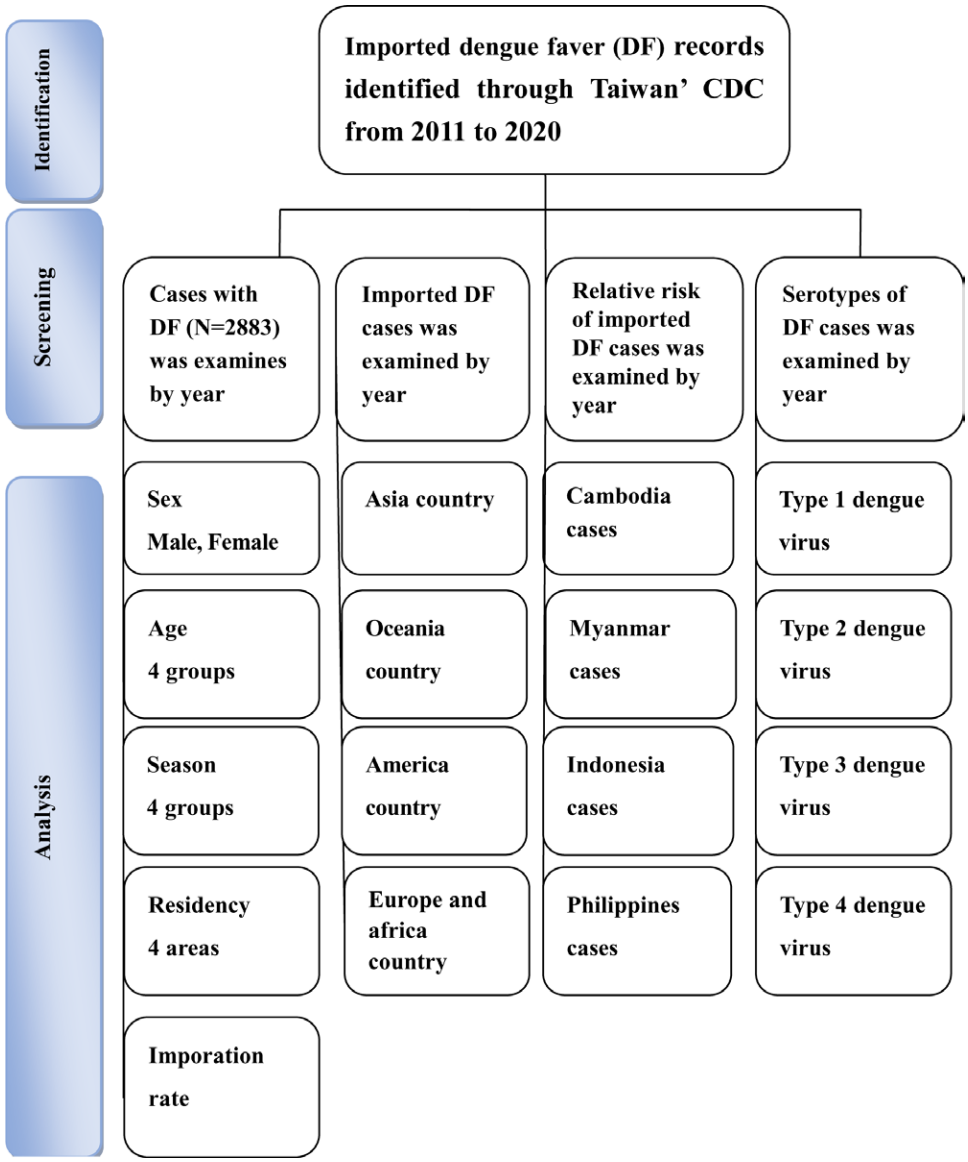

Figure 1. Flowchart of the study sample selection from Taiwan Centers for Disease Control Database in Taiwan during January 2011 and December 2020. DF = dengue fever.

