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A Spatial analysis of chickenpox in Chongqing, China, during 2015–2023

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The disease burden of Chickenpox has gradually increased in Chongqing in recent years. This study aims to investigate the epidemiology and spatial clustering of chickenpox in Chongqing. Data on chickenpox cases during 2015–2023 in Chongqing were collected from the China Information System for Disease Control and Prevention. Descriptive analysis and flexible spatial scan statistic were used to summarize epidemiological and spatial clusters of chickenpox cases. A total of 247,071 cases of chickenpox and 1 death were reported in Chongqing from 2015 to 2023, with an average annual incidence of 88.3 per 100,000, and the highest incidence was 133.85 per 100,000 in 2019. The male-to-female ratio of cases was approximately 1.12. Two peak epidemic pattern was observed with one from April to July and the other from October to January of the following year, except for 2020. The population group aged 0–14 years and students comprised the high-incidence groups. Cases have been reported in all 39 districts (counties) of Chongqing, with an average annual incidence rate ranging from 27.90 per 100,000 to 149.78 per 100,000. The annual flexible spatial scan statistic showed that the most likely clusters included Jiangbei District, Nan'an District, Beibei District, Yubei District and Bishan District. The most likely cluster areas were predominantly located in the main urban area, but they have gradually shifted to counties in southeast and northeast Chongqing during2015-2023. The incidence spatially clustered in several high-risk clusters in the main urban area of Chongqing, as well as in the southeast and southwest regions. Children under the age of 14 and students were the high-risk groups.

Keywords Chickenpox, Incidence, Epidemiology, Spatial cluster, Chongqing

Chickenpox, also known as varicella, was a common acute infectious disease caused by varicella zoster virus (VZV) infection, characterized by systemic symptoms and the appearance of rashes, papules, and blisters on the skin and mucous membranes. In addition, this disease can lead to serious complications, such as secondary bacterial infections and central nervous system involvement, resulting in hospitalizations and deaths[1–5]. It was prone to cluster and occur in kindergartens, schools, and other units, seriously affecting the physical health and teaching order of children, a serious public health problem.

Chickenpox vaccination is the most effective and reliable method to prevent chickenpox[6,7]. The overall efficacy rate of chickenpox vaccine is 81%, and the prevention efficacy rate for moderate or severe chickenpox is 98%[8]. Some countries[9–12] have included chickenpox vaccine in their immunization plans. The vaccination rate of chickenpox is high, so the hospitalization rate and incidence rate caused by chickenpox are reduced. Therefore, the chickenpox vaccination program has had a positive impact on the epidemiology and disease burden of chickenpox. However, the chickenpox vaccine is a Class II vaccine in China, and residents receive it voluntarily and at their own expense, with only a few areas providing the vaccine for free. The vaccination rate of chickenpox vaccine in China is estimated to be 61%, lower than 80% recommended by the World Health Organization[13]. It is reported that the incidence rate of chickenpox has increased from 55 cases per 100,000 in 2016 to 70 cases per 100,000 in 2019, with an average of 1000 outbreaks per year[14,15]. In 2018 and 2019, the reported incidence rate of chicken pox in Chongqing ranked second in China, both higher than the national average. To effectively monitor the chickenpox epidemic in Chongqing, since 2014, the Chongqing Municipal Health and Family Planning Commission has listed chickenpox as an infectious disease for reference in the report of Class C infectious diseases[16]. All practitioners in medical agencies in Chongqing have been required

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to report chickenpox cases by Notifiable Infectious Disease Surveillance System, Chinese Center for Disease Control and Prevention (CISDCP) within 24 h after the diagnosis of chickenpox was made[16–18].

