

Vital Surveillances

Effectiveness of One- and Two-Dose Varicella Vaccination Among Children and Adolescents Aged 0–18 Years — Chaoyang District, Beijing, China, 2007–2025

Jianliang Zhao^{1,2}; Ziwei Zhao³; Chaofan Wang^{1,2}; Yang Cao³; Yeran Jiaerken^{1,2}; Hai Fang^{2,4,#}; Zhen Li^{3,#}

ABSTRACT

Introduction: Varicella is a highly contagious respiratory disease caused by the varicella-zoster virus that predominantly affects children and is prone to outbreaks in congregate settings. This study evaluated the effectiveness of varicella vaccination among children and adolescents aged 0–18 years in Chaoyang District and examined factors associated with infection risk.

Methods: A retrospective cohort study was conducted among 551,980 children and adolescents born between 2007 and 2025 using varicella surveillance data from the Chaoyang District Center for Disease Control and Prevention. Incidence rates were calculated, and vaccine effectiveness was estimated using Cox proportional hazards models.

Results: Among the 551,980 participants, 9,170 varicella cases were identified. The incidence rate was 20.79 per 1,000 person-years (PY) in the unvaccinated group, 2.28 per 1,000 PY in the one-dose group, and 0.34 per 1,000 PY in the two-dose group. Increasing vaccine dose number was significantly associated with a lower risk of infection. The cumulative incidence of varicella was lowest and most stable in the two-dose group during follow-up. Vaccine effectiveness (VE) was 96.8% [95% confidence interval (CI): 95.7%, 97.6%] for one-dose vaccination and 98.2% (95% CI: 97.9%, 98.5%) for two-dose vaccination. Males accounted for 56.2% of cases and had a slightly higher infection risk than females.

Conclusion: Two doses of varicella vaccine provided strong protection against varicella. These findings support efforts to increase two-dose vaccination coverage and optimize varicella immunization schedules.

varicella-zoster virus. Before widespread vaccination, it was endemic among children globally; in regions without vaccination programs, nearly all individuals acquired infection by early adulthood (1). In the 1970s, the first live attenuated varicella vaccine was developed in Japan, marking a pivotal advancement in prevention and control. Subsequent evidence has demonstrated that varicella vaccination is among the most cost-effective interventions for reducing disease burden at the population level.

Vaccine effectiveness is influenced by multiple factors, including dosage, age at vaccination, interval between doses, timing of vaccination, sex, geographic region, and population characteristics (2–3). In addition, vaccine-induced immunity, particularly after single-dose vaccination, wanes over time, contributing to breakthrough infections (4). These issues highlight the need to further optimize immunization strategies. In China, most studies on varicella vaccine effectiveness have been conducted in first-tier cities in southern regions, while real-world evidence from northern China remains limited. A global meta-analysis has also reported substantial regional heterogeneity in vaccine effectiveness, underscoring the importance of local epidemiological evaluation (5). Moreover, vaccination coverage in China varies considerably across regions due to differences in health policy implementation and socioeconomic development. Chaoyang District, a highly urbanized area with dense population and relatively high vaccination coverage, provides a representative setting for evaluating real-world vaccine performance. This study uses a large retrospective cohort to address evidence gaps in northern China and inform optimization of varicella immunization schedules.

METHODS

Setting and Participants

Chaoyang District, located in eastern Beijing, is one

Varicella is a highly contagious disease caused by

of six central urban districts of the city, with a permanent population exceeding 3 million. The city has a high density of kindergartens, primary schools, and secondary schools, resulting in frequent contact among children and adolescents. The study included all permanent residents born between 2007 and 2025. Inclusion required complete varicella vaccination records and reliable infection history data, enabling longitudinal follow-up and estimation of vaccine effectiveness.

Data Sources

Data were obtained from the Chaoyang District CDC. Since 2007, the CDC has maintained an electronic immunization registry linking vaccination records with disease surveillance data for all registered residents. Individuals without varicella vaccination were defined as the reference group, and vaccine protection was assumed to begin 42 days after vaccination.

Varicella case data were extracted from the national Infectious Disease Reporting Information Management System. All confirmed cases must be reported by medical institutions within 24 hours of diagnosis. Subsequently, community health centers complete case investigation and specimen collection within 48 hours. Surveillance procedures follow the Beijing Municipal Varicella Surveillance Protocol, supported by annual training of healthcare personnel and quarterly supervisory inspections. These measures are designed to minimize underreporting and misclassification of cases.

