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Article

High Effectiveness of the Changchun Baike Varicella Vaccine in a Real-World Outbreak Setting: An Observational Study from Yanji City, China

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Abstract

This study aimed to investigate the protective effect of Changchun Baike varicella vaccine in Yanji City from 2018 to 2024. Varicella surveillance data from 2018 to 2024 and vaccination records from 2018 to 2020 were collected from the China Disease Prevention and Control Information System and analyzed. In total, 2,452 varicella cases were reported in Yanji from 2018 to 2024, with an average annual incidence rate of 62.71 per 100,000 population. Notably, the annual incidence rates decreased from 142.37 per 100,000 in 2018 to 55.25 per 100,000 population in 2024. Additionally, the highest and lowest incidence rates were observed in the 10–14 and ≥ 40 years age groups, respectively. Moreover, Changchun Baike varicella vaccine showed protective efficacies of 98.0–99.0% and 99% for the first and second doses, respectively, from 2018 to 2024. Importantly, the two-dose varicella vaccination schedule demonstrated superior protective efficacy compared with the single-dose schedule.

Keywords: varicella; live attenuated varicella vaccine; epidemiological characteristics; protective effect

1. Introduction

Varicella, caused by the varicella-zoster virus (VZV), is highly contagious and primarily transmitted through respiratory droplets or direct contact [1]. Varicella affects individuals of all ages, with a higher incidence among infants, preschool, and school-aged children, often leading to outbreaks [2]. Globally, approximately 140 million people are infected with varicella annually, posing a significant public health challenge [3]. Recently, varicella has become the leading vaccine-preventable infectious disease among children in China, with a national incidence rate of approximately 25–30 per 100,000 population in 2022, highlighting the urgent need for enhanced control measures [4,5]. As an economic and transportation hub in Jilin Province with a dense population, Yanji City is prone to varicella outbreaks in schools and childcare facilities. Vaccination is the most effective method for preventing the disease [6]. Notably, Changchun Baike varicella vaccine is the primary vaccine used in the immunization program of Yanji, reducing the average annual incidence rate to 62.71 per 100,000 population between 2018 and 2024. However, single-dose vaccination has limited protective efficacy, and breakthrough infections may occur (7, 8). In this study, we conducted an epidemiological analysis of varicella in Yanji from 2018 to 2024 and evaluated

the protective efficacy of varicella vaccine from 2018 to 2020 to provide guidance for varicella prevention and control.

2. Materials and methods

2.1. Data Sources

Varicella case data were obtained from the China Disease Prevention and Control Information System and the Infectious Disease Reporting System. Varicella cases were filtered for residents of Yanji with onset dates of January 1, 2018, to December 31, 2024, totaling 2,452 confirmed cases, excluding suspected cases. Additionally, varicella vaccination data from 2018 to 2020 were collected for this study.

2.2. Methods

Descriptive epidemiological methods were used to analyze the temporal, spatial, and population distributions of varicella incidence in Yanji from 2018 to 2024. Additionally, a screening method was employed to assess varicella vaccination rates and protective efficacy. Individuals were divided into vaccinated and unvaccinated groups based on vaccination status in 2018, 2019, and 2020, categorized as one dose, two doses, or both. Disease occurrence was observed from 2018 to 2022, 2019 to 2023, and 2020 to 2024. Cases were matched by age (< 15 years), excluding those with onset within 1 year of birth or within 42 days post-vaccination. Matched cases were included in the protective efficacy analysis of Changchun Baike varicella vaccine.

Due to imbalances in variables, such as age and dose number between the vaccinated and unvaccinated groups, propensity score matching (PSM) was used to balance covariates. A 1:1 matching ratio was applied with a caliper value of 0.2 and random seed of 50. Logistic regression was used to estimate propensity scores, and nearest-neighbor matching was used. Considering that the vaccinated group was smaller, the unvaccinated group was matched with replacement, with each unvaccinated subject matched no more than three times [9].

2.3. Statistical Analysis

Data collected in this study were organized using Excel 365. Descriptive epidemiological methods and SPSS 22.0 were used for count data analysis, with chi-square tests ($p < 0.05$ indicating statistical significance). Varicella incidence trend was analyzed using the Joinpoint regression model. Data were processed using SPSS 24.0 after PSM was performed using the MatchIt package in R (version 4.4.1). Additionally, the survival package was used for stratified Cox regression analysis. Covariate distributions between the vaccinated and unvaccinated groups were compared using chi-square tests ($\alpha = 0.05$). Notably, the Kaplan–Meier survival curves showed no crossover, meeting the Cox regression assumptions. Disease occurrence was the dependent variable, with covariates included in the stratified Cox regression model to calculate the adjusted hazard ratios (aHR) and 95% confidence intervals (CI). Additionally, adjusted vaccine efficacy (aVE) was calculated as $(1 - \text{aHR}) \times 100\%$ [9].