Relevant studies have indicated that the incidence of chickenpox exhibits spatial clustering patterns. Detecting spatial clustering is conducive to identifying high-incidence areas, analyzing causes, formulating targeted prevention and control measures, and rationally adjusting medical and health resources. Numerous methods have been developed for detecting spatial clustering of diseases, among which the most widely applied is the circular spatial scan statistic method (SatScan) proposed by Martin Kulldorff[19,20]. Toshiro Tango et al.[21,22] had introduced the flexible spatial scan statistic method (FleXscan), which is suitable for detecting irregular clusters in disease monitoring and control. Method comparison[23,24] found that although the clustering areas detected by the two methods are essentially the same, they have substantial differences in the shape of the clustering areas and the covered streets. The method comparison study conclude that the FlexScan method has better accuracy and rationality in scanning results than the SatScan method.

In this study, we aim to describe the epidemiological characteristics and spatial clustering of chickenpox in Chongqing from 2015 to 2023, providing a scientific basis for the prediction, early warning and intervention measures of the epidemic.

Materials and methods

Study area

Chongqing, situated in the southwest of China with the latitude (28°10'-32°13' N, 105°11'-110°11' E) and upriver of the Yangzi River, is the only interior municipality in the central and western regions of China with a large area and over 32 million registered residents, consisting of 39 districts and counties.

Data

Data on reported chickenpox cases and population statistics in Chongqing from January 1, 2015 to December 31, 2023 were collected from CISDCP, which is the world's largest internet-based disease reporting system that was established by the Chinese government after the 2003 SARS epidemic. In all medical institutions across the municipality, physicians are required to complete a Notifiable Infectious Disease Report Card within 24 h of diagnosing chickenpox. The reporting process follows a dual-verification protocol: (1) Initial Verification: Public health physicians within the hospital first review the report card for accuracy and completeness before submitting it to the China CDC's National Notifiable Disease Surveillance System. (2) Secondary Validation: Within 24 h of submission, experts from the Prevention and Control Division of District/County CDC's Infectious Disease Prevention Institute conduct a secondary review of the report data. Only after passing both verification stages does the report card qualify as a valid epidemiological record for inclusion in the national surveillance database.

Confirmed cases are clinically diagnosed cases and laboratory-confirmed cases. The former refers to the patient with pruritic papule and vesicular rash on the skin and mucous membranes, with or without fever and headache, and without the possibility of other eruptive diseases during the chickenpox epidemic season or in those with a history of contact with chickenpox or herpes zoster patients in the 2–3 weeks preceding the onset of illness. The latter refers to clinically diagnosed cases accompanied by any of the following items: the immunoglobulin M (IgM) antibody of the varicella-zoster virus was positive without chickenpox vaccine inoculation in the last month, chickenpox zoster virus was isolated, or the antigen of the varicella-zoster virus was detected by direct fluorescence assay (DFA) or polymerase chain reaction (PCR), or the titer of the immunoglobulin G (IgG) antibody of the varicella-zoster virus alongside the sera increased more than four-fold at 2–4 week intervals.

Descriptive analysis

The characteristics (such as age, gender, occupation) of chickenpox cases in Chongqing from 2015 to 2023 were described using descriptive epidemiological methods, and an epidemiological curve was plotted based on the annual number of chickenpox cases and incidence rates. The incidence of chickenpox in various districts and counties was correlated with geographical data using administrative district codes, and annual incidence maps were subsequently created to illustrate the spatial distribution of chickenpox in Chongqing. The vectored provincial boundary electronic map of Chongqing is downloaded from the website of the National Geomatics Center of China (http://www.ngcc.cn/ngcc/).