The vaccination strategy in Chaoyang District follows a standard two-dose schedule. Individuals aged ≥ 13 years primarily represent catch-up vaccination recipients.

Statistical Analysis

Baseline characteristics included age, sex, vaccination status, and infection outcomes. Incidence rates were calculated as the number of cases per person-years of follow-up. Kaplan-Meier survival curves were used to describe cumulative incidence of varicella across vaccination groups. Vaccination status at baseline was fixed for descriptive Kaplan-Meier analyses and not updated during follow-up.

A time-dependent Cox proportional hazards model was used to estimate the association between vaccination and varicella risk: $h(t) = h_0(t) \cdot \exp(\beta_1 V_{ax1}(t) + \beta_2 V_{ax2}(t) + \gamma_1 X_1 + \dots + \gamma_p X_p)$. Covariates included sex

and age group (0–1, 1–3, 4–6, and 7–18 years). Entry time was defined as date of birth (earliest cohort: January 1, 2007), and exit time was defined as date of varicella onset for cases or December 31, 2025 for non-cases. Individuals contributed person-time to the unvaccinated category until vaccination, after which they were reclassified into one-dose or two-dose groups following a predefined immune activation period. No loss to follow-up or death was recorded. Hazard ratios (HRs) with 95% confidence intervals (CIs) were estimated, and vaccine effectiveness was calculated as vaccine effectiveness (VE) = $(1 - HR) \times 100\%$. Sensitivity analyses were conducted by varying assumed immunity onset periods to evaluate robustness.

All statistical analyses were performed using R (version 4.5.2; R Foundation, Vienna, Austria). A two-sided $P < 0.05$ was considered statistically significant.

RESULTS

A total of 551,980 individuals were included in the cohort. Among them, 68% received two doses of varicella vaccine, 19.4% received one dose, and 12.6% remained unvaccinated. The cohort included 287,151 males and 264,829 females, with a relatively balanced sex distribution. Participants ranged from 0 to 18 years of age, with broad representation across childhood and adolescence. During follow-up, 9,170 varicella cases were identified. Among cases, 62.1% were unvaccinated, 22.4% received one dose, and 15.5% received two doses. Male cases accounted for 56.2%, slightly higher than their proportion in the cohort (52.0%), while female cases accounted for 43.8%.

Vaccination coverage varied across birth cohorts. From 2007 to 2018, two-dose coverage increased steadily, while one-dose-only coverage declined, reflecting improved completion of the full schedule. From 2022 onward, observed reductions in coverage indicators and shifts in dose distribution were primarily attributable to incomplete follow-up among younger cohorts rather than true changes in vaccination uptake. The 2025 birth cohort contributed limited follow-up time but still accounted for 8 observed cases, reflecting early-life exposure among unvaccinated individuals (Table 1).

Incidence rates decreased markedly with the increasing number of vaccine doses. Compared with the two-dose group, incidence was approximately 6.71 times higher in the one-dose group and 61.15 times higher in the unvaccinated group. These findings demonstrate a clear dose-response relationship, with

TABLE 1. Distribution of the vaccination cohort by birth cohort ($N=551,980$).

