Observational Study

Medicine

OPEN

Epidemiological features and risk factors for measles and rubella in Taiwan during 2011 to 2020

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Abstract

The risk of geographic transmission of infectious diseases due to air travel varies greatly. Our aim is to survey empirical data that provide a retrospective historical perspective on measles and rubella. This study used the open data website provided by the Taiwan Centers for Disease Control (TCDC) to extract the reported numbers of measles and rubella case between 2011 and 2020. There were 306 cases of measles and 135 cases of rubella. The incidence of measles and rubella per million population were 0 to 6.0 and 0 to 2.6, respectively. There was a gradual increase in the numbers of cases in those aged 20–39 years, and distinct duration patterns. It indicated that the risk of contracting rubella has significantly decreased in the last 5 years. Measles cases aged 20 to 39 years accounted for 72.5% of all cases. Rubella cases aged 20 to 39 years accounted for 59.3% of all cases. The male and residency in the Taipei metropolitan area or northern area were identified as potential risk factors for measles and rubella. Coverage with the first dose of the measles, mumps and rubella (MMR) vaccine in Taiwan increased from 97.31% to 98.86%, and the uptake rate of the second dose of the MMR vaccine increased from 95.73% to 98.39% between 2010 and 2020. Furthermore, the numbers of imported cases of measles (n = 0) and rubella (n = 0) reported during the coronavirus disease 2019 (COVID-19) pandemic were lower than those from 2011 to 2019. Measles and rubella cases were imported most frequently from Cambodia and Vietnam. This study represents the first report of confirmed cases of acquired measles and rubella from surveillance data of the TCDC between 2011 and 2020, also demonstrates that the numbers of cases of measles and rubella significantly decreased in Taiwan during the COVID-19 pandemic.

Abbreviations: COVID-19 = coronavirus disease-2019, MMR = measles, mumps and rubella, TCDC = Taiwan centers for disease control, TNIDSS = Taiwan national infectious disease statistics system.

Keywords: epidemiology, incidence, measles, retrospective study, rubella

1. Introduction

Measles is highly contagious; the transmission rate in susceptible individuals ex-posed to measles is 90%.[1,2] The annual incidence of measles cases reported world-wide decreased by 83%, from 145 cases to 25 cases per million population, between 2000 and 2017.[3] In 2017, it was estimated that 109,000 people died from measles worldwide, which was than 545,000 people in 2000. During this period, 21.1 million deaths were prevented by measles vaccination.[4]

The recent increase in the measles incidence in the United States and other industrialized countries was part of a worldwide increase in reported measles cases, which began in 2018 and continued until 2019. The countries with the largest number of measles cases reported in the last 6-month period were Madagascar, Ukraine, India, Brazil, the Philippines, Venezuela, Thailand, Kazakhstan, Nigeria, and Pakistan.[5] Most cases in the world occur in countries with weak health systems, and refusal to vaccinate is a risk factor for measles outbreaks. The World Health Organization listed "vaccine hesitancy" as 1 of the top 10 global health threats in 2019.[6] Measles virus belongs to the Paramyxoviridae family and is transmitted mainly through respiratory droplets and secretions.[7] Measles virus shedding from the nasopharynx begins before the typical morbilliform rash appears, and the virus can survive in the air or on objects and surfaces for up to 2 hours.[8] Transmission occurs via person-to-person contact as well as airborne droplets. Measles transmission between airplane passengers in air-ports and during flights has been described,[9–12] and large outbreaks in crowded areas such as schools and densely populated communities can occur.

Rubella is a contagious viral infection, usually causing benign systemic illness resembling a mild case of measles and previously known as "germane" (hence, "German") measles.[13,14] The reported incidence of rubella in the United States was 58 cases per 100,000 population before the vaccine was

The authors have no funding and conflicts of interest to disclose.

The datasets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

Taiwan Centers for Disease Control. Taiwan National Infectious Disease Statistics System. Available online: https://nidss.cdc.gov.tw/ch/ (accessed on 1 July 2021).

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How to cite this article: Yu C-P, Chen B-C, Chou Y-C, Hsieh C-J, Lin F-H. Epidemiological features and risk factors for measles and rubella in Taiwan during 2011 to 2020. Medicine 2022;101:43(e31254).

Received: 16 March 2022 / Received in final form: 15 September 2022 / Accepted: 19 September 2022

http://dx.doi.org/10.1097/MD.0000000000031254

released in 1969. Fewer than 0.5 cases per 100,000 people were reported in 1983. There was an outbreak of rubella in California and Pennsylvania in the United States, and the disease became epidemic again in the United States in 1990 and 1991. The United States officially announced that rubella had been eliminated in 2004.[15] Rubella was officially declared to be eliminated from the Americas in 2015.[16] Among 194 countries, 168 (87%) included rubella vaccination in vaccination programs, of which 81 (42%) eliminated the transmission of rubella by the end of 2018.[17] Despite these advances, rubella cases continue to occur, and there were 14,621 cases worldwide in 2018.[18] According to reports, African and Southeast Asian countries have the highest incidence of rubella.[19] The rubella virus is a member of the Togavirus family, which includes 2 genera of small, enveloped RNA viruses: Alphavirus and Rubivirus.[20,21] If a pregnant woman is infected with rubella, the virus can be transmitted vertically to the fetus through the placenta, which may cause stillbirth, spontaneous abortion or damage to the main organs of the fetus. This is called congenital rubella syndrome.[22,23]