Spatial clustering analysis

The deformable spatial scanning metrology method[21] constructs a spatial scanning window based on population and incidence, calculates the theoretical incidence within the window according to the Poisson distribution, and then calculates the actual incidence by comparing it with Construct a restricted log likelihood ratio (RLLR) based on the theoretical number of cases to evaluate the degree of abnormality in the number of cases within the scanning window. The larger the RLLR value, the higher the degree of abnormality in the number of cases in that window. When the LLR test $P < 0.05$, it is considered that the area is a clustering zone. The region with the highest RLLR value is the first level spatial cluster (MLC), while the regions with lower LLR values than the first level cluster are the secondary spatial clusters, and so on. Relative risk (RR) is the ratio of the incidence risk within the scanning window to the incidence risk outside the scanning window. When $RR > 1$, it indicates that the incidence risk within the window is greater than that outside the window; When $RR < 1$, it indicates that the disease risk within the window is lower than outside the window. Due to the use of a preset maximum number of adjacent areas K in the Flexible space scanning window, impossible shapes in the monitoring area are avoided. The K value increases from 1 to the preset maximum value, usually set to 15, which is set to 15 in this study. The model is set to "Poisson" and Monte Carlo randomization is used to calculate the P-value of the test statistic, with 999 iterations selected. The space scan analysis was performed using FleXscan (version 3.1.2).

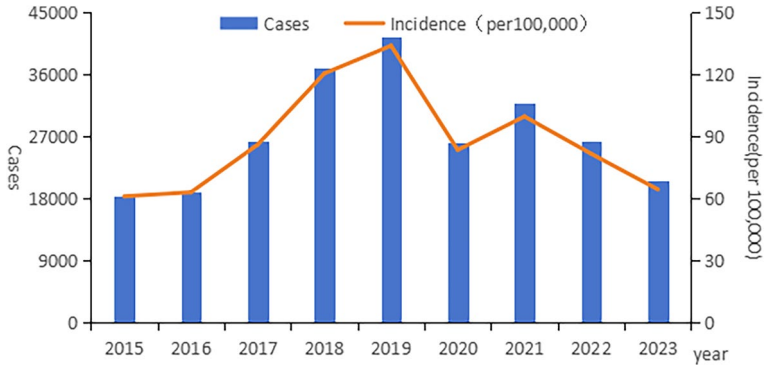

Fig. 1. Incidence of chickenpox in Chongqing from 2015 to 2023.

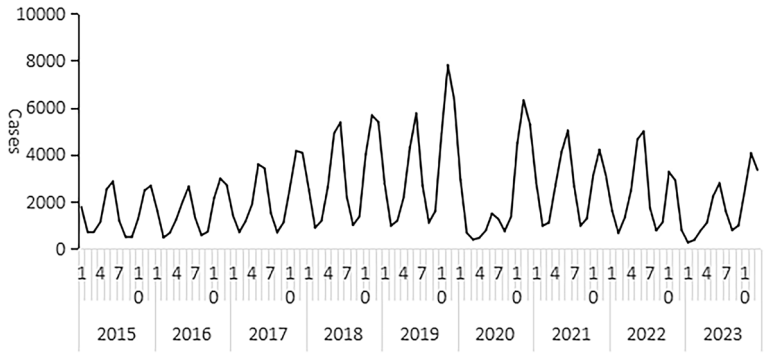

Fig. 2. Seasonal distribution of chickenpox incidence in Chongqing from 2015 to 2023.

Statement

We confirm that all methods were carried out in accordance with relevant guidelines and regulations. Protocol for study conducted using the collected data was submitted to the Ethics Committee of the Chongqing Center for Disease Control and Prevention, which ensures that the use of data falls within the scope specifically agreed upon by chickenpox patients.

Results

Incidence feature

A total of 247,071 cases of chickenpox and 1 death were reported in Chongqing from January 1, 2015 to December 31, 2023. The incidence rate was between 61.07 per 100,000 and 133.85 per 100,000, and the annual average incidence rate was 88.3 per 100,000; Among these years, 2019 had the highest incidence rate, while 2015 had the lowest. The overall trend shows an initial increase followed by a decrease (Fig. 1).

Seasonal distribution

Chickenpox cases were reported every month, showing a bimodal distribution. The first peak was from October to January of the following year, accounting for 48.84% (126365/258755); The second smaller peak was from April to July each year, accounting for 38.34% (99202/258755). Low incidence periods were February to March and August to September of each year (Fig. 2).