Birth cohort	N	1-dose		2-dose			
		1-dose average age (years)	Coverage rate of only 1-dose (%)	2-dose average age (years)	Average interval between the doses (months)	2-dose coverage rate (%)	Coverage rate of ≥ 1 -dose (%)
2007	27,558	2.23 $\pm$ 2.18	31.45	6.96 $\pm$ 2.29	63.38 $\pm$ 29.10	57.96	89.40
2008	25,859	2.20 $\pm$ 2.12	25.72	6.13 $\pm$ 2.26	53.66 $\pm$ 28.23	66.33	92.05
2009	25,587	2.27 $\pm$ 2.09	19.47	5.43 $\pm$ 2.15	44.85 $\pm$ 26.20	74.27	93.74
2010	25,226	2.18 $\pm$ 2.05	17.2	5.27 $\pm$ 2.01	43.15 $\pm$ 24.65	77.48	94.69
2011	29,784	2.24 $\pm$ 2.05	13.51	5.08 $\pm$ 1.71	40.25 $\pm$ 21.58	81.75	95.26
2012	36,171	2.66 $\pm$ 1.99	12.21	5.03 $\pm$ 1.65	34.55 $\pm$ 20.20	82.88	95.09
2013	32,847	2.59 $\pm$ 1.89	11.61	4.78 $\pm$ 1.33	32.24 $\pm$ 16.48	83.86	95.48
2014	42,614	2.52 $\pm$ 1.69	10.42	4.67 $\pm$ 1.06	31.20 $\pm$ 13.66	85.33	95.75
2015	26,475	2.43 $\pm$ 1.59	9.61	4.64 $\pm$ 0.96	31.27 $\pm$ 12.60	86.13	95.74
2016	41,509	2.34 $\pm$ 1.47	8.56	4.51 $\pm$ 0.83	30.36 $\pm$ 11.12	87.72	96.28
2017	35,001	2.30 $\pm$ 1.38	7.79	4.49 $\pm$ 0.82	30.31 $\pm$ 11.04	88.86	96.65
2018	29,121	2.57 $\pm$ 1.49	5.56	4.57 $\pm$ 0.76	31.12 $\pm$ 10.34	91.37	96.93
2019	31,814	2.21 $\pm$ 1.15	6.34	4.35 $\pm$ 0.56	30.21 $\pm$ 7.96	89.51	95.86
2020	27,040	2.04 $\pm$ 0.80	10.08	4.21 $\pm$ 0.33	28.55 $\pm$ 6.02	85.94	96.02
2021	22,850	2.00 $\pm$ 0.62	21.46	4.10 $\pm$ 0.20	27.29 $\pm$ 4.92	73.78	95.24
2022	22,165	1.83 $\pm$ 0.36	92.59	2.54 $\pm$ 0.73	14.24 $\pm$ 7.67	0.53	93.12
2023	22,453	1.77 $\pm$ 0.23	86.91	1.74 $\pm$ 0.41	6.64 $\pm$ 3.36	0.11	87.03
2024	23,768	1.64 $\pm$ 0.19	22.69	1.44 $\pm$ 0.16	4.87 $\pm$ 2.19	0.04	22.72
2025	24,138		0			0	0
Total	551,980	2.08 $\pm$ 1.42	19.36	4.85 $\pm$ 1.48	35.26 $\pm$ 19.03	68.04	87.40

Note: The apparent decline in 2-dose coverage among recent birth cohorts should be interpreted as a consequence of insufficient follow-up time, rather than a true decline in vaccination uptake.

two-dose vaccination conferring the strongest protection (Table 2).

Kaplan-Meier curves (Figure 1) demonstrated the highest cumulative incidence in the unvaccinated group, reaching approximately 0.20 by 15 years of follow-up. The one-dose group showed an intermediate trajectory, while the two-dose group consistently exhibited the lowest cumulative incidence and the flattest curve, indicating sustained and stable protection over time.

Sensitivity analyses confirmed that vaccine effectiveness remained high under different assumptions regarding immunity onset (28 days, 42 days, and 3 months). At 42 days post-vaccination, VE was 96.8% for one dose and 98.2% for two doses. When immunity onset was assumed at 28 days, estimates were slightly higher, whereas extending onset to 3 months resulted in modestly lower VE estimates, although overall protection remained strong. These consistent findings support the robustness of the results (Table 3).

The 42-day immunity onset period was selected based on immunological evidence indicating that protective antibody levels are typically achieved within 4–6 weeks after vaccination. This definition reduces misclassification of early infections as vaccine failures while avoiding overestimation associated with very short post-vaccination windows.

DISCUSSION

This study demonstrates high real-world effectiveness of varicella vaccination in an urban Beijing population, with particularly strong protection conferred by the two-dose regimen. Several factors may contribute to the relatively high effectiveness observed. First, prior surveillance data from Beijing (2011–2017) reported two-dose vaccine effectiveness of 94.4% (6), consistent with the present findings. Chaoyang District benefits from well-developed public health infrastructure and high vaccination adherence (7). In this study, two-dose coverage reached 68.04%. Earlier

TABLE 2. Varicella incidence rates by doses received.