Taiwan is located at 22° to 25° N and 102° to 122° E and has a subtropical climate. The monthly average temperature ranges from 16°C to 29°C, and the monthly average relative humidity ranges from 75% to 90%. Taiwan is a developed country with a per capita gross domestic product of US$34,523.[24] Tourists from overseas, especially countries that are near Taiwan, including China and Southeast Asian countries, often import respiratory diseases (such as measles and rubella infection) into Taiwan through air tourism.[25] This may indicate that the effect of epidemic prevention measures to control or eliminate the disease may be limited. Local cases of measles and rubella occur in Taiwan throughout the year, and a number of imported cases are re-ported every year. However, there is very little epidemiological information from big data to explore the risks of measles and rubella in Taiwan. To bridge this knowledge gap, this study accessed the Taiwan National Infectious Disease Statistics System (TNIDSS)[25] to analyze the numbers of domestic and imported cases of measles and rubella considering epidemiological characteristics and trends such as age, sex, season, and area of residence from 2011 to 2020.

2. Materials and Methods

2.1. Ethical policy

This study analyzed information that is freely available in the public domain and open datasets for which data have been properly anonymize; therefore, this study did not require ethical approval. The authors guarantee the added value of this study, thus conforming to the guidelines for public use of government reports.[26,27]

2.2. Data source

Because both measles and rubella are notifiable diseases in Taiwan, once a measles/rubella case has been identified, it is mandatory that it is reported to the centers for disease control. Therefore, this study used the open data website provided by the Taiwan Centers for Disease Control (TCDC) to ex-tract reported case numbers for measles and rubella between January and December 2011 to 2020.[28]

2.3. Data analysis

This was a retrospective study of all measles and rubella cases since 2011. We confirmed the number of people diagnosed with measles and rubella from 2011 to 2020 and examined the distributions of their epidemiological characteristics (sex, age, time of diagnosis, residence), differences, and results. Descriptive data are presented as means and summary statistics, where appropriate. Categorical variables were compared using the chi-square test/Fisher's exact probability test. All statistical analyses were performed using SPSS (IBM SPSS version 21; Asia Analytics Taiwan, Taipei, Taiwan). All statistical tests were 2-sided, with an α value of 0.05. P values of <.05 were considered to represent statistical significance.

3. Results

Table 1 shows the epidemiological features of domestic and imported cases of measles in Taiwan between 2011 and 2020. Table 2 shows the epidemiological features of domestic and imported cases of rubella in Taiwan between 2011 and 2020. Table 3 shows an epidemiological feature analysis of measles and rubella cases. Among the 110 imported cases of measles for which the region of import is known, 30 (27.3%) patients had traveled to China, 25 (22.7%) to Thailand, 23 (20.9%) to Vietnam, 15 (13.6%) to the Philippines, 7 (6.4%) to Indonesia, 4 (3.6%) to Cambodia, 3 (2.7%) to India and 3 (2.7%) to China. For travelers from Taiwan, the relative risk of contracting measles was 12.45 for travel to Thailand, 9.59 for travel to Vietnam, 6.62 for travel to the Philippines, 3.67 for travel to Indonesia, 71.06 for travel to Cambodia, 9.47 for travel to India, and 0.42 for travel to South Korea compared with the risk associated with travel to China (Table 4). Among the 78 imported cases of rubella for which the region was known, 38 (48.7%) had traveled to China, 21 (26.9%) to Vietnam, 5 (6.4%) to Japan, 4 (5.1%) to the Philippines, 4 (5.1%) to Malaysia, 3 (3.8%) to Indonesia, and 3 (3.8%) to Thailand. For travelers from Taiwan, the relative risk of contracting rubella was 6.91 for travel to Vietnam, 0.23 for travel to Japan, 1.39 for travel to the Philippines, 0.71 for travel to Malaysia, 1.24 for travel to Indonesia, and 1.18 for travel to Thailand compared with the risk associated with travel to China (Table 4). Table 5 shows the measles, mumps and rubella (MMR) vaccine coverage for measles and rubella in Taiwan between 2011 and 2019. The incidence per 1000,000 population and numbers of measles cases reported in Taiwan that were locally transmitted and imported

Table 1

Epidemiological features of domestic and imported cases of measles in Taiwan between 2011 and 2020.

Variable	All cases N = 306 (%)	Domestic cases N = 183 (%)	Imported cases N = 123 (%)
Sex			
Male	177 (57.8)	103 (56.3)	74 (60.2)
Female	129 (42.2)	80 (43.7)	49 (39.8)
Age group			
<20	57 (18.6)	26 (14.2)	31 (25.2)
20–39	222 (72.5)	145 (79.2)	77 (62.6)
49–59	27 (8.8)	12 (6.6)	15 (12.2)
≥60	0	0	0
Yr group			
2011–2015	105 (34.3)	66 (36.1)	39 (31.7)
2016–2020	201 (65.7)	117 (63.9)	84 (68.3)
Season			
Spring	173 (56.5)	123 (67.2)	50 (40.7)
Summer	62 (20.3)	30 (16.4)	32 (26.0)
Fall	19 (6.2)	9 (4.9)	10 (8.1)
Winter	52 (17.0)	21 (11.5)	31 (25.2)
Residency			
Northern	230 (75.2)	144 (78.7)	86 (69.9)
Central	45 (14.7)	29 (15.8)	16 (13.0)
Southern	29 (9.5)	10 (5.5)	19 (15.4)
Eastern	2 (0.6)	0	2 (1.6)

Table 2

Epidemiological features of domestic and imported cases of rubella in Taiwan between 2011 and 2020.