Gender and occupation distribution

There were 130,558 male cases and 116,513 female cases, with annual incidence rates of 92.16 per 100,000 and 84.29 per 100,000 respectively, resulting in a male-to-female ratio of 1.12:1. The incidence rate among males was higher than that among females every year($p < 0.05$, Table S1). In terms of occupational distribution, the top three categories with the highest number of cases were students (158,126 cases, accounting for 64.00%), children in nurseries and kindergartens (42,730 cases, 17.29%), and scattered children (19,063 cases, 7.72%). The overall proportion of students increased from 58.09% in 2015 to 71.88% in 2023 (Table 1).

Age distribution

Regarding age distribution, the highest incidence rates were observed in the 5–9, 10–14, and 0–4 age groups, with rates of 532.27 per 100,000, 446.70 per 100,000, and 256.88 per 100,000 respectively. The lowest incidence rate was found in the age group of 35 and above, which was 2.65 per 100,000 (Table 2; Fig. 3, Table S2).

Year	Gender			Occupation			
	Male	Female	Sex ratio	Scattered children[1]	Kindergarten children[2]	Student[3]	Others[4]
2015	9709 (53.14)	8560 (46.86)	1.13:1	1901 (10.41)	3842 (21.03)	10,613 (58.09)	18,371 (10.47)
2016	10,062 (52.90)	8960 (47.10)	1.12:1	1963 (10.32)	3406 (17.91)	11,400 (59.93)	18,785 (11.84)
2017	13,742 (52.36)	12,501 (47.64)	1.10:1	2455 (9.35)	4562 (17.38)	16,309 (62.15)	25,343 (11.12)
2018	19,212 (51.85)	17,843 (48.15)	1.08:1	3108 (8.39)	6946 (18.74)	23,149 (62.47)	35,221 (10.40)
2019	21,877 (52.69)	19,641 (47.31)	1.11:1	2979 (7.18)	7711 (18.57)	26,231 (63.18)	38,940 (11.07)
2020	13,656 (52.34)	12,437 (47.66)	1.10:1	2114 (8.10)	4171 (15.99)	17,007 (65.18)	25,312 (10.73)
2021	16,967 (53.12)	14,976 (46.88)	1.13:1	1993 (6.24)	5756 (18.02)	20,833 (65.22)	30,603 (10.52)
2022	14,157 (53.97)	12,074 (46.03)	1.17:1	1484 (5.66)	4312 (16.44)	17,708 (67.51)	25,526 (10.39)
2023	11,176 (54.00)	9521 (46.00)	1.17:1	1066 (5.15)	2024 (9.78)	14,876 (71.87)	19,989 (13.20)
total	130,558 (52.84)	116,513 (47.16)	1.12:1	19,063 (7.72)	42,730 (17.29)	158,126 (64.00)	27,152 (10.99)

Table 1. Gender and occupation distribution of chickenpox in Chongqing from 2015 to 2023. Note: 1: Scattered children refers to children who have not yet reached the age of 3 years (the age for attending kindergarten), or who are taken care of by their family members; 2: Kindergarten children refers to children who have reached the age of 3 years and attended kindergarten; 3. students refers to individuals who have reached the age of 6 years and attended primary school, junior high school, senior high school or university;4. other refers to individuals who were not Scattered children, Kindergarten children or students.

Year	0–4 year		5–9 year		10–14 year		15–19 year		20–34 year		≥35 year	
	Case	Incidence	Case	Incidence	Case	Incidence	Case	Incidence	Case	Incidence	Case	Incidence
2015	3240	199.61	7858	470.90	3802	250.95	1438	64.89	1775	35.15	156	0.92
2016	3310	206.61	7275	442.09	4283	286.99	1878	86.24	2075	41.11	201	1.15
2017	4300	253.08	10,092	578.30	6406	404.75	2406	108.19	2711	52.60	328	1.81
2018	6095	347.64	14,048	779.31	9764	598.31	3211	146.79	3441	67.35	496	2.72
2019	6623	365.94	14,187	812.16	11,513	657.47	4427	246.57	4151	73.26	617	3.61
2020	3880	217.95	7847	457.06	7874	446.44	3493	196.99	2505	43.71	494	2.79
2021	4486	286.63	8954	503.76	9918	564.85	4957	271.64	2978	50.25	650	3.46
2022	3338	239.92	7782	453.86	7778	424.72	4414	244.14	2307	36.73	612	3.31
2023	1870	151.41	4596	269.09	6182	345.17	5044	269.77	2293	37.67	712	3.87
total	37,142	256.88	82,639	532.27	67,520	446.70	31,268	174.91	24,236	48.42	4266	2.65