Vaccination status	N	Cases	Person-years	Incidence rate (/1,000 PY)
Unvaccinated	69,565	5,693	273,841	20.79
1 dose	106,855	2,056	900,734	2.28
2 doses	375,560	1,421	4,160,606	0.34
Total	551,980	9,170	5,335,181	1.72

Note: In this descriptive table, participants were classified according to their final (cumulative) vaccination status at the end of follow-up. Abbreviation: PY=person-years.

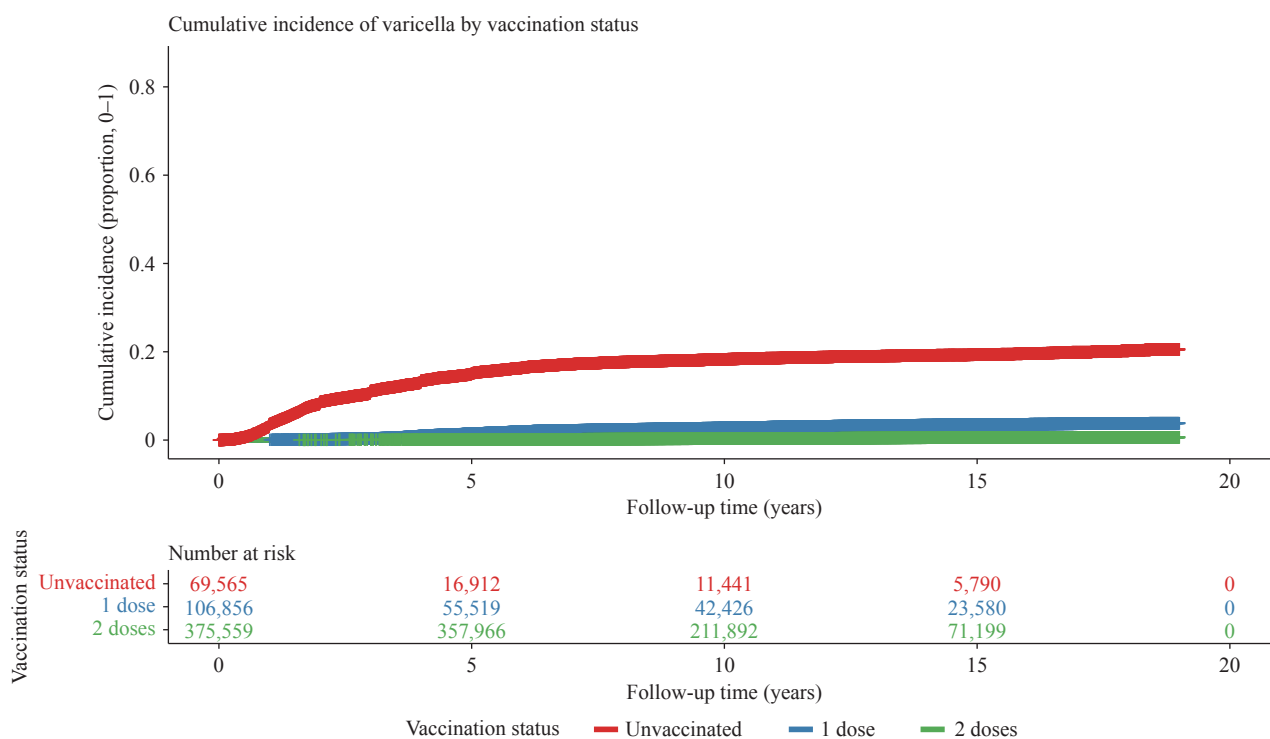


FIGURE 1. Cumulative incidence of varicella by vaccination status.

Note: The cohort only tracks individuals up to the age of 18, so the corresponding value for age 20 is 0.

TABLE 3. HR and VE of varicella vaccine.

Immune onset period	Doses received	HR (95% CI)	VE (%) (95% CI)
28 days	1	0.014 (0.012–0.017)	98.6 (98.3–98.8)
	2	0.014 (0.011–0.016)	98.6 (98.4–98.9)
42 days	1	0.032 (0.024–0.043)	96.8 (95.7–97.6)
	2	0.018 (0.015–0.021)	98.2 (97.9–98.5)
3 months	1	0.077 (0.060–0.099)	92.3 (90.1–94.0)
	2	0.044 (0.038–0.053)	95.6 (94.7–96.2)

Note: Cox proportional hazards regression models were adjusted for gender and age group.