Variable	All cases N = 135 (%)	Domestic cases N = 48 (%)	Imported cases N = 87 (%)
Sex			
Male	87 (64.4)	28 (58.3)	59 (67.8)
Female	48 (35.6)	20 (41.7)	28 (32.2)
Age group			
<20	10 (7.4)	3 (6.3)	7 (8.0)
20–39	80 (59.3)	33 (68.8)	47 (54.0)
49–59	44 (32.6)	11 (22.9)	33 (37.9)
≥60	1 (0.7)	1 (2.1)	0
Yr group			
2011–2015	93 (68.9)	38 (79.2)	55 (63.2)
2016–2020	42 (31.1)	10 (20.8)	32 (36.8)
Season			
Spring	73 (54.1)	24 (50)	49 (56.3)
Summer	28 (20.7)	11 (22.9)	17 (19.5)
Fall	13 (9.6)	9 (18.8)	4 (4.6)
Winter	21 (15.6)	4 (8.3)	17 (19.5)
Residency			
Northern	84 (62.2)	32 (66.7)	52 (59.8)
Central	26 (19.3)	11 (22.9)	15 (17.2)
Southern	24 (17.8)	4 (8.3)	20 (23.0)
Eastern	1 (0.7)	1 (2.1)	0

Table 3

Epidemiological features of measles and rubella cases in Taiwan between 2011 and 2020.

Variable	Measles cases N = 306 (%)	Rubella cases N = 135 (%)	*P*
Sex			
Male	177 (57.8)	87 (64.4)	.192
Female	129 (42.2)	48 (35.6)	
Age group			
<20	57 (18.6)	10 (7.4)	<.001
20–39	222 (72.5)	80 (59.3)	
49–59	27 (8.8)	44 (32.6)	
≥60	0	1 (0.7)	
Yr group			
2011–2015	105 (34.3)	93 (68.9)	<.001
2016–2020	201 (65.7)	42 (31.2)	
Season			
Spring	173 (56.5)	73 (54.1)	.628
Summer	62 (20.3)	28 (20.7)	
Fall	19 (6.2)	13 (9.6)	
Winter	52 (17.0)	21 (15.6)	
Residency			
Northern	230 (75.2)	84 (62.2)	.032
Central	45 (14.7)	26 (19.3)	
Southern	29 (9.5)	24 (17.8)	
Eastern	2 (0.6)	1 (0.7)	

between 2011 and 2020 are shown in Figure 1. The incidence per 1000,000 population and numbers of rubella cases reported in Taiwan that were locally transmitted and imported between 2011 and 2020 are shown in Figure 2. Measles and rubella cases were imported to Taiwan from 5 continents and various countries, respectively (Figs. 3 and 4).

4. Discussion

Because of global climate change and increased travel between continents, air-borne diseases in Taiwan, including measles and rubella, are more likely to spread than in the past. Humans face new challenges in the control of these diseases. Prior to vaccination and the revival of immunization programs, measles accounted for high child morbidity and mortality,[29] with at least 95% of children aged under 15 years contracting measles,[30] resulting in over 2 million deaths and 15,000 to 60,000 cases of blindness worldwide per annum. The health consequences of measles and rubella infections can be lifelong and include economic losses for individuals, families and societies.[31] This study analyzed publicly available annual summary data of reported imported and domestic measles and rubella cases from 2011 to 2020 published by the TCDC and is the first report covering such an area in Taiwan in the past 10 years. During the period of investigation, more than 90% of the cases of measles and rubella were imported from Asian countries. The number of imported cases of measles was greater than the number of local cases. Between January 2011 and December 2020, the number of imported cases reached a cumulative total of 210 (123 for measles and 87 for rubella). Most of the imported cases originated in China (68 cases), Vietnam (44 cases), and Thailand (28 cases). Hot zones for measles and rubella are mainly distributed in the tropical and subtropical areas of the Northern Hemisphere, in which relatively high temperatures and numerous travelers are the main causes of disease spread.[32] In other words, airlines contribute substantially to airborne disease transmission, and busy airports are breeding grounds for pathogens (viruses, bacteria, etc). Therefore, the government should provide disease information and establish control measures for inbound travelers from disease hot zones to improve the effectiveness of epidemic control.

This study comparing measles and rubella cases between 2011 and 2020 revealed no significant differences between sexes. Specifically, sex was not a risk factor for measles and rubella; however, the rate was slightly higher in males (57.8% for measles cases and 64.4% for rubella cases) than in females. Patient age exhibited a significant difference. Cases of measles occurred mainly in 20- to 39-year-olds (attack rate = 72.5%); rubella cases also predominantly occurred in 20- to 39-year-olds (attack rate = 59.3%). The younger population accounted for a larger proportion of confirmed cases, probably because young adults contacted infected surfaces and were exposed to infected air-borne droplets more frequently than other age groups, and they tended to underestimate the risk of contracting

Table 4

Travel destinations of 110 persons with imported cases of measles and 78 persons with imported cases of rubella in Taiwan between 2011 and 2020.