Table 2. Age incidence rate of chickenpox in Chongqing from 2015 to 2023 (incidence rate (1/100,000)).

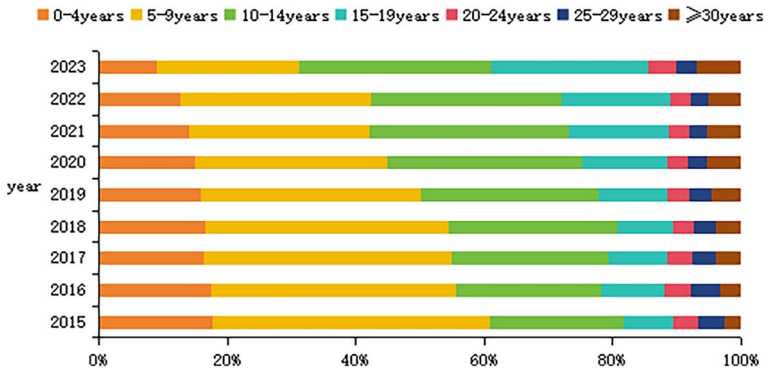

Fig. 3. Age composition of chickenpox in Chongqing from 2015 to 2023.

Geographical distribution

Cases were reported in all 39 districts (counties) of the city, with an annual average incidence rate ranging from 27.90 per 100,000 to 149.78 per 100,000. The top five districts and counties with the largest numbers of reported cases were Yubei District (9.8%), Kaizhou District (5.08%), Nan'an District (4.82%), Jiangjin District (4.74%) and Yongchuan District (4.21%).The number of cases among these 5 districts accounted for 28.75% of the total number. Yubei District showed the highest annual average incidence rate (149.78 per 100,000), followed by Nan'an District (134.81 per 100,000), while Fengdu County was the lowest (27.9 per 100,000) (Fig. 4).

Spatial cluster

The annual flexible spatial scan statistic showed that cases had spatial clusters each year ($P < 0.05$) during 2015–2023. The most likely clusters included Jiangbei District, Nan'an District, Beibei District, Yubei District and Bishan District. The secondary clusters included Kaizhou District, Rongchang District, Wushan County and Xiushan County. Nine regions (Wanzhou District, Fuling District, Yuzhong District, Qijiang District, Wulong District, Fengdu County, Zhongxian County, Fengjie County, Wuxi County) showed no significant spatial cluster in any year during the 2015–2023 periods. Jiangjin District, Tongliang District, and Tongnan District showed no significant spatial cluster between 2015 and 2018, while were included in the most likely clusters in the following years. Shapingba District were included in the most likely clusters between 2015 and 2018, while showed no significant spatial cluster during 2020–2023 (Fig. 5).