2.4. Ethical reflections

Informed consent was secured from all study participants; they were apprised of their right to withdraw from the study and assured that their data would remain strictly confidential and utilized solely for scientific analysis. The research was executed in accordance with the principles of the Declaration of Helsinki and received approval from the Institutional Review Board of Yanbian University. (Ethics Code: 10249).

3. Results

3.1. Temporal Distribution

In total, 2,452 varicella cases were reported in Yanji from 2018 to 2024, with an average annual incidence rate of 62.71 per 100,000 population. Although not statistically significant, the incidence rate decreased during this period. Cases were reported monthly, with a biphasic pattern peaking from April to July (31.83%, 2,219/6,972 cases) and from October to January of the following year (51.71%, 3,605/6,972 cases) (Figures 1–3).

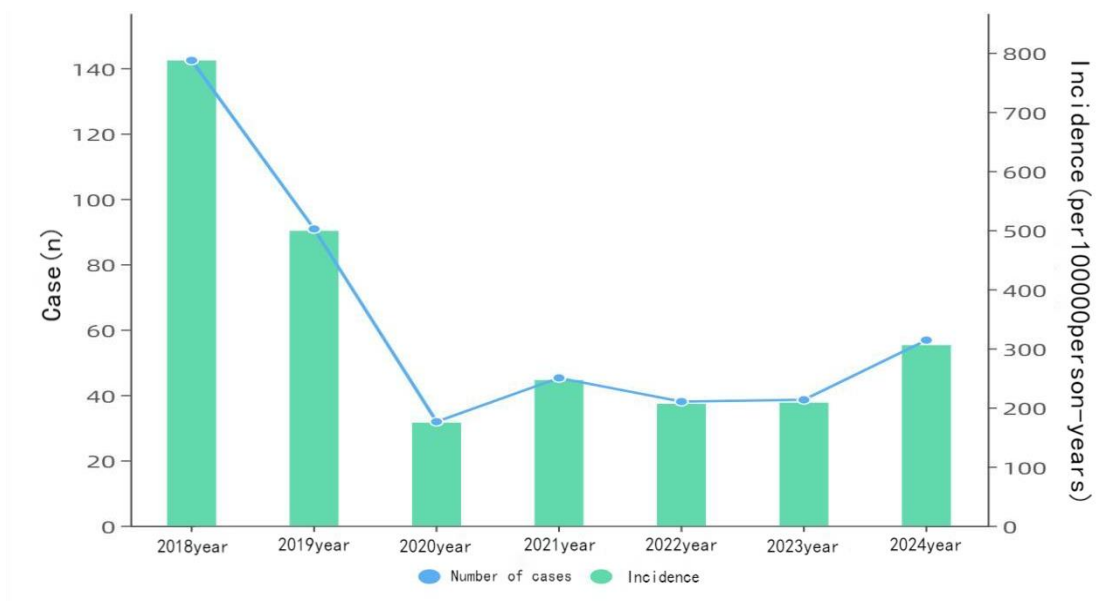


Figure 1. Varicella case counts and incidence rates in Yanji city from 2018 to 2024.

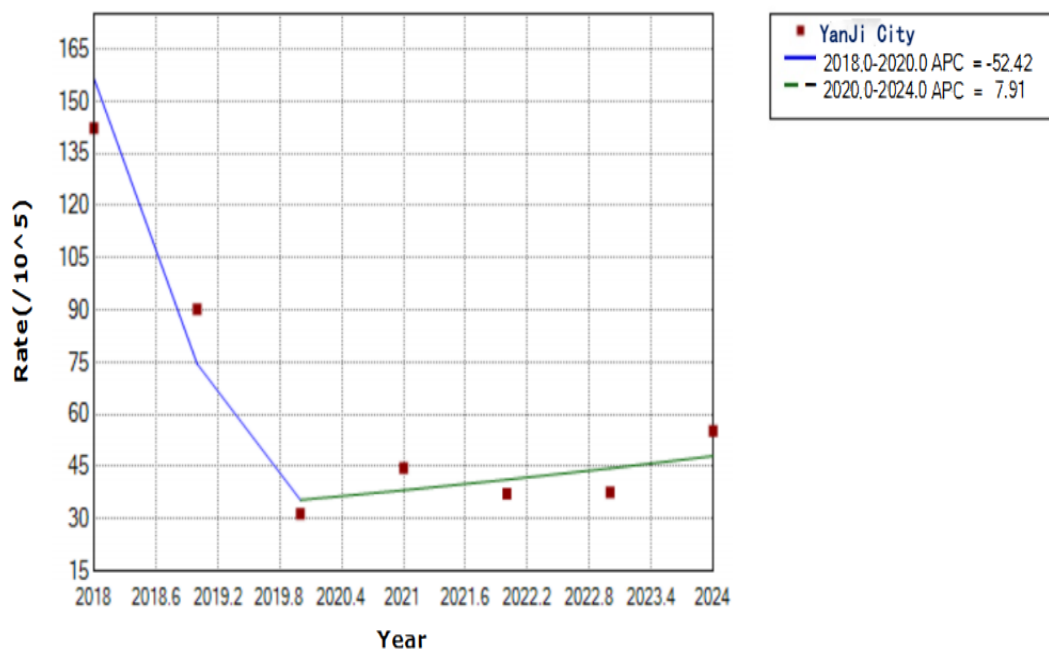


Figure 2. Trends in varicella incidence rates in Yanji city from 2018 to 2024.