The male-to-female ratio was 1.3 (1637/1246) to 1. Most cases occurred in summer (1015/2883, 35.2%), followed by fall (817/2883, 28.3%). Most patients for residency were northern area (1590/2883, 55.2%), followed by southern area (736/2883, 25.5%) in Taiwan. The highest annual number of dengue cases occurred in 2019 (540 cases) and the lowest in 2020 (64 cases). Disease incidence varied between sex, age groups, season ($P < .001$), and residence from 2011 to 2020. Risk factors were summer in 2013 (OR = 1.605), fall in 2015 (OR = 1.537), and winter in 2020 (OR = 7.370).

The annual number of cases of dengue fever reported by region of likely acquisition in Taiwan, 2011 to 2020 (Table 2). Most imported cases were from other Asian countries (2843/2883, 98.6%). Among the 2883 imported cases for which the region of infection was known, the highest was from travelers from Indonesia (548, 19.6%), followed by those from Vietnam (516, 18.4%), the Philippines (500, 17.8%), Malaysia (340, 12.1%), Thailand (320, 11.4%), Cambodia (213, 7.6%), Myanmar (124, 4.4%), Singapore (94, 3.4%), India (69, 2.5%), the Maldives (42, 1.5%), and China (36, 1.3%). For travelers from Taiwan, the risk ratio of becoming infected by dengue fever was 31,712 when they traveled to the Maldives, 3153 for Cambodia, 996 for Myanmar, 240 for Indonesia, 184 for the Philippines, 182 for India, 179 for Vietnam, 133 for Thailand, 63 for Malaysia, and 20 for Singapore compared with the risk for traveling to China (Table 3).

Of the 2819 cases, serotypes 1 and 2 accounted for 493 (17.5%) each; serotype 3, 239 (8.5%); serotype 4, 178 (6.3%); and unspecified serotype, 1416 (50.2%). Stratified by year, the highest annual number of cases of dengue serotype 1 was 90 in 2019; serotype 2, 147 in 2019; serotype 3, 60 in 2019; and serotype 4, 38 in 2019 (Table 4). The numbers of dengue serotypes varied between 2011 and 2020 ($P < .001$). Risk factors of infected dengue were dengue serotype 1 in 2018 (OR = 1.365), serotype 2 in 2019 (OR = 2.090), serotype 3 in 2019 (OR = 1.466), and serotype 4 in 2012 (OR = 1.872). Among the 2819 cases for which both the region of acquisition and the infecting serotypes were known, dengue serotypes 1 and 2 each accounted for 22.5% (111/493) of the infections acquired in Vietnam, serotype 3 accounted for 35.6% (85/239) of the infections acquired in Indonesia, and serotype 4 accounted for 20.9% (55/178) of the infections acquired in Indonesia (Table 5).

Table 1

Epidemiological features of imported with dengue fever in Taiwan during 2011–2020.

Variables	Overall	Year										*P*
		2011	2012	2103	2104	2015	2016	2017	2018	2019	2020	
Sex												
Male	1637	94	118	143	141	199	193	198	204	307	40	.682
Female	1246	63	89	121	99	166	170	135	146	233	24	
Age group												
<20	324	18	32	31	19	34	45	31	40	68	6	.199
20–39	1594	87	101	156	146	198	193	187	184	300	42	
40–59	733	37	59	62	60	111	91	88	89	123	13	
>60	232	15	15	15	15	22	34	27	37	49	3	
Season												
Spring	429	10	44	34	46	59	58	37	44	85	12	<.001
Summer	1015	68	86	120*	66	88	134	124	115	208	6	
Fall	817	45	41	55	83	133†	88	98	125	145	4	
Winter	622	34	36	55	45	85	83	74	66	102	42‡	
Residency												
Northern	1590	89	121	164	124	195	200	196	185	284	32	.401
Central	522	29	40	38	39	64	67	64	71	99	11	
Southern	736	39	44	59	75	99	90	72	89	148	21	
Eastern	35	0	2	3	2	7	6	1	5	9	0	

CI = confidence interval, OR = odds ratio.

*OR = 1.605, 95% CI = 1.243–2.072, $P < .001$

†OR = 1.537, 95% CI = 1.221–1.936, $P < .001$

‡OR = 7.370, 95% CI = 4.365–12.444, $P < .001$

Table 2

The annual numbers of dengue fever reported by region/country of likely acquisition in Taiwan during 2011–2020.