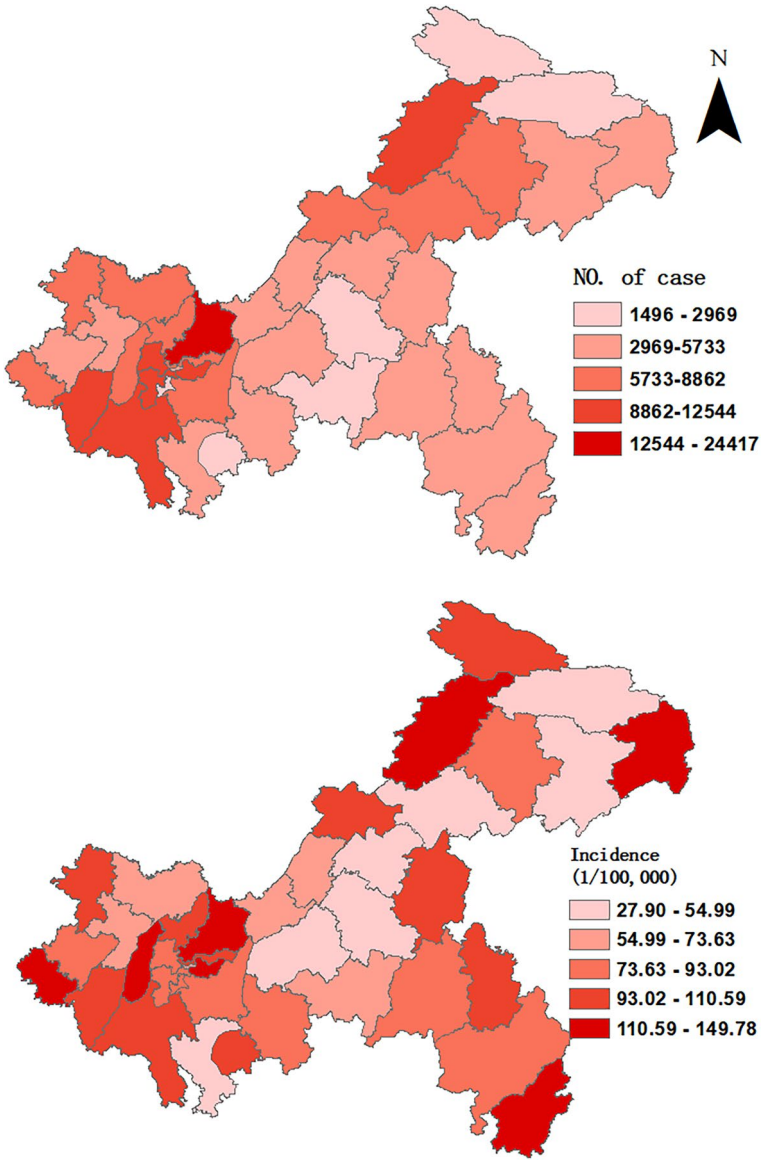

Fig. 4. Geographical distribution of chickenpox in Chongqing from 2015 to 2023.