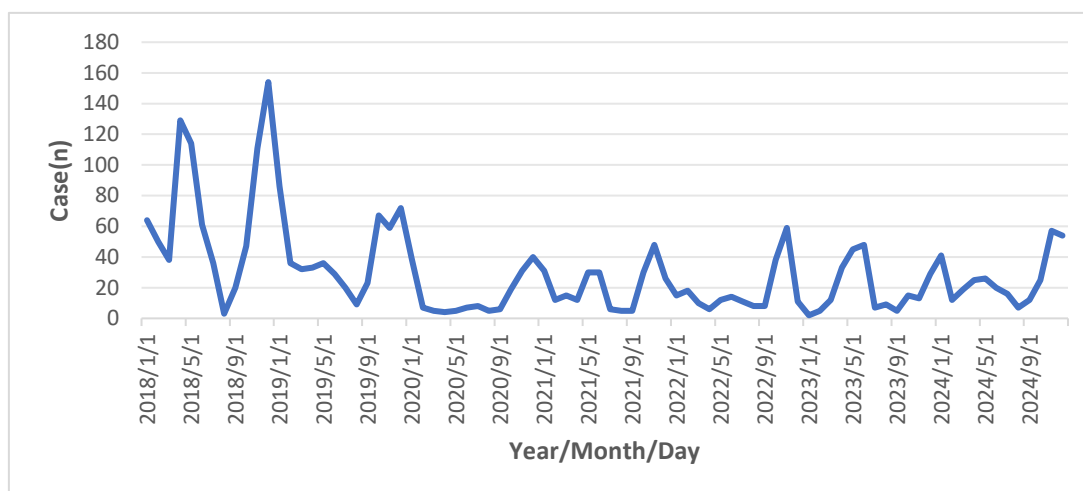


Figure 3. Monthly distribution of varicella cases in Yanji city from 2018 to 2024.

3.2. Spatial Distribution

All six streets and four towns in Yanji reported varicella cases from 2018 to 2024, with annual incidence rates ranging from 7.29 per 100,000 population (Xinxing Street) to 20.16 per 100,000 population (Jin Xue Street). Although not statistically significant, the incidence rate decreased in all areas (Figure 4).

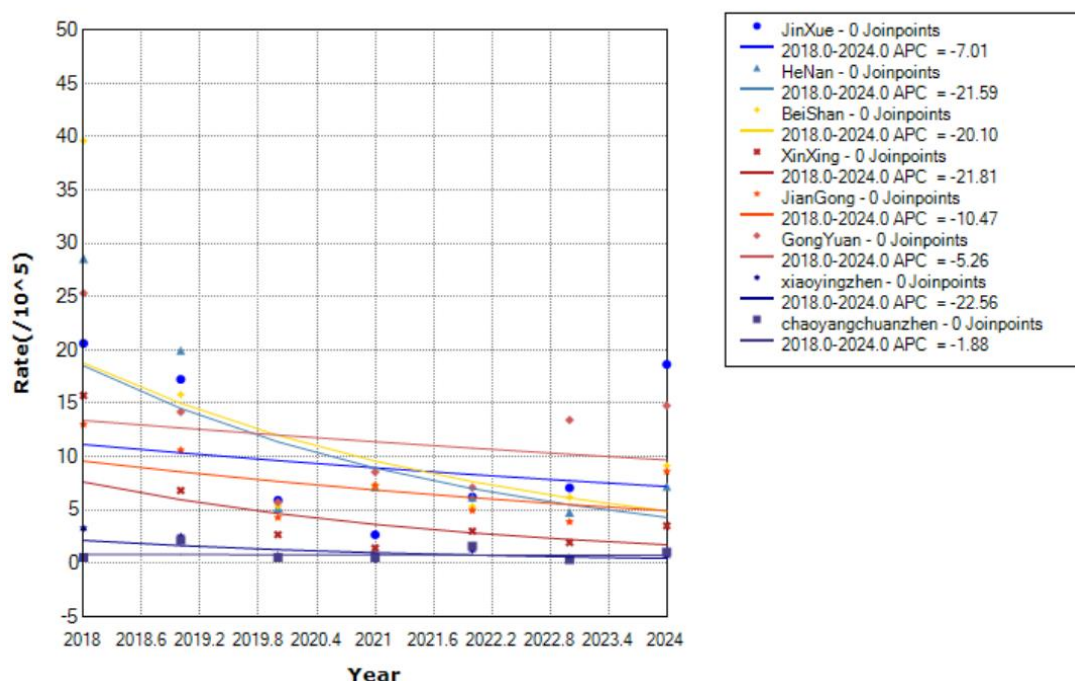


Figure 4. Trends in varicella incidence rates in six streets and four towns in Yanji city from 2018 to 2024.