Region/country	Overall	Year									
		2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Asia											
Indonesia	548	25	45	71	58	81	113	27	29	78	21
Vietnam	516	34	30	17	9	57	44	104	68	140	13
Philippines	500	34	74	38	33	54	73	39	61	81	13
Malaysia	340	13	14	26	71	58	44	42	36	31	5
Thailand	320	21	20	63	10	42	35	42	37	45	5
Cambodia	213	8	10	7	3	11	14	8	69	81	2
Myanmar	124	4	5	9	10	24	10	29	11	20	2
Singapore	94	4	1	10	12	14	17	10	8	16	2
India	69	8	4	10	3	6	1	13	9	15	0
Maldives	42	0	0	0	0	4	6	7	11	14	0
China	36	0	0	3	23	2	1	1	3	3	0
Sri Lanka	15	0	0	4	0	2	0	1	4	3	1
Bangladesh	13	6	2	0	2	0	0	3	0	0	0
Laos	7	0	0	2	0	1	1	1	1	1	0
Nepal	4	0	0	0	0	0	0	0	0	4	0
Japan	1	0	0	0	1	0	0	0	0	0	0
Saudi Arabia	1	0	0	0	1	0	0	0	0	0	0
Oceania	19	0	2	2	3	3	3	3	0	3	0
America	16	0	0	2	0	5	0	3	2	4	0
Europe	1	0	0	0	1	0	0	0	0	0	0
Africa	4	0	0	0	0	1	10	0	1	1	0

TDCD implements fever screening and quarantine measures for inbound travelers who enter Taiwan on ships, aircraft, and other means of transportation. From 2011 to 2020, 81, 89, 115, 118, 155, 152, 154, 148, 241, and 39 confirmed cases of imported dengue fever, respectively, were identified by fever screening at points of entry (Table 6).

Figure 2 shows the number of suspected and imported cases of dengue and the proportion of imported cases of dengue from January 2011 through December 2020. The annual number of suspected cases of dengue ranged from 305 in 2011 to 1718 in 2019 and 231 in 2020; the annual number of imported cases of dengue cases ranged from 157 (25.8%) in 2011 to 540 in 2019 and 64 (46.4%) in 2020. Thus, the proportion of imported cases increased significantly from 2011 to 2020, with a 79.8% increase in 2020 compared with 2011.

4. Discussion

Dengue fever is mainly concentrated in tropical and subtropical countries, where *A aegypti* and *A albopictus* are distributed. Although dengue fever has never been declared a public health emergency of international concern, it is the most common arboviral disease in tropical and subtropical regions of the world and is expected to increase in intensity and geographic extent.

Furthermore, dengue fever is the only mosquito-borne viral disease whose incidence has continued to increase since 2000, surpassing malaria on all continents except Africa.[27] According to the Global Burden of Diseases Study 2019, the global, regional, and national burden of the dengue fever from 1990 to 2019 revealed that the proportion of deaths in the 15- to 49-year age group in 2019 exceeded that in the 0- to 5-year age group in 1990.[28] The global land-ocean temperature index and air travel passenger index were significantly correlated with dengue fever burden in the context of urbanization, warming climate, and increased tourist mobility in most parts of the world.

With globalization and the increasing convenience of travel, the mutual circulation between countries and use of air travel and cruises have increased. This led dengue fever to spread to various countries, particularly after the 1980s, thereby becoming a serious global public health problem. In Southeast Asia, the annual morbidity rate increased from an average of 50 dengue cases per 1000 returning travelers in nonepidemic years to an average of 159 per 1000 returning travelers in epidemic years.[29] According to a time-series forecast analysis in Spain, the incidence of imported dengue fever is expected to continue to increase, with an estimated increase of 65% by 2025 in the worst-case scenario.[30] Dengue fever also occurs now in places where dengue was not normally detected. For instance, in Nepal, an outbreak of dengue fever occurred through infection by international hikers[31] in the Republic of Senegal, a local dengue fever outbreak also occurred during the pilgrimage to Grand Magal of Touba.[32] In Australia, because of its vast territory and various geographical tourist attractions, dengue is imported by tourists, and local dengue fever outbreak occurs.[33]

Table 3

Travel destination of 2802 imported cases of dengue fever in Taiwan during 2011–2020.