Country of destination*	No. cases	No. of air passengers (100,000)	R.R.
Measles			
China	30	271.82	Reference
Thailand	25	18.20	12.45
Vietnam	23	21.74	9.59
Philippines	15	20.52	6.62
Indonesia	7	17.27	3.67
Cambodia	4	0.51	71.06
India	3	2.87	9.47
South Korea	3	64.20	0.42
Rubella			
China	38	271.82	Reference
Vietnam	21	21.74	6.91
Japan	5	156.12	0.23
Philippines	4	20.52	1.39
Malaysia	4	40.53	0.71
Indonesia	3	17.27	1.24
Thailand	3	18.20	1.18

*Case numbers larger than or equal to 3 are listed.

Table 5

Immunization coverage of measles and rubella in Taiwan between 2011 and 2019.

MMR vaccine	Yr*									Overall
	2011	2012	2013	2014	2105	2016	2017	2018	2019	
First dose										
Target population (person)	194,689	178,619	200,667	239,045	197,948	215,705	215,853	210,429	197,663	1850,618
Vaccinated population (person)	190,910	173,817	197,208	235,140	194,546	211,738	212,455	207,425	195,418	1818,657
Vaccination coverage (%)	98.06	97.31	98.28	98.37	98.28	98.16	98.43	98.57	98.86	98.3
First grade of elementary school										
Target population (person)	215,365	210,527	200,866	205,350	201,453	194,849	188,148	220,908	217,881	1855,347
Vaccinated population (person)	211,890	206,696	196,791	199,285	196,399	189,694	180,119	213,423	211,801	1806,098
Vaccination coverage (%)	98.39	98.18	97.97	97.05	97.49	97.35	95.73	96.61	97.21	97.3

MMR = measles, mumps and rubella.

*Taiwan's CDC has not released 2020 data up to August 2021.

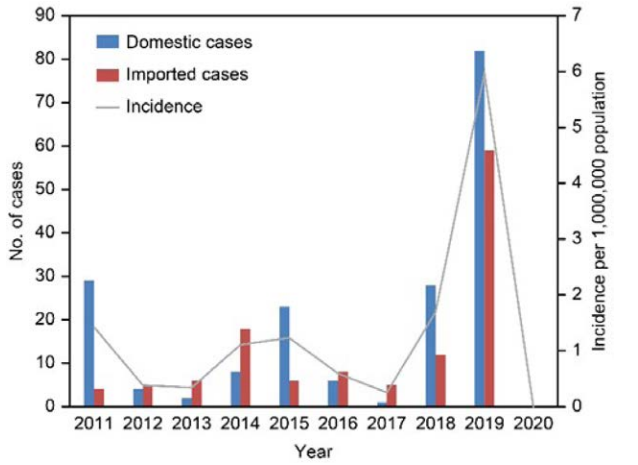

Figure 1. Incidence per 10,00,000 population and numbers of measles cases reported in Taiwan that were locally transmitted and imported between 2011 and 2020.

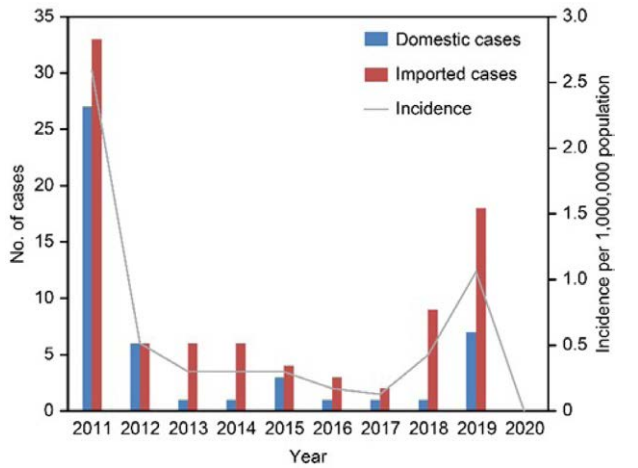

Figure 2. Incidence per 10,00,000 population and numbers of rubella cases reported in Taiwan that were locally transmitted and imported between 2011 and 2020.

a disease. Vaccination is one of the most effective medical measures for preventing infectious diseases. Even though there are recommendations for specific occupational groups that have an increased risk of infection, for example, armed forces personnel, there are gaps in the vaccination rates of this personal. Previous