3.3. Population Distribution

3.3.1. Sex Distribution

From 2018 to 2024, 1,366 male and 1,086 female cases were reported, with a sex ratio of 1.26:1. Additionally, the annual incidence rates were 34.93 per 100,000 males and 27.77 per 100,000 females.

Moreover, varicella incidence declined for both sexes, with a faster decline in males (APC = -14.62, $p < 0.01$) than in females (Figure 5).

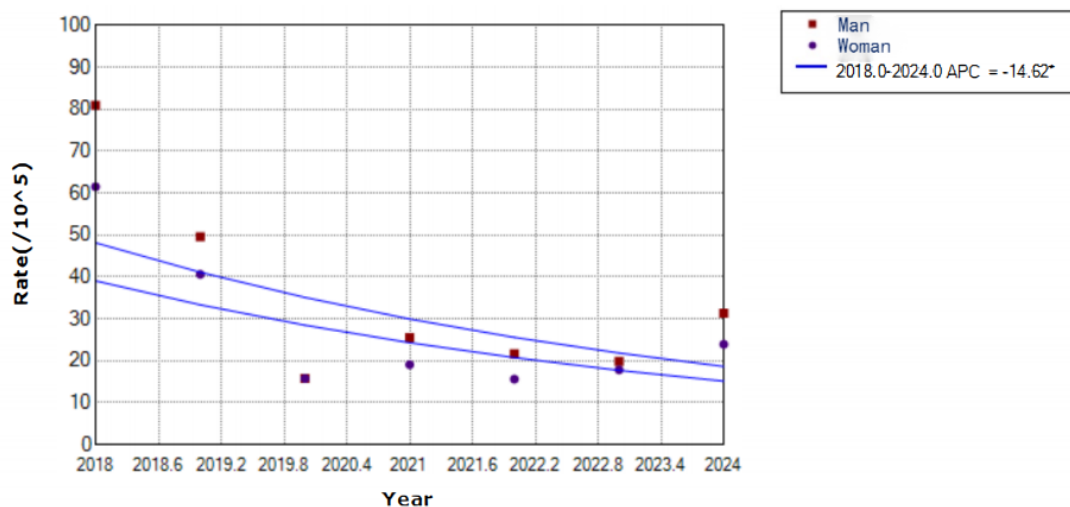


Figure 5. Trends in varicella incidence rates by sex in Yanji city from 2018 to 2024.

3.3.2. Age Distribution

From 2018 to 2024, children aged 0–12 years accounted for 1,337 cases (54.53%), whereas those aged 35–49 years accounted for 96 cases (3.92%). Notably, the annual incidence rates per 100,000 population by age group were: 0–4 years (4.67), 5–9 years (17.32), 10–14 years (18.08), 15–19 years (11.41), 20–24 years (3.80), 25–29 years (3.12), 30–34 years (2.38), 35–39 years (1.71), and ≥ 40 years (0.89). Additionally, the 10–14 years age group had the highest incidence, with a declining trend (APC = -8.79%, $p < 0.01$), followed by the 5–9 years age group. Moreover, the 0–4 age years group showed the fastest decline (APC = -32.74%, $p < 0.01$), followed by the 30–34 years age group (APC = -14.72%, $p < 0.01$). However, the other age groups showed no significant trends (Figure 6).

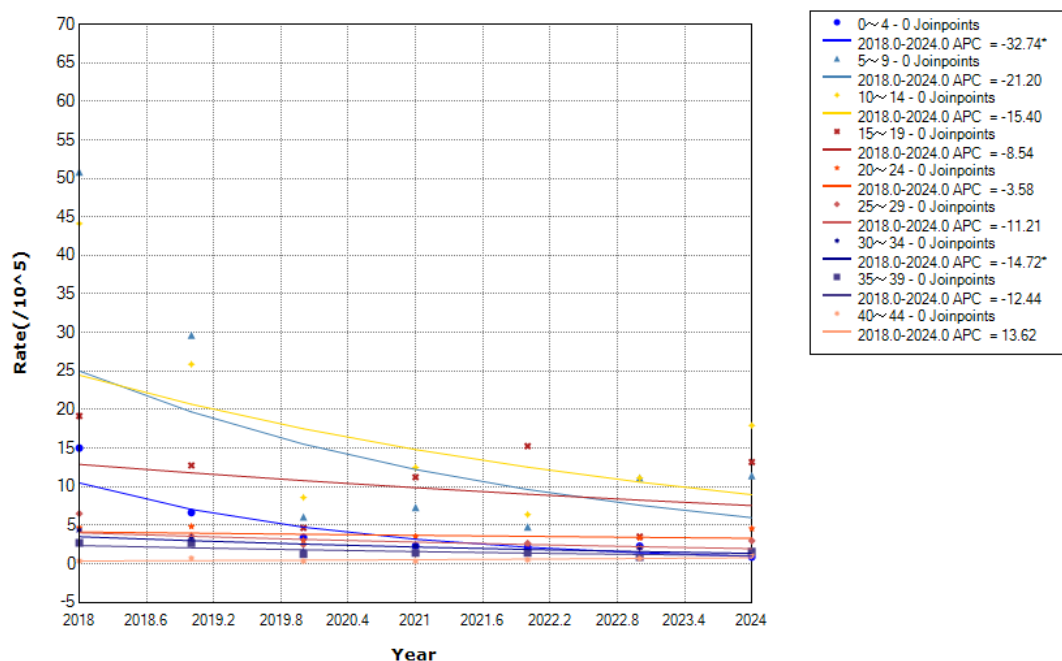


Figure 6. Trends in varicella incidence rates by age group in Yanji city from 2018 to 2024.