Country of destination	No. cases (%)	No. of air passengers (100,000)	RR
China	36	271.82	Reference
Indonesia	548	17.27	240
Vietnam	516	21.74	179
Philippines	500	20.52	184
Malaysia	340	40.53	63
Thailand	320	18.20	133
Cambodia	213	0.51	3153
Myanmar	124	0.94	996
Singapore	94	35.32	20
India	69	2.87	182
Maldives	42	0.01	31,712

RR = risk ratio.

Taiwan is located in the subtropical region, which is the most preferred growth environment for *Aedes* mosquitoes and is thus a high-risk area for dengue fever. Dengue fever is not endemic to Taiwan.[34] A Taiwanese study identified a possible relationship between the period of disease concealment and the number of imported dengue cases, which resulted in epidemics of domestic dengue fever in local communities.[34] It also suggested that once the dengue virus is imported into Taiwan through travel, it is highly likely to cause a local epidemic. Thus, the prevention of disease importation and efficient identification of dengue cases within high-risk communities remain major priorities for control in Taiwan.

From 2011 to 2020, dengue fever occurred mostly in northern cities in Taiwan (e.g., Taipei metropolitan area), accounting for 55.2% of imported cases. Dengue fever is closely related to population density and mobility as well as to economic and traffic development.[35–38] The Taipei metropolitan area has a much smaller area but a larger population; it also has a much more developed economy. Because of the different spatial locations and social conditions, the Taipei metropolitan area had a much higher average yearly incidence of imported dengue fever during 2011 to 2020.

A study indicated that southern provinces of China (e.g., Guangdong and Yunnan) had similar seasonal patterns for dengue fever, with a longer peak period in Guangdong province. They also had similar seasonal patterns for temperature and rainfall.[39] Dengue fever is closely related to climatic factors, such as temperature and rainfall.[37,38,40] Yunnan province borders a torrid zone, with an annual rainfall of 800 to 1600 mm. The southern region of Guangdong province of China borders a subtorrid zone, with an annual rainfall of >1600 mm. These similar climates are responsible for the similar seasonal patterns of indigenous dengue fever in China.[41] However, dengue fever from these provinces is imported into Taiwan by travelers, increasing Taiwan's medical burden and local risk of infection. This study suggested that the importation of dengue fever is closely related to the economy, population migration, business, and travel and that Taiwan has numerous sources of imported dengue fever.

A strong male predominance was noted in the imported cases. Moreover, most dengue cases (80.7%) were among individuals aged 21 to 59 years. This might reflect a population of young working men who tend to travel more domestically and regionally and thus have more exposure risk to dengue.[42] In addition, imported cases occurred across all age groups in Taiwan, which is different from the pattern in other Southeastern Asian countries, where most dengue cases occur among children or younger adults.[43] This is probably because dengue is endemic to Southeastern Asian countries, so their populations, particularly the adults and older adults, have higher rates of immunity.[44–46] Furthermore, most of the imported cases to Taiwan

Table 4

Association between the serotypes of dengue virus and annual dengue cases by Chi-square test and logistic regression analysis.

		Year									
Seroypes	Overall	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	*P*
Type 1	493	34	44	50	52	46	53	48	76†	90	34	<.001
Type 2	493	37	35	33	40	50	34	38	79	147‡	15	
Type 3	239	15	17	18	22	21	38	21	27	60§	5	
Type 4	178	13	22¶	16	9	18	15	20	27	38	4	
Unspecified	1416	58	89	147	117	230	223	206	141	205	79	

CI = confidence interval, OR = odds ratio.

†Cases with dengue type 1 virus infection (OR = 1.365, 95% CI = 1.037–1.797, $P = .027$) in 2018 compared with other years.

‡Cases with dengue type 2 virus infection (OR = 2.090, 95% CI = 1.675–2.607, $P < .001$) in 2019 compared with other years.

§Cases with dengue type 3 virus infection (OR = 1.466, 95% CI = 1.077–1.997, $P = .015$) in 2019 compared with other years.