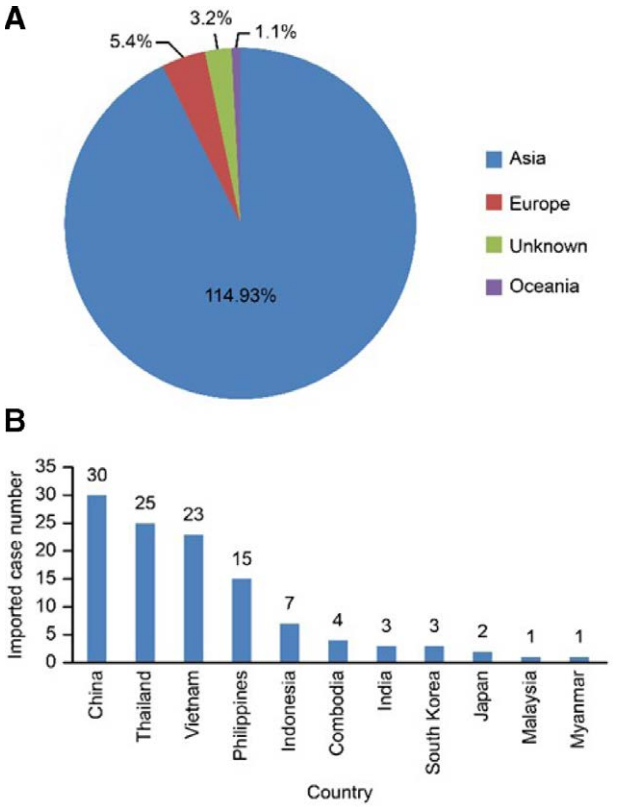

Figure 3. Measles cases reported in Taiwan that were globally transmitted (a) and imported from Asia (b) from 2011 to 2020.

study indicated that the vaccination rates for influenza (50.5% and 49.1%) and tick-borne encephalitis (57.1% and 60.7%) were particularly low, for measles, mumps, and rubella they were high (94.3% and 97.8%). A highly significant increase ($P < .001$) in vaccination rates was observed for experimental (a mean age of 27.7 ± 6.5 years) and control groups (27.9 ± 6.3 years). This study suggest that it is possible reason that because the younger adults are a high-risk group for measles and rubella, a high vaccination rate is required to prevent the spread and transmission of measles and rubella.[33] Over the last 5 years, there has been a significant increase in the number of measles cases and a significant decrease in the number of rubella cases. This study indicates that different respiratory diseases have had significant disease burdens in different years. Similar epidemic trends also emerged according to season of confirmation; specifically, the numbers of confirmed measles and rubella cases increased in spring and summer. These increases may have

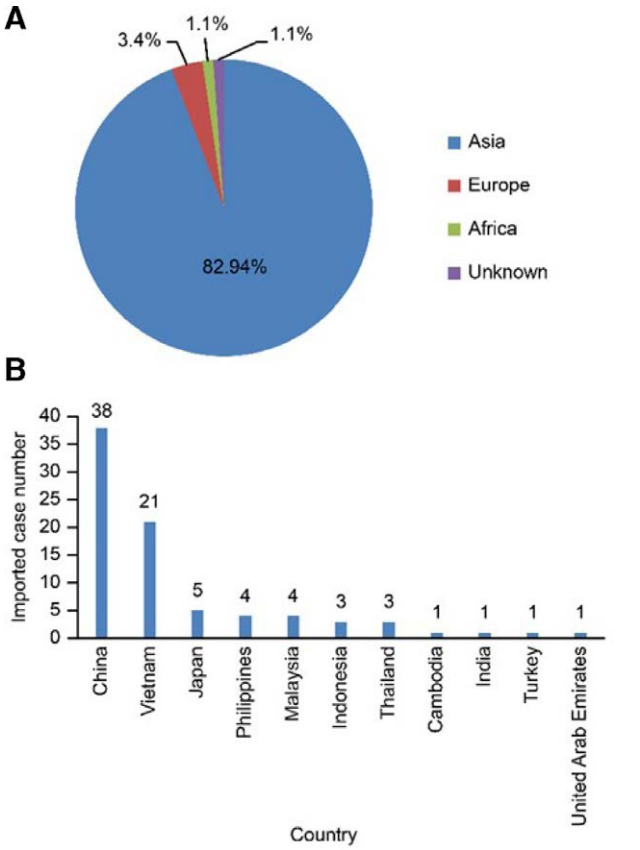

Figure 4. Rubella cases reported in Taiwan that were globally transmitted (a) and imported from Asia (b) between 2011 and 2020.

occurred because imported cases accelerated the spread of the disease, thereby indirectly increasing the number of domestic cases. A significant difference was also observed in the patients' places of residence. Taipei city is a metropolitan center located in northern Taiwan, in which residents were probably exposed to more imported cases of measles and rubella, contributing to the larger number of confirmed cases; thus, they had a higher risk of acquiring the disease. Overall, patient age, duration by year and residency at confirmation may be risk factors for measles and rubella in the Taiwanese population.

Foreign research has demonstrated that hot environments are associated with rapid disease transmission due to contamination with various pathogens.[34] Considering temperature increases every decade over the past 40 years, the United Nations World Meteorological Organization stated in its annual assessment report[35] in late 2019 that climate change has progressed beyond human capacity to adapt. Global temperatures since 2019 have exceeded those before the industrial revolution by 1.1°C, and this decade will be the hottest in history. According to Taiwan's Central Weather Bureau,[36] Taiwan's average temperature in 2019 was 24.56°C, which was 0.34°C higher than that in 2018 and the highest since 1947. Therefore, the large numbers of confirmed cases of measles and rubella in the fall of 2019 were probably caused by increased temperatures during this year. Increases in temperature also accelerate viral replication in the community and expand the geographic spread of diseases. Taiwan is facing climate change and a climate emergency, both of which require an immediate response. Because of global warming, Taiwan has a mild climate and is more suitable for the survival and reproduction of respiratory viruses during spring and summer; this has contributed to the spread of airborne diseases (e.g., measles and rubella), posing a great threat to public health. The government should develop public health policies in advance and thoroughly implement preventive measures to safeguard the health of citizens.