3.3.3. Occupational Distribution

In this study, the top three occupations among varicella cases from 2018 to 2024 were students (69.86%), preschool children (13.34%), and unemployed/household workers (8.24%) (Figure 7).

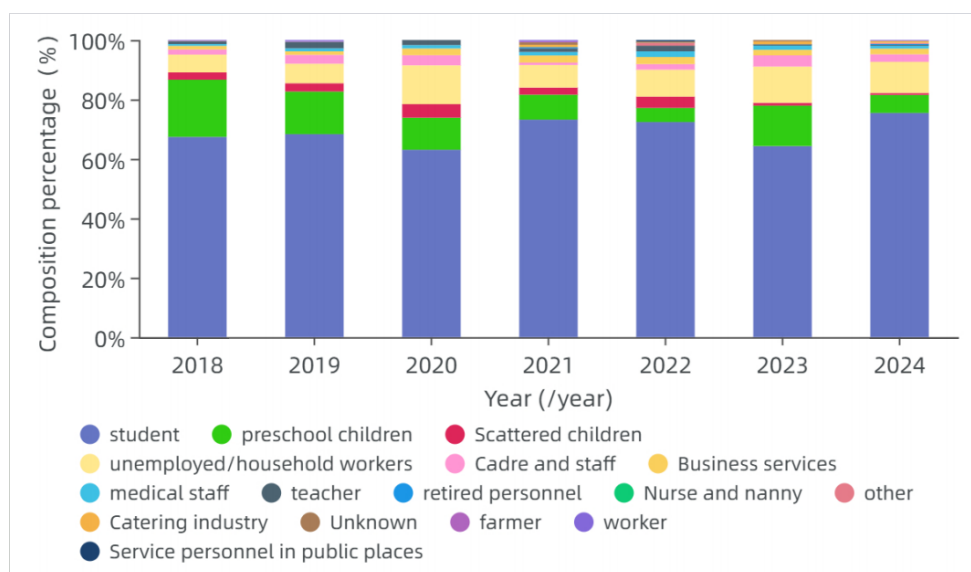


Figure 7. Occupational distribution of varicella cases in Yanji city from 2018 to 2024.

3.3.4. Vaccination Status

In total, 31,088 doses of varicella vaccine were administered in Yanji from 2018 to 2020, including 5,091 doses of Changchun Baike vaccine (16.38% of total doses). In 2018, 3,491 doses of Changchun Baike vaccine were administered (28.3% of total vaccinations), with Henan street having the highest proportion (35.7%) and Sandaowan town the lowest (0%). In 2019, 641 doses were administered (7.34%), with Jin Xue street having the highest proportion (11.3%) and Sandaowan town the lowest (0%). In 2020, 959 doses were administered (9.58%), with Chaoyangchuan and Sandaowan towns having the highest (76.1%) and lowest (0%) proportions, respectively (Tables 1–3).

Table 1. Proportion of Changchun Baike Varicella vaccine in Yanji City, 2018.

Region	Total varicella vaccinations	Changchun Baike vaccinations	Proportion (%)
Yanji city	12,342	3,491	28.3
Jin Xue street	2,198	631	28.7
Beishan street	1,999	487	24.4
Xinxing street	1,771	373	21.1
Jiangong street	2,647	723	27.3
Henan street	1,780	636	35.7
Gongyuan street	2,062	522	25.3
Chaoyangchuan town	234	71	30.3
Yilan town	523	25	4.7
Xiaoying town	77	23	29.8
Sandaowan town	0	0	0

Table 2. Proportion of Changchun Baike Varicella vaccine in Yanji City, 2019.

Region	Total varicella vaccinations	Changchun Baike vaccinations	Proportion (%)
Yanji city	8735	641	7.34
Jin Xue street	1203	137	11.3
Beishan street	1169	39	3.3
Xinxing street	766	57	7.4
Jiangong street	2120	161	7.6
Henan street	1619	161	9.9
Gongyuan street	1602	202	10.1
Chaoyangchuan town	164	15	9.1
Yilan town	25	5	20
Xiaoying town	69	2	2.8
Sandaowan town	0	0	0

Table 3. Proportion of Changchun Baike Varicella vaccine in Yanji City, 2020.