Abbreviation: HR=hazard ratio; VE=vaccine effectiveness; CI=confidence interval.

completion of the second dose and shorter dosing intervals have been shown to enhance immunogenicity

and vaccine effectiveness (8). Second, the high population density in Chaoyang District may facilitate stronger herd immunity effects once vaccination coverage exceeds a critical threshold (9). Widespread immunization reduces circulation of varicella-zoster virus, thereby lowering exposure risk even among susceptible individuals. Third, non-pharmaceutical interventions introduced during the coronavirus disease 2019 (COVID-19) pandemic, such as masking, environmental disinfection, and school-based infection control measures, likely reduced transmission of multiple respiratory infections, including varicella (10). However, these interventions may also have reduced overall exposure risk differentially across cohorts. Later birth cohorts with higher vaccination coverage were more likely to contribute follow-up during the pandemic period. Consequently, vaccine effectiveness

estimates based on the full cohort may be modestly inflated relative to non-pandemic conditions.

Despite high effectiveness of a single dose, a two-dose regimen remains strongly recommended. Although short-term protection after one dose appears substantial, evidence indicates waning immunity over time and increased risk of breakthrough infection. In contrast, two-dose vaccination provides more durable immunity and more consistent protection across age groups. In addition, higher completion of the two-dose schedule enhances herd immunity and reduces outbreak potential in school and childcare settings.

A slight male predominance in varicella cases was observed (56.2%), consistent with national epidemiological data showing higher incidence in males under 20 years (11). Similar sex-related differences in vaccine response and immune outcomes have been reported internationally (12), although underlying biological mechanisms remain unclear. These findings suggest potential value in incorporating sex-specific considerations into future prevention strategies.

This study has several limitations. First, as a single-center study conducted in a highly urbanized district, generalizability to rural or less developed regions may be limited (13–14). Second, individual-level confounders such as baseline health status, socioeconomic status, household size, and school attendance were not included (3,15). Third, vaccine brand was not captured, although prior studies have reported variability in effectiveness across manufacturers (13). Adjustment was limited to age, sex, and birth year, which may have introduced residual confounding and led to slight overestimation of vaccine effectiveness (16).

Interpretation of findings from the 2025 birth cohort should be cautious due to limited follow-up time and incomplete vaccination eligibility, which may affect descriptive comparisons but does not materially influence overall time-to-event estimates.

In conclusion, this study provides robust real-world evidence that varicella vaccination is highly effective in an urban Beijing setting. Two-dose vaccination provides stronger and more durable protection than a single dose. These findings support efforts to increase two-dose coverage, particularly in regions with lower uptake, and to further optimize immunization schedules. Future research should adopt multicenter designs, incorporate additional individual-level confounders, and extend follow-up duration to better characterize long-term vaccine effectiveness and

immunity waning.

Conflicts of interest: No conflicts of interest.

Ethical statement: Ethical approval was obtained from the Peking University Biomedical Ethics Review Committee (IRB00001052-24053).

Funding: Supported by the Beijing Natural Science Foundation Changping Innovation Joint Fund (Key Research Topic) (Grant No. L234005).

doi: 10.46234/ccdcw2026.131

Corresponding authors: Zhen Li, cyqwjwcdclz01@bjchy.gov.cn; Hai Fang, hfang@hsc.pku.edu.cn.

¹ School of Public Health, Peking University, Beijing, China; ² China Center for Health Development Studies, Peking University, Beijing, China; ³ Chaoyang District Center for Disease Control and Prevention (Chaoyang District Health Supervision Institute), Beijing, China; ⁴ National Health Committee Key Laboratory of Health System Reform and Governance, Peking University, Beijing, China.

Copyright © 2026 by Chinese Center for Disease Control and Prevention & Chinese Academy of Preventive Medicine. All content is distributed under a Creative Commons Attribution Non Commercial License 4.0 (CC BY-NC).