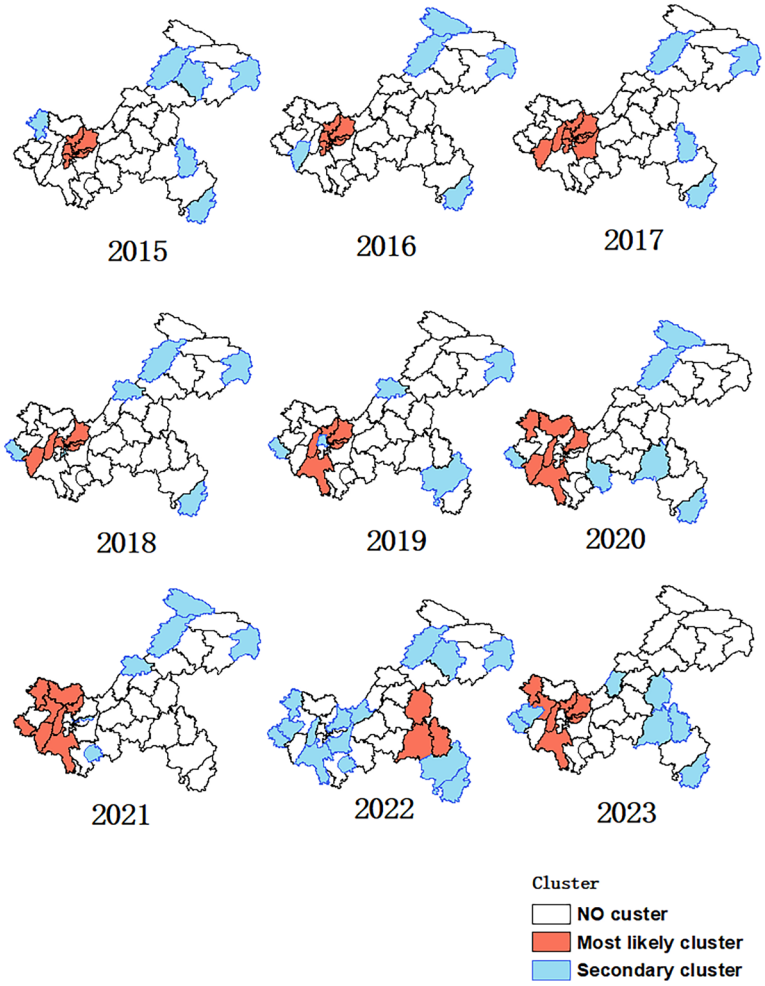

Fig. 5. Spatial clusters of chickenpox in Chongqing from 2015 to 2023.

Discussion

Based on the 9-year surveillance of chickenpox cases in Chongqing, our study provided a systematic description of the epidemic trend and identified the incidence hotpots areas of chickenpox. In most cities, chickenpox is categorized as "other infectious diseases" without mandatory reporting requirements after diagnosis. The findings of our study can offer valuable insights and recommendations for other cities. For instance, chickenpox could be classified as a Class C infectious disease, requiring doctors to fill out an infectious disease report card within 24 h after diagnosis and report it to CISDCP, in order to grasp the true incidence and epidemic characteristics of chickenpox, and provide reference for the prevention and control of chickenpox epidemic.

The reported incidence of chickenpox in Chongqing increased by approximately 24% annually from 2015 to 2019, with annual average incidence rate of 88.3 per 100,000, which is largely consistent with the rising trend in other regions of China[25–27]. The incidence peaked in 2019 at 133.85 per 100,000 people, which is higher than the national average, Guizhou Province, and other regions[25,27,28]. The higher incidence of chickenpox in Chongqing may be related to the increased sensitivity of infectious disease surveillance in recent years, while chickenpox was implemented Class C management since August 2014, and also may be related to the insufficient coverage of vaccination. But the reported incidence rate declined from 2020 to 2023, which may be related to factors such as the COVID-19 pandemic and the implementation of a two-dose chickenpox vaccination program. However, the annual reported incidence rate has consistently ranked among the top five infectious diseases reported in Chongqing, indicating that chickenpox remains a major infectious disease requiring attention.

The epidemiology of chickenpox in Chongqing exhibited a bimodal seasonal distribution, with peaks occurring from April to July and from October to January of the following year, which was consistent with the seasonal epidemiological characteristics observed nationwide and in other regions[29,30], but differs from that in Henan Province[31].This discrepancy may be attributed to factors such as economic level, vaccination rates, population composition, geographical factors, and meteorological conditions[32,33]. In 2020, the incidence of chickenpox significantly declined and only a predominate winter peak occurred; this phenomenon has also been observed for other respiratory infectious diseases[34–36]. Following the COVID-19 pandemic, many public health measures have been strictly implemented, which may have reduced the exposure to other respiratory viruses[37,38].

The incidence of chickenpox was high during school terms and low during winter and summer vacations, primarily associated with exposure among high-risk groups such as students and children in kindergarten.