Region	Total varicella vaccinations	Changchun Baike vaccinations	Proportion (%)
Yanji city	10011	959	9.58
Jin Xue street	1249	85	6.8
Beishan street	1256	43	3.4
Xinxing street	996	40	4
Jiangong street	1917	269	14
Henan street	1171	15	1.2
Gongyuan street	2105	232	11
Chaoyangchuan town	210	160	76.1
Yilan town	20	10	50
Xiaoying town	139	105	75.5
Sandaowan town	0	0	0

3.4. Vaccine Protective Efficacy

3.4.1. Protective Efficacy of Changchun Baike Varicella Vaccine, 2018–2022

For one-dose vaccination, 558,172 cases met the inclusion criteria: 1,904 vaccinated and 70,882 unvaccinated cases in the < 15 years age group and 23 vaccinated and 485,363 unvaccinated cases in the ≥ 15 years age group, with significant age differences ($p < 0.001$). After 1:1 PSM, 1,927 case-control pairs showed no significant age differences ($p > 0.05$). For two-dose vaccination, 558,172 cases were included: 1,559 vaccinated and 71,241 unvaccinated in the < 15 age group and 9 vaccinated and 485,363 unvaccinated in the ≥ 15 age group, with significant age differences ($p < 0.001$). After PSM, 1,568 pairs showed no significant differences ($p > 0.05$). For one- or two-dose schedule, 557,972 cases were included: 3,463 vaccinated and 69,386 unvaccinated in the < 15 years age group and 32 vaccinated and 485,091 unvaccinated in the ≥ 15 years age group, with significant differences ($p < 0.001$). After PSM, 3,495 pairs showed no significant differences ($p > 0.05$). Cox regression showed that the varicella-positive risk in the one-dose vaccinated group was 0.01 times that of the unvaccinated group (OR = 0.01, 95% CI: 0.01–0.02; $p < 0.001$), with a protective efficacy of 99.0% (95% CI: 98.0–99.0%). Additionally, the efficacy of two doses and combined doses was 99.0% (95% CI: 98.0–99.0%) (Tables 4 and 5).

Table 4. Distribution characteristics of vaccinated and unvaccinated groups before and after PSM, 2018–2022.

Variable	Before matching				X2	p	After matching				X2	p
	Unvaccinated group		Vaccinated group				Unvaccinated group		Vaccinated group			
	Cases	Proportion (%)	Cases	Proportion (%)			Cases	Proportion (%)	Cases	Proportion (%)		
1 Dose												
< 15	70882	12.74	1904	98.81	12543.498	<.001	1904	98.81	1904	98.81	0.000	1.000
≥ 15	485363	87.26	23	1.19			23	1.19	23	1.19		
2 Doses												
< 15	71241	12.80	1559	99.43	10345.675	<.001	1559	99.43	1559	99.43	0.000	1.000
≥ 15	485363	87.20	9	0.57			9	0.57	9	0.57		
1 or 2 Doses												
< 15	69386	12.55	3463	99.08	19121.808	<.001	3463	99.08	3463	99.08	0.000	1.000
≥ 15	485091	87.45	32	0.92			32	0.92	32	0.92		

Table 5. Cox regression analysis of changchun Baike Varicella vaccine, 2018–2022.

Variable	β	S.E	Z	p	HR (95% CI)	aVE (%) (95% CI)
Doses						
0	-	-	-	-	1.00 (Reference)	-
1	-4.68	0.29	-16.14	<.001	0.01 (0.01–0.02)	99.0 (98.0–99.0)
2	-4.70	0.30	-15.51	<.001	0.01 (0.01–0.02)	99.0 (98.0–99.0)
All Doses	-4.22	0.21	-20.09	<.001	0.01 (0.01–0.02)	99.0 (98.0–99.0)

3.4.2. Protective Efficacy of Changchun Baike Varicella Vaccine, 2019–2023

For one-dose vaccination, 560,743 cases were included: 321 vaccinated and 72,273 unvaccinated in the < 15 years age group and 22 vaccinated and 488,127 unvaccinated in the ≥ 15 years age group, with significant age differences ($p < 0.001$). After 1:1 PSM, 343 pairs showed no significant differences ($p > 0.05$). For two-dose vaccination, 560,743 cases were included: 321 vaccinated and 72,273 unvaccinated in the < 15 years age group and 22 vaccinated and 488,127 unvaccinated in the ≥ 15 years age group, with significant differences ($p < 0.001$). After PSM, 343 pairs showed no significant differences ($p > 0.05$). For one or two vaccine doses, 561,502 cases were included: 642 vaccinated and 72,139 unvaccinated in the < 15 years age group and 44 vaccinated and 488,677 unvaccinated in the ≥ 15 years age group, with significant differences ($p < 0.001$). After PSM, 686 pairs showed no significant differences ($p > 0.05$). Cox regression analysis showed that varicella-positive risk in the one- and two-dose vaccinated groups was 0.01 times that of the unvaccinated group (OR = 0.01, 95% CI: 0.00–0.03; $p < 0.001$), with a protective efficacy of 99.0% (95% CI: 97.0%–100.0%). For one or two doses, the risk was 0.01 times (OR = 0.01, 95% CI: 0.01–0.02; $p < 0.001$), with an efficacy of 99.0% (95% CI: 97.0%–100.0%) (Tables 6 and 7).