Submitted: April 15, 2026

Accepted: May 25, 2026

Issued: June 26, 2026

REFERENCES

1. World Health Organization. WHO position paper on varicella vaccines. 2025. <https://www.who.int/publications/i/item/who-wer10047-567-590>. [2025-11-21].
2. Danino D, Kalron Y, Haspel JA, Hazan G. Diurnal rhythms in varicella vaccine effectiveness. *JCI Insight* 2024;9(20):e184452. <https://doi.org/10.1172/jci.insight.184452>.
3. Li JX, Huang Y, Chen SY, Song DY, Chen YL, Chang YK, et al. Real-world effectiveness of varicella vaccination in Guangzhou, China, 2017–2022: a matched case-control analysis. *Expert Rev Vaccines* 2025;24(1): 601 – 11. <https://doi.org/10.1080/14760584.2025.2536086>.
4. Baxter R, Ray P, Tran TN, Black S, Shinefield HR, Coplan PM, et al. Long-term effectiveness of varicella vaccine: a 14-Year, prospective cohort study. *Pediatrics* 2013;131(5):e1389 – 96. <https://doi.org/10.1542/peds.2012-3303>.
5. Marin M, Marti M, Kambhampati A, Jeram SM, Seward JF. Global varicella vaccine effectiveness: a meta-analysis. *Pediatrics* 2016;137(3): e20153741. <https://doi.org/10.1542/peds.2015-3741>.
6. Suo LD, Lu L, Zhao D, Pang XH. Impact of a 2-dose voluntary vaccination strategy on varicella epidemiology in Beijing, 2011–2017. *Vaccine* 2020;38(20):3690 – 6. <https://doi.org/10.1016/j.vaccine.2020.01.087>.
7. Wang LL, Yang X, Wang XW, Shi P, Zhang XH. Assessing vaccine effectiveness for varicella in Wuxi, China: a time-series analysis. *Ann Med* 2023;55(2):2246369. <https://doi.org/10.1080/07853890.2023.2246369>.
8. Shu MM, Zhang DD, Ma R, Yang TC, Pan XQ. Long-term vaccine efficacy of a 2-dose varicella vaccine in China from 2011 to 2021: a retrospective observational study. *Front Public Health* 2022;10: 1039537. <https://doi.org/10.3389/fpubh.2022.1039537>.
9. Ahern S, Walsh KA, Paone S, Browne J, Carrigan M, Harrington P, et al. Clinical efficacy and effectiveness of alternative varicella vaccination strategies: an overview of reviews. *Rev Med Virol* 2023;33(1):e2407. <https://doi.org/10.1002/rmv.2407>.

10. Höhle M, Siedler A, Bader HM, Ludwig M, Heininger U, Von Kries R. Assessment of varicella vaccine effectiveness in Germany: a time-series approach. *Epidemiol Infect* 2011;139(11):1710 – 9. <https://doi.org/10.1017/S0950268810002815>.
11. Luan GJ, Yao HY, Yin DP, Liu JJ. Trends and age-period-cohort effect on incidence of varicella under age 35 - China, 2005-2021. *China CDC Wkly* 2024;6(18):390 – 5. <https://doi.org/10.46234/ccdcw2024.076>.
12. St Clair LA, Chaulagain S, Klein SL, Benn CS, Flanagan KL. Sex-Differential and Non-specific Effects of Vaccines Over the Life Course. *Curr Top Microbiol Immunol*. 2023;441:225 – 251 <https://doi.org/10.1007/978-3-031-35139-69>.
13. Fu CX, Wang M, Liang JH, Xu JX, Wang CB, Bialek S. The effectiveness of varicella vaccine in China. *Pediatr Infect Dis J* 2010;29(8):690 – 3. <https://doi.org/10.1097/INF.0b013e3181d7380e>.
14. Xu YY, Liu Y, Zhang XP, Zhang XC, Du J, Cai YX, et al. Epidemiology of varicella and effectiveness of varicella vaccine in Hangzhou, China, 2019. *Hum Vaccin Immunother* 2021;17(1):211 – 6. <https://doi.org/10.1080/21645515.2020.1769395>.
15. Son M, Shapiro ED, LaRussa P, Neu N, Michalik DE, Meglin M, et al. Effectiveness of varicella vaccine in children infected with HIV. *J Infect Dis* 2010;201(12):1806 – 10. <https://doi.org/10.1086/652798>.
16. Suh J, Choi JK, Lee J, Park SH. Estimation of single-dose varicella vaccine effectiveness in South Korea using mathematical modeling. *Hum Vaccin Immunother* 2022;18(5):2085468. <https://doi.org/10.1080/21645515.2022.2085468>.