¶Cases with dengue type 4 virus infection (OR = 1.872, 95% CI = 1.169–2.998, $P = .009$) in 2012 compared with other years.

Table 5

The serotypes of dengue virus reported by region/country of likely acquisition in Taiwan during 2011–2020.

		Dengue virus senotype				
Region/country	**Overall N = 2819**	**Type 1 N = 493**	**Type 2 N = 493**	**Type 3 N = 239**	**Type 4 N = 178**	**Unspecified N = 1416**
Asia						
Indonesia	527	71	87	85	55	250
Vietnam	503	111	111	3	39	252
Philippines	487	61	57	79	42	261
Malaysia	335	76	68	25	9	162
Thailand	315	44	68	16	14	178
Cambodia	211	64	44	1	9	95
Myanmar	122	19	13	14	8	70
Singapore	92	20	20	7	1	46
India	69	11	12	9	1	36
Maldives	42	3	14	3	1	21
China	36	7	1	0	0	28
Sri Lanka	14	3	2	0	0	10
Bangladesh	13	3	1	1	0	8
Laos	7	1	2	0	0	4
Nepal	4	0	1	0	0	3
Japan	1	0	0	0	0	1
Saudi Arabia	1	0	0	0	0	1
Oceania						
Papua New Guinea	4	1	0	0	1	2
Solomon Islands	3	0	0	1	0	2
Fiji	1	0	0	0	0	1
Nauru	2	0	0	0	0	2
Tuvalu	1	0	1	0	0	0
Australia	3	0	0	0	0	3
Palau	2	0	2	0	0	0
Polynesia	1	1	0	0	0	0
Marshall Islands	2	0	0	0	0	2
Africa						
South Africa	1	0	0	0	0	1
Kenya	1	0	1	0	0	0
Nigeria	2	0	1	0	0	1
America						
Brazil	6	3	0	0	1	2
Saint Lucia	1	0	0	0	1	0
Costa Rica	1	1	0	0	0	0
Mexico	2	0	0	0	0	2
Ecuador	1	0	0	0	0	1
Cuba	3	1	1	0	0	1
Honduras	1	0	1	0	0	0
Belize	1	1	0	0	0	0
Europe						
France	1	0	0	0	0	1
Total						

were from businessmen. Attempts should be made to increase the level of knowledge of dengue prevention among businessmen to reduce the number of imported dengue fever cases in Taiwan. This study analyzed the imported cases of dengue fever, and suggested that it was less related to the local vector mosquitoes in Taiwan. Furthermore, this study analyzes the imported cases of dengue fever, and the northern part of Taiwan (Taipei) is a political and economic center and a large concentration of passengers from overseas, suggested that the number of cases of dengue fever is the largest in Taipei metropolitan area.

Studies have reported that 93.9% of the imported cases to Taiwan are from 9 Southeast Asian countries, where dengue fever is more endemic,[47–50] which is similar to our results; 98.6% of cases were from 10 Southeast Asian countries, mostly from Indonesia, Vietnam, and the Philippines. A study indicated that domestic dengue outbreaks were triggered by imported cases.[51] According to Taiwanese literature,[52] imported dengue cases were clustered in outbreaks similarly to those in Taoyuan City of Taiwan. Therefore, stakeholders should focus on disease prevention and on monitoring the northern areas of Taiwan, especially Taoyuan City. Furthermore, mosquito-borne exposure is highly prevalent; it occurs when travelers with dengue fever arrive in Taiwan and are bitten by mosquitoes or when mosquitoes are transported to dengue-free areas by flight. By the end of 2016, 291,964 outbreak-associated dengue cases had been reported in previous literature, mainly from China (27.9%), Singapore (27.0%), and Malaysia (15.1%).[53] In developed countries, dengue fever is commonly observed in travelers and immigrants.[54] Our study had a similar finding; travelers from dengue-endemic areas had a higher rate of importing dengue fever to Taiwan. Another study indicated that approximately half of the cases of imported dengue fever in developed countries were from travelers who had been in Asia.[39] This study suggested that immigration, foreign workers, and the increased international movement of people have increased the incidence of this disease, which also leads to an increase in incidence among local Taiwanese populations.