Similar to previous studies, the incidence of chickenpox among males was higher than that among females, which was also found in Anhui Province[13]. This may be related to men's greater social activities, poorer hygiene habits, or immune status. Research results suggest that the antibody positive rate among healthy girls is higher than that among boys[39]. In terms of age, the incidence was mainly concentrated in the age group under 14 years old, with the highest incidence in the 5–9 age group, followed by the 10–14 and 0–4 age groups, while the incidence was lowest in the age group of 35 and above. This corresponded to the occupational distribution, which was dominated by students, children in kindergarten, and scattered children. This may be related to poor hygienic habits among children, low immunity, densely populated and frequently active areas such as schools, and the lack of knowledge about infectious disease prevention and control[40]. More children are now vaccinated compared to the historical proportion, and the vaccine is demonstrated to be effective in reducing the risk of infection in younger age groups. The high-risk age has gradually shifted from 0 to 9 years old to 10–19 years old, showing a phenomenon of age lag[41,42]. This indicated that the key population for chickenpox prevention and control in Chongqing is still children over 3 years old and adolescents who are susceptible. Meanwhile, the incidence rate and proportion of the age group over 35 years old were increasing year by year, which also requires special attention.

The spatial distributions of chickenpox were not random in Chongqing. The incidence map revealed a higher prevalence of chickenpox in the main urban area, potentially attributed to the spread of infectious diseases facilitated by factors such as population density, economic prosperity, and frequent population movement[43,44]. The FlexScan scan results indicated that the chickenpox cluster areas in Chongqing had been constantly changing from 2015 to 2023, with the number of cluster areas increasing from 12 in 2015 year to 17 in 2022 year. Initially, the most likely cluster areas were predominantly located in the main urban area, but they have gradually shifted to counties in southeast and northeast Chongqing, where the economy lags behind. These regions face challenges such as lower socioeconomic status, limited average household income, and insufficient understanding of vaccines or disease-related information, all of which impede the distribution of voluntarily self-paid vaccines[43]. Several studies found that respiratory infectious diseases showed patterns of high-risk clusters in remote rural where economic, educational, and medical resources are often lacking[45,46]. It is recommended to strengthen the prevention and control measures for chickenpox outbreaks in cluster areas, while simultaneously preventing the spread of chickenpox from these clusters to surrounding areas. Further exploration should be conducted on the reasons for the high incidence and clustering of chickenpox, providing reference for the scientific development of chickenpox prevention and control plans.

There are several limitations of this study. First, the data on chickenpox were collected through passive monitoring; therefore, the actual numbers of chickenpox cases may have been underestimated. Second, our study only analyzed spatial clustering and did not conduct a spatiotemporal clustering analysis, therefore, the actual time of clustering in the cluster areas cannot be determined. Finally, factors that affect the spread of infectious diseases, such as economy, population density, vaccination rates, and climate information, have not been investigated because this work only describes the clustering phenomenon of chickenpox. Therefore, potential associated factors warrant future research.

In conclusion, the incidence rate of chickenpox in Chongqing showed a trend of first rising and then declining, reaching the highest level in 2019. It exhibited obvious seasonal variations. Cases were clustered in several spatial high-risk clusters in the main urban area of Chongqing, as well as in the southeast and southwest regions. Children under the age of 14 and students were the high risk groups. It is recommended to carry out targeted health education and monitoring for key areas and populations before the peak of disease incidence.

Data availability

The datasets used and analyzed during the current study were collected from the Notifiable Infectious Disease Surveillance System, Chinese Center for Disease Control and Prevention, but the availability of these data was limited, so they were not disclosed. However, data can be obtained from the corresponding author Li Qi (E-mail: qili19812012@126.com) on reasonable request.

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Author contributions

YL, LJ and QL conceived and designed the research; YL and YJL analyzed the data; TDC and ZH contributed the collection of materials; YL wrote the paper.LJ and QL wrote-review & editing, administrated project and Funding acquisition. All Authors contributed to the final version of the manuscript. All authors read and approved the final manuscript.

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Competing interests

The authors declare no competing interests.

Ethics approval and consent to participate

Protocol for each study conducted using the collected data was submitted to the Ethics Committee of the

Chongqing Center for Disease Control and Prevention, which ensures that the use of data falls within the scope specifically agreed upon by chickenpox patients.

Additional information

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