Declines in respiratory infectious diseases, such as invasive pneumococcal disease, tuberculosis and influenza, were reported in early 2020 in Taiwan.[37–39] Recently, Rana et al[40] reported that a rapid reduction in the number of measles cases during the coronavirus disease 2019 (COVID-19) pandemic was observed in Pakistan. In this study, a similar scenario was seen for measles and rubella in Taiwan. The numbers of measles and rubella cases dramatically reduced to zero in 2020, which marks the beginning of the COVID-19 outbreak. Zero cases in a year had not been achieved in the previous 9 years. Decreased numbers of imported cases of measles and rubella (transmission) in Taiwan during the COVID-19 pandemic may perhaps be attributed to the implementation of aggressive infection control measures during this period. First, the implementation of "border control," particularly with regard to China since the early COVID-19 out-break, might have directly led to the absence of imported measles and rubella cases and indirectly reduced the occurrence of imported case-associated locally transmitted cases. Second, infection control measures, such as mask wearing, increased hand washing, crowd avoidance and social distancing, might have helped reduce the risk of measles/rubella spread by reducing exposure to contaminated surfaces and airborne droplets. These interventions may have prevented the circulation of locally transmitted measles/rubella cases, as has been reported for other airborne infectious diseases in South Korea.[41] However, it is also possible that underreporting or underdiagnosis due to the fear of visiting hospitals during the COVID-19 pandemic may have resulted in underestimates of the numbers of actual measles and rubella cases. Further study comparing the number of people visiting clinics for respiratory symptoms during the COVID-19 pandemic with those in previous years may help estimate the effect of this issue.

Ideally, control efforts should focus on immunization, followed by outbreak control, elimination, and finally eradication.[42] Population immunity >95% is needed to interrupt ongoing measles transmission.[43] Global coverage of a first measles vaccine dose increased from 72% to 85% between 2000 and 2010[44] and again in 2019 with 122 countries (63% of World Health Organization member states) achieving ≥ 90% coverage, a 42% increase from 86 (45%) countries in 2000. In Taiwan, measles has been listed as a reportable disease since 1985 and is under control after the implementation of effective vaccination and the strengthened quality of the surveillance system. In Taiwan, coverage with the first dose of the MMR vaccine increased from 97.31% to 98.86% between 2010 and 2020. This study indicated that Taiwan's MMR vaccine coverage rate was indeed better than the global average. This also highlights Taiwan's public health measures and sustainable efforts in medical care. It is well known that measles elimination is not achievable without 2 doses of the MMR vaccine, though much progress has occurred in this area. The estimated global coverage of the second dose measles-containing vaccine (2) nearly quadrupled between 2000 and 2019, from 18% to 71%, largely due to an 86% increase in the number of countries providing an MCV2 (from 95 to 177 countries between 2000 and 2019).[45] Taiwanese coverage of the second dose of the MMR vaccine increased from 95.73% to 98.39% between 2010 and 2020. Vaccine (e.g., MMR) coverage of preschool or school-age children in Taiwan is overseen by the government's health department. This study suggests that children require publicly funded vaccines to strengthen protection against infectious diseases.

Individuals at risk for measles/rubella include children too young to be vaccinated, those who have not been vaccinated for medical or other reasons, those who have not received a second dose of the MMR vaccine, and those for whom the

vaccine failed to elicit a protective immune response (a very small fraction of those immunized). Travel to areas where measles is endemic or contact with ill persons arriving from these countries increases the risk of exposure to measles.[45] Data from other studies show that approximately half of the travelers with measles and rubella returning to developed countries had traveled to Asia.[46] Our study revealed similar findings for Taiwan. Immigration and the increased movement of international populations (e.g., travelers from China, Vietnam, Cambodia, and Thailand) affect morbidity caused by diseases in Taiwan, similar to the results of a previous study.[47] In addition, this study found that all cases of measles and rubella among patients increased when the numbers of imported cases of measles and rubella among immigrants and international travelers increased. This study suggests that international passengers arriving from abroad to a destination country might be a risk factor for measles and rubella in Taiwan.

This study has 2 limitations. First, the TCDC's TNIDSS (infectious disease statistics) includes only basic epidemiological data of patients with measles and rubella and provides no clinical data. Therefore, in this study, differences or trends in clinical data of patients could not be compared. Second, data provided by the TNIDSS contain no information about the genotypes or strains of measles and rubella viruses isolated. Accordingly, this study could not analyze the type of measles or rubella virus strain ins Taiwan or perform phylogenetic comparisons between viral strains in Taiwan and other countries. This study has the advantage of using diverse data provided by Taiwan's public sector on its online platform (including the initial version of the platform). All historical data are stored on this platform, and researchers can use this data to conduct statistical analyses and create academic value. Such data are worth exploring to guide expansion of the monitoring of infectious diseases and their characteristics, thereby continually increasing the capacity of scientific research.