Table 6. Distribution characteristics of vaccinated and unvaccinated groups before and after PSM, 2019–2023.

Variable	Before matching				X2	p	After matching				X2	p
	Unvaccinated group		Vaccinated group				Unvaccinated group		Vaccinated group			
	Cases	Proportion (%)	Cases	Proportion (%)			Cases	Proportion (%)	Cases	Proportion (%)		
1 Dose												
< 15	72273	12.90	321	93.59	1660.372	<.001	321	93.59	321	93.59	0.000	1.000
≥ 15	488127	87.10	22	6.41			22	6.41	22	6.41		
2 Dose												
< 15	72273	12.90	321	93.59	1660.372	<.001	321	93.59	321	93.59	0.000	1.000

≥ 15	488127	87.10	22	6.41		22	6.41	22	6.41			
1 or 2 Doses												
< 15	72139	12.79	642	93.59	6371.477	<.001	642	93.59	642	93.59	0.000	1.000
≥ 15	488677	87.21	44	6.41			44	6.41	44	6.41		

Table 7. Cox regression analysis of Changchun Baike Varicella vaccine, 2019–2023.

Variable	β	S.E	Z	<i>p</i>	HR (95% CI)	aVE (%) (95% CI)
Doses						
0	-	-	-	-	1.00 (Reference)	-
1	-4.99	0.71	-7.04	<.001	0.01 (0.00–0.03)	99.0 (97.0–100.0)
2	-4.99	0.71	-7.04	<.001	0.01 (0.00–0.03)	99.0 (97.0–100.0)
All Doses	-4.59	0.58	-7.91	<.001	0.01 (0.01–0.02)	99.0 (97.0–100.0)

3.4.3. Protective Efficacy of Changchun Baike Varicella Vaccine, 2020–2024

For one-dose vaccination, 506,747 cases were included: 325 vaccinated and 72,273 unvaccinated in the < 15 years age group and 22 vaccinated and 488,127 unvaccinated in the ≥ 15 years age group, with significant age differences ($p < 0.001$). After 1:1 PSM, 343 pairs showed no significant differences ($p > 0.05$). For two-dose vaccination, 561,826 cases were included: 606 vaccinated and 72,130 unvaccinated in the < 15 years age group and 6 vaccinated and 489,084 unvaccinated in the ≥ 15 years age group, with significant differences ($p < 0.001$). After PSM, 343 pairs showed no significant differences ($p > 0.05$). For one or two doses, 561,878 cases were included: 931 vaccinated and 71,857 unvaccinated in the < 15 years age group and 28 vaccinated and 489,062 unvaccinated in the ≥ 15 years age group, with significant differences ($p < 0.001$). After PSM, 959 pairs showed no significant differences ($p > 0.05$). Cox regression showed that the varicella-positive risk in the one-dose vaccinated group was 0.02 times that of the unvaccinated group (OR = 0.02, 95% CI: 0.00–0.07; $p < 0.001$), with a protective efficacy of 98.0% (95% CI: 97.0–99.0%). For two doses, the risk was 0.01 times (OR = 0.01, 95% CI: 0.00–0.02; $p < 0.001$), with an efficacy of 99.0% (95% CI: 98.0–100.0%). For one or two doses, the risk was 0.01 times, with an efficacy of 99.0% (95% CI: 98.0–100.0%) (Tables 8 and 9).

Table 8. Distribution characteristics of vaccinated and unvaccinated groups before and after PSM, 2020–2024.

Variable	Before matching				X2	<i>p</i>	After matching				X2	<i>p</i>
	Unvaccinated group		Vaccinated group				Unvaccinated group		Vaccinated group			
	Cases	Proportion (%)	Cases	Proportion (%)			Cases	Proportion (%)	Cases	Proportion (%)		
1 Dose												
< 15	72273	12.90	325	93.66	1660.372	<.001	321	93.59	321	93.59	0.000	1.000
≥ 15	488127	87.10	22	6.34			22	6.41	22	6.41		
2 Dose												
< 15	72130	12.85	606	99.02	3686.416	<.001	321	93.59	321	93.59	0.000	1.000
≥ 15	489084	87.15	6	0.97			22	6.41	22	6.41		
1 or 2 Doses												
< 15	71857	12.79	931	97.08	6371.477	<.001	931	97.08	931	97.08	0.000	1.000
≥ 15	489062	87.21	28	2.92			28	2.92	28	2.92		

Table 9. Cox regression analysis of Changchun Baike Varicella vaccine, 2020–2024.