Our study indicated that travel to endemic countries was a risk factor for dengue fever. In 2012, the number of international

Table 6

Statistic of CDC "Communicable Diseases Survey Form" during 2011–2020, Taiwan.

		Cases with fever symptom		Cases sample taking of notifiable disease					
Variables	Person time of inbound passengers	Case number	Case percentage (%)	Case number	COVID-19 number	Dengue fever case number	Chikungunya fever case number	ZIKA virus infection case number	Malaria case number
2011	15,648,884	14,930	0.10	-	-	81	1	-	1
2012	17,491,283	14,556	0.08	-	-	89	1	-	-
2013	19,072,276	12,924	0.07	-	-	115	17	-	-
2014	21,707,379	15,280	0.07	-	-	118	4	-	-
2015	23,601,215	17,779	0.08	-	-	155	4	-	-
2016	25,227,784	25,366	0.09	3740	-	152	7	5	-
2017	26,396,941	26,707	0.10	4231	-	154	8	2	-
2018	27,623,223	26,404	0.10	4330	-	148	7	0	-
2019	29,033,313	27,335	0.09	5208	-	241	31	1	-
2020	3,972,399	17,804	0.45	10,805	236	39	2	-	-

The data of inbound passenger numbers were provided by the Taiwan National Immigration Agency. The data of cases with symptoms were provided by the Taiwan CDC National Symptom Surveillance System. "-" indicates not application, unit indicates number of person time.

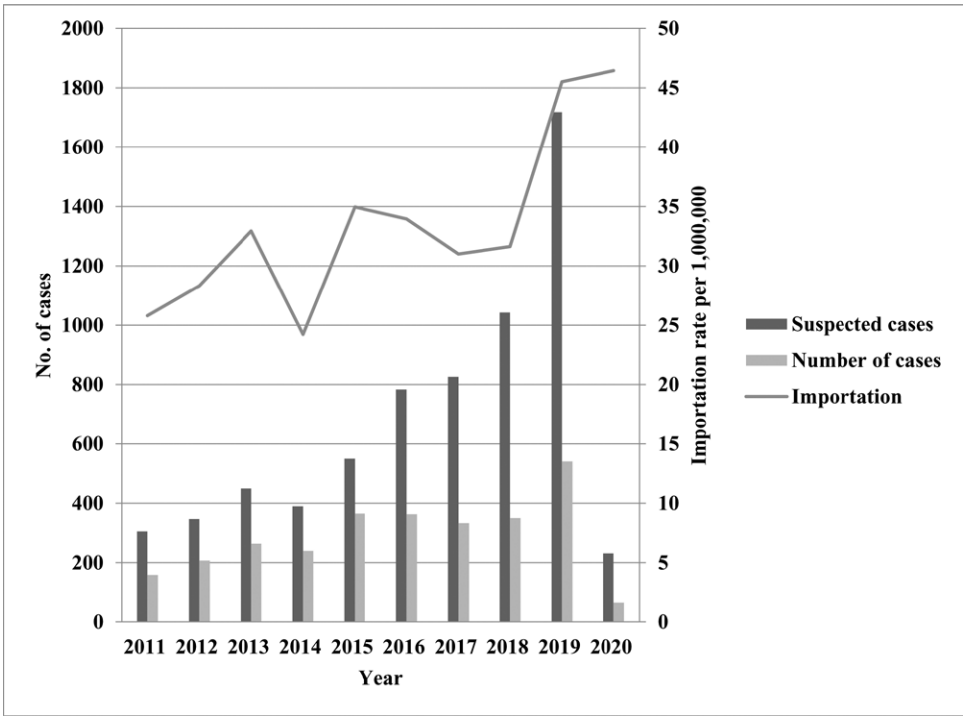

Figure 2. Number of suspected and imported cases and proportion of imported dengue cases in Taiwan, 2011–2020.

tourist arrivals worldwide was approximately 1 billion, a 48% increase from the 674 million arrivals in 2000.[55] Travel-related infection not only occurs during travel but also after travel. Worldwide, 8% of travelers from industrialized to developing countries report becoming ill enough to seek health care during or after travel.[56,57] Travelers have contributed to the global spread of infectious diseases, including novel and emerging pathogens. Therefore, as international travel continues to rise, the surveillance of travel-related morbidity continues to be an essential component of global public health surveillance.[58]