5. Conclusions

This study was the first in Taiwan to analyze the epidemiological characteristics and trends of imported and domestic cases of measles and rubella from 2011 to 2020. On the basis of data from the TCDC, 306 cases of measles and 135 cases of rubella occurred. The incidence of measles and rubella per million population was 0 to 6.0 and 0 to 2.6, respectively. Moreover, the data analyzed in this study showed significant differences with regard to sex (male patients accounted for the largest proportion), age (patients aged 20–40 years accounted for the largest proportion), season of confirmation (spring accounted for the largest proportion), and place of residence (Taiwan's northern area accounted for the largest proportion). The largest number of imported cases of measles came from Cambodia. The largest number of imported cases of rubella came from Vietnam. This study also demonstrated that measles and rubella transmission decreased in Taiwan during the COVID-19 pandemic. Aggressive implementation of infection control and prevention measures during the COVID-19 pandemic can, therefore, be seen as advantageous for not only limiting the severe acute respiratory syndrome coronavirus 2 outbreak but also limiting outbreaks of other infectious diseases, such as measles and rubella, as focused on in this study. This information will be useful for policy makers and clinical experts in directing prevention and control measures regarding measles and rubella, which causes illness among the Taiwanese population. This study highlights the importance of longitudinal and geo-graphically extended studies to understand the implications of airborne disease transmission in the Taiwanese population. Critical data were identified to inform future surveillance and research efforts in Taiwan.

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Acknowledgments

The authors are grateful to all our colleagues at the School of Public Health in National Defense Medical Center, Taipei, Taiwan for their help in the collection of government data.

References

[1] Simpson RE. Infectiousness of communicable diseases in the household. Lancet. 1952;260:549–54.
[2] Centers for Disease Control and Prevention. Epidemiology and Prevention of Vaccine-Preventable Diseases. 12th ed, second printing. Atkinson W, Wolfe C, Hamborsky J, eds. Washington, DC: Public Health Foundation; 2012.
[3] Strebel PM, Orenstein WA. Measles. N Engl J Med. 2019;381:349–357
[4] Dabbagh A, Laws RL, Steulet C, et al. Progress toward regional measles elimination—worldwide, 2000–2017. MMWR Morb Mortal Wkly Rep. 2018;67:1323–9.
[5] World Health Organization. Immunization, Vaccines and Biologicals: New Measles Surveillance Data for 2019. Geneva, Switzerland: WHO: 2019.
[6] World Health Organization. Ten Threats to Global Health in 2019. Geneva, Switzerland: WHO, 2019.
[7] Kohnen M, Hoffmann P, Frisch C, et al. Diagnostic challenges and pockets of susceptibility identified during a measles outbreak, Luxembourg, 2019. Euro Surveill. 2021;26:2000012.
[8] Centers for Disease Control and Prevention (CDC). Measles. In Epidemiology and Prevention of Vaccine-Preventable Diseases. 13th ed. Hamborsky J, Kroger A, Wolfe S, eds. Washington DC: Public Health Foundation; 2015.
[9] Bitzegeio J, Bukowski B, Hausner M, et al. Two measles clusters in connection with short inner-European air travels indicating impediments to effective measles control: a cluster analysis. Travel Med Infect Dis. 2020;33:101542.
[10] Centers for Disease Control and Prevention (CDC). Notes from the field: Multiple cases of measles after exposure during air travel—Australia and New Zealand, January 2011. MMWR Morb Mortal Wkly Rep. 2020;2011:851.
[11] Vega JS, Escobedo M, Schulte CR, et al. Centers for Disease Control and Prevention (CDC). Notes from the field: Measles transmission at a domestic terminal gate in an international airport—United States, January 2014. MMWR Morb Mortal Wkly Rep. 2014;63:1211.
[12] Banerjee E, Hickman C, Engels K. Cynthia Kenyon centers for disease control and prevention (CDC). Notes from the field: Measles transmission in an international airport at a domestic terminal gate—April–May 2014. MMWR Morb Mortal Wkly Rep. 2015;64:679.
[13] Krawiec C, Hinson JW. Rubeola (Measles). In StatPearls. Treasure Island (FL): StatPearls Publishing; 2021.
[14] Griffith JPC. Rubella (Rötheln: German Measles): with a report of one hundred and fifty cases. Med Rec. 1887;32:11.
[15] Centers for disease control and prevention. In Epidemiology and Prevention of Vaccine-Preventable Diseases. Atkinson W, Wolfe C, Hamborsky J, eds. Washington, DC: Public Health Foundation; 2011; pp. 275–290.
[16] Pan American Health Organization. Americas region is declared the world's first to eliminate rubella. Available at: http://www.paho.org/hq/index.php?option=com_content&view=article&id=10798%3Aamericas-free-of-rubella&catid=740%3Anews-press-releases&Itemid=1926&lang=en (access on May 4, 2015).
[17] Grant GB, Desai S, Dumolard L, et al. Progress toward rubella and congenital rubella syndrome control and elimination—worldwide, 2000–2018. MMWR Morb Mortal Wkly Rep. 2019;68:855–9.