Variable	β	S.E	Z	<i>p</i>	HR (95% CI)	aVE (%) (95% CI)
Doses						
0	-	-	-	-	1.00 (Reference)	-
1	-3.82	0.58	-6.54	<.001	0.02 (0.00 ~ 0.07)	98.0 (97.0~99.0)
2	-5.23	0.58	-9.04	<.001	0.01 (0.00 ~ 0.02)	99.0 (98.0~100.0)
All Doses	-4.63	0.41	-10.65	<.001	0.01 (0.01 ~ 0.03)	99.0 (98.0~100.0)

4. Discussion

In this study, we investigated the epidemiological characteristics of varicella and the protective efficacy of Changchun Baike in Yanji from 2018 to 2024. In total, 2,452 cases were reported from 2018 to 2024, with an average annual incidence rate of 62.71 per 100,000 population. Notably, the incidence rate declined from 142.37 per 100,000 in 2018 to 55.25 per 100,000 population by 2024. This decline is closely linked to the widespread use of Changchun Baike varicella vaccine, which reduces the risk of VZV transmission through humoral and cellular immunity [7]. Additionally, cases were concentrated among preschool and school-aged children, with a slightly higher incidence in males than in females. Moreover, the decline in the incidence rate was faster in males than in females during the period under consideration. Among the areas surveyed, the densely populated Jin Xue and Beishan streets had relatively high incidence rates. Additionally, the economically underdeveloped Sandaowan town had a higher transmission risk due to low vaccination coverage [10,11]. Vaccine efficacy analysis showed an adjusted efficacy of 98.0–99.0% (95% CI: 97.0–100.0%) for the one-dose schedule and 99.0% (95% CI: 98.0–100.0%) for the two-dose schedule, with latter schedule significantly outperforming the former schedule in preventing breakthrough infections [12,13]. However, breakthrough infections and inadequate vaccination coverage suggest the need for optimized vaccination strategies to further reduce the disease burden [14,15].

Consistent with findings in Qingyang, Gansu, and Shenyang [2,16], varicella incidence exhibited a distinct seasonal pattern, with peaks from April to July (31.83%) and October to January (51.71%). Winter peaks are associated with increased indoor gatherings and higher respiratory droplet transmission risk in cold conditions, whereas late spring to early summer peaks are correlated with increased school-related contact and social activities [7,8]. Despite the declining incidence, the seasonal pattern remained unchanged, indicating that VZV transmission is driven by climate and behavioral factors [17]. Enhanced surveillance in schools and childcare facilities during peak seasons is crucial for identifying and controlling outbreaks.

Spatially, all six streets and four towns reported cases with significant variations in incidence rates. Jin Xue and Beishan streets, with high population density and frequent mobility, were high-risk areas, reflecting the role of social contact in transmission chains [18–20]. Economically disadvantaged areas, such as Sandaowan town, had a higher transmission risk due to poor sanitation and low vaccination coverage [21]. Targeted interventions, including increased vaccination coverage, improved public health infrastructure, and health education, are necessary to reduce transmission in high-risk areas.

Regarding population distribution, cases were concentrated among children aged 0–14 years, with the 10–14 years age group having the highest incidence, followed by the 5–9 years age group. Preschool- and school-aged children are more susceptible to the disease than adults because of their underdeveloped immune systems and frequent contact in crowded settings [22,23]. Notably, the incidence rate increased in the ≥ 40 years age group, possibly due to waning single-dose vaccine efficacy or lack of vaccination in some adults [24]. Additionally, the higher incidence rate in males than in females may be due to more active social interactions, poorer hygiene, and lower parental acceptance of vaccination among males [25–27]. Male patients are more prone to complications, such as skin infections and pneumonia, which may increase the healthcare burden [28]. Moreover, occupational distribution highlighted students, preschool children, and unemployed/household workers as primary case groups, driven by school and childcare environments, low vaccination coverage, and limited parental awareness of vaccine safety [29,30].

Importantly, Changchun Baike varicella vaccine demonstrated excellent protective efficacy. One-dose aVE was 99.0% (95% CI: 98.0–99.0%) and two-dose was 99.0% (95% CI: 98.0–99.0%) from 2018 to 2022; both were 99.0% (95% CI: 97.0–100.0%) from 2019 to 2023; and one-dose was 98.0% (95% CI: 97.0–99.0%) and two-dose was 99.0% (95% CI: 98.0–100.0%) from 2020 to 2024. Cox regression confirmed that two-dose vaccination had a lower hazard ratio, offering significant advantages in preventing breakthrough infections [31]. Our results align with international findings, such as the > 90% incidence reduction in the U.S. after implementing a two-dose strategy [32]. However, the

incidence of breakthrough infections suggests that vaccine efficacy is influenced by individual immune responses, age at vaccination, and storage conditions [33]. Children vaccinated at ≤ 15 months had a higher infection risk, and single-dose antibody titers wane over time, whereas two doses significantly extend protection [31]. Economic barriers and insufficient health education limit second-dose uptake [17]. For example, the free two-dose policies in Shanghai and Tianjin significantly reduced the incidence of the disease [34,35]. Additionally, schools and childcare facilities should implement vaccination verification and routine VZV surveillance to curb varicella outbreaks [36]. Future research should focus on the long-term efficacy of two-dose vaccination schedule and the pathogenesis of breakthrough infections to optimize strategies and strengthen control measures.

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