Concerns regarding the cocirculation of dengue during the COVID-19 pandemic have been raised.[59] The COVID-19 outbreak has imposed considerable burdens on health care and the public health system, resulting in a surge in dengue cases in Southern Asia and Latin America, particularly in low- and middle-income countries.[60] To investigate the effect of COVID-19 preventive measures on dengue, we compared the number of imported dengue cases in Taiwan before and after the COVID-19 outbreak and found that the number during the COVID-19 pandemic in 2020 was much smaller than that in the previous 9 years, likely because of the implementation of infection control measures, including the closing of borders. Surprisingly, we noted that although the number of imported cases decreased considerably in 2020, the importation rate also increased. We inferred that the ostensible reason for the implementation of Taiwan's border control policies and measures may simply be a decrease in international flights and tourist arrivals, resulting in a sharp decrease in imported dengue fever cases. Nonetheless, dengue fever may remain out of control and prevalent in dengue-endemic countries during the COVID-19 pandemic (particularly Southeast Asian countries), which is why the importation rate in Taiwan is increasing year by year. Previous study indicated that annual incidence of imported dengue ranged from 8.29/100,000 (n = 917 cases) to 22.10/100,000 (n = 2203) annual traveler movements between 2012 and 2019, decreased in 2020 (6.74/100,000 traveler movements; n = 191) and 2021

(3.32/100,000 traveler movements; n = 10) during COVID-19-related border closures. In this study, the number of dengue cases in 2020 was lower than that in 2011 to 2019. Previous results were similar to this study.

When an *Aedes* mosquito bites a patient with dengue who is in a contagious period, it will also be infected with the dengue virus. Once the virus enters the Taiwanese community from abroad and the surrounding environment is suitable for vector-borne mosquitoes to breed, a dengue fever outbreak may ensue. Therefore, eradication of the breeding sources of *Aedes* mosquitoes is crucial. Moreover, the public should be vigilant and understand the symptoms of dengue fever. In addition, Taiwan's health policy recommends that when travelers go abroad or to dengue fever-endemic areas, they should take self-protection measures, wear light-colored and long-sleeved clothes, and apply mosquito repellents approved by governmental authorities that contain diethyltoluamide, picaridin, or IR3535.[61] The government has also advised pregnant women to avoid travel to domestic and international dengue-endemic areas unless necessary.

This study has 3 limitations. First, the Taiwan CDC's TNIDSS includes only basic epidemiological data of patients with dengue fever and provides no clinical data. Therefore, we could not compare clinical data between patients in terms of their differences or trends. Second, the data provided on TNIDSS contain no sequence information regarding the genotypes or strains of the dengue fever virus, precluding analysis of the affinity between virus strains in Taiwan and other countries. Third, there is no data on the correlation between gender and dengue serotype in the CDC database. Therefore, this study only appears that separate analyses were done for each epidemiological variable of interest. Our study used various data provided by Taiwan's public sector on its online platform (including the initial version of the platform). This open platform stores all historical data, which researchers can use to perform statistical analyses or create academic value. Such data are worth exploring to improve the monitoring of infectious diseases and their characteristics and strengthen capacities for scientific research.

Our study is the first in Taiwan to analyze the epidemiological characteristics and trends of imported cases of dengue fever from 2011 to 2020. On the basis of data from the Taiwan Centers for Disease Control, 2883 imported cases of dengue fever were examined. Moreover, the imported cases of dengue fever in Taiwan exhibited significant differences in sex (male cases accounted for the largest proportion), age (patients aged 20 to 39 accounted for the largest proportion), month of confirmation (summer cases accounted for the largest proportion), and place of residence (northern area of Taiwan accounted for the largest proportion). The importation of dengue viruses from neighboring countries through commercial links and air travel is considered to be the cause of local outbreaks. Therefore, policymakers and clinical experts should direct prevention and control measures efforts toward preventing the importation of dengue into Taiwan.

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