[18] WHO Fact Sheet. Rubella. Available at: http://www.who.int/en/news-room/fact-sheets/detail/rubella (access on February 18, 2020).
[19] WHO. Measles and rubella surveillance data. Available at: http://www.who.int/immunization/monitoring_surveillance/burden/vpd/surveillance_type/active/measles_monthlydata/en/ (access on October 3, 2019).
[20] Hobman T, Chantler J. Rubella virus. In Fields Virology, 5th ed. Knipe DM, Howley PM, eds. Philadelphia: Lippincott Williams & Wilkins; 2007; pp. 1069–1100.
[21] Plotkin SA, Reef SE. Rubella vaccine. In Vaccines, 5th ed. Plotkin S, Orsenstein W, Offit P, Eds.; Philadelphia: Saunders Elsevier; 2008; pp. 735–771.
[22] Shukla S, Maraqa NF. Congenital rubella. In StatPearls. Treasure Island, FL: StatPearls Publishing; 2021.
[23] Leonor MC, Mendez MD. Rubella. In StatPearls. Treasure Island, FL: StatPearls Publishing; 2020.
[24] National Statistics, R. O. C. (Taiwan). Taiwan: Taiwan. Available at: https://www.stat.gov.tw/point.asp?index=1
[25] Taiwan National Infectious Disease Statistics System (TNIDSS). Taiwan: Taiwan centers for disease control. Available at: https://nidss.cdc.gov.tw/nndss/disease?id=0701
[26] Hsieh CJ, Li CW, Cheng CA, et al. Epidemiologic characteristics of domestic patients with hemorrhagic fever with renal syndrome in Taiwan: a 19-year retrospective study. Int J Environ Res Public Health. 2020;17:5291.
[27] Chou YC, Hsieh CJ, Cheng CA, et al. Epidemiologic characteristics of imported and domestic chikungunya cases in Taiwan: a 13-year retrospective study. Int J Environ Res Public Health. 2020;17:3615.
[28] Statistics of Communicable Diseases and Surveillance Report, 2011–2020. Taiwan: Taiwan centers for disease control. Available at: https://www.cdc.gov.tw/InfectionReport/List/DRiONFTwYxu8T162Hm6yFw [access date March 1, 2022]
[29] Moss WJ. Measles. Lancet 2017;390:2490–502.
[30] World Health Organization. Measles vaccines: WHO position paper, April 2017 – recommendations. Wkly Epidemiol Rec. 2019;92:205–27.
[31] Mbivnjo EL, Lynch M, Huws JC. Measles outbreak investigation process in low- and middle-income countries: a systematic review of the methods and costs of contact tracing. Z Gesundh Wiss. 2022;30:2407–26.
[32] Nakamura S, Wada K, Yanagisawa N, et al. Health risks and precautions for visitors to the Tokyo 2020 Olympic and Paralympic games. Travel Med Infect Dis. 2018;22:3–7.
[33] Arnold JN, Gundlach N, Böckelmann I, et al. Randomised controlled study on measures to increase vaccination rates among German Armed Forces Soldiers. Int J Environ Res Public Health. 2022;19:8568.
[34] Dávalos-Becerril E, Correa-Morales F, González-Acosta C, et al. Urban and semi-urban mosquitoes of Mexico City: a risk for endemic mosquito-borne disease transmission. PLoS One. 2019;14:e0212987.
[35] World Meteorological Organization. 2019 concludes a decade of exceptional global heat and high-impact weather. Available at: https://public.wmo.int/en/media/press-release/2019-concludes-decade-of-exceptional-global-heat-and-high-impact-weather (access on 23 March 2020).
[36] Taiwan Central Weather Bureau. Taiwan's average temperature reached a new high point in 2019. Available at: https://www.cwb.gov.tw/Data/service/Newsbb/CH/20191231press.pdf (access on March 23, 2020).
[37] Juan HC, Chao CM, Lai CC, et al. Decline in invasive pneumococcal disease during COVID-19 pandemic in Taiwan. J Infect. 2020;82:282–327.
[38] Lai CC, Yu WL. The COVID-19 pandemic and tuberculosis in Taiwan. J Infect. 2020;81:e159–61.
[39] Hsu YL, Lin HC, Wei HM, et al. One benefit of COVID-19 measures in Taiwan: the reduction of influenza infections and severe complications. Influenza Other Respir Viruses. 2020;14:757–8.
[40] Rana MS, Usman M, Alam MM, et al. Impact of COVID-19 pandemic on Measles surveillance in Pakistan. J Infect. 2021;82:414–51.
[41] Kim DH, Nguyen TM, Kim JH. Infectious respiratory diseases decreased during the COVID-19 Pandemic in South Ko-rea. Int J Environ Res Public Health. 2021;18:6008.
[42] Durrheim DN, Crowcroft NS, Strebel PM. Measles – the epidemiology of elimination. Vaccine. 2014;32:6880–3.
[43] Global Vaccine Action Plan. Decade of vaccine collaboration. Vaccine. 2013;31(Suppl 2):B5–B31.
[44] Patel MK, Goodson JL, Alexander JP, Jr., et al. Progress toward regional measles elimination—worldwide, 2000–2019. MMWR Morb Mortal Wkly Rep. 2020;69:1700–5.
[45] Sotir MJ, Esposito DH, Barnett ED, et al. Measles in the 21st century, a continuing preventable risk to travelers: data from the GeoSentinel global network. Clin Infect Dis. 2016;62:210–2.
[46] Kirolos A, Waugh C, Templeton K, et al. Imported case of measles in a university setting leading to an outbreak of measles in Edinburgh, Scotland from September to December 2016. Epidemiol Infect. 2018;146:741–6.
[47] Shimizu K, Teshima A, Mase H. Measles and rubella during COVID-19 pandemic: Future challenges in Japan. Int J Environ Res Public Health. 2020;18:9.