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Estimated COVID-19 Mortality in China, December 16, 2022 - January 19, 2023

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Reported COVID-19 Mortality — Chinese CDC

The recent wave of COVID-19 in China peaked in late December of 2022, with **0.07 million deaths confirmed** in hospitals between December 16, 2022 and January 19, 2023 [1].

Extreme bounds on COVID-19 Mortality

First, we bound the estimates by considering two extreme scenarios for vaccine efficacy in China. We estimate the total number of COVID deaths and provide a plausible range for the number that would be reported by the Chinese CDC, given China's strict exclusion of COVID-related deaths that list other causes of deaths. The CrI's reflect uncertainty in age-specific IFR's [2].

- If vaccine effectiveness against mortality is zero
    - **5.28 (95% CrI: 4.20, 6.13) million total deaths**
    - **Range of reported deaths: 0.23 - 2.27 million**
- If 100% of cases are vaccinated and vaccine effectiveness against mortality is 98.1%:
    - **0.10 (95% CrI: 0.08, 0.12) million total deaths**
    - **Range of reported deaths: 0.004 - 0.043 million**

Estimated COVID-19 mortality

Using a simulation method that incorporates data on vaccine coverage, vaccination timing, vaccine efficacy and waning of protection in different age groups, we estimate:

- **Total deaths: 1.46 (95% CrI: 1.17, 1.69) million**
- **Range of reported deaths: 0.064 - 0.627 million**

Simulation-based method for estimating COVID-19 mortality in China

We run 100 simulations each with 1,000,000 individuals assigned ages according to the national age distribution in China. Each simulation produces an estimated number of COVID-19 deaths between December 16, 2022 and January 19, 2023, as described below. We report the 2.5th percentile (lower CI bound), median, and 97.5th percentile (upper CI bound) values across the 100 simulations.

To estimate a plausible range of *reported* deaths, we multiply the lower bound by 5.5% [7] and the upper bound by 37% [9], corresponding to low and high estimates for the fraction of COVID-19 death reports that do not include other causes of death.

The full parameter specification is given in Table A. In each simulation, we do the following:

- For each age group *a*, select a random IFR (IFR_a) from the estimated distributions given in Table A and assign each individual their age-specific IFR. (For each age group, draw from triangle distributions with lower bound, mode and upper bound equal to the corresponding lower CI, mean, and upper CI, respectively.)
- Assign each individual a random infection time, based on the time series of reported SARS-CoV-2 test positivity in China [1].
- Administer doses to each individual according to reported daily age-specific vaccination rates in China [4]:
    - Randomly select the date of the first dose (t_1) based on the estimated first-dose rate, $C^1_a(t)$.
        - For children 3-11 years old, first doses begin November 1, 2021.
        - For children 12-17 years old, first doses begin August 1, 2021.
        - For children 18-59 years old, first doses begin December 1, 2020.
        - For adults over 60 years old, first doses begin April 1, 2021.
    - Randomly select the date of the second dose (t_2) based on the estimated second-dose rate, $C^2_a(t)$, beginning 3 weeks after their first dose.
    - Randomly select the date of the booster dose (t_3) for adults over 18 years old based on the estimated booster rate, $C^3_a(t)$, starting at the CDC-recommended time waiting period after their second dose (i.e., 6 months before December 4, 2022, and 3 months after December 5, 2022).
- Determine VE for each individual based on the date of their last dose. Assume that vaccine-acquired protection begins two weeks after each dose is administered and that protection wanes stepwise six months following each dose [4].
- For each individual, determine whether they die from COVID based on their IFR and VE.

- Assuming that 90.36% of the Chinese population was infected during this period [1], we scale deaths in simulated population to all of China (by age group)

Table A. Model Parameters and Data Sources.

Symbol	Description	Values	Sources
N_a	Age-specific population size in China	Age 0-9: 168127944 Age 10-19: 157940134 Age 20-29: 166789007 Age 30-39: 223158122 Age 40-49: 207180217 Age 50-59: 222565082 Age 60-69: 147388498 Age 70-79: 80828885 Age ≥ 80: 35800835	China Statistical Yearbook 2021 [5]
r	Proportion of deaths that have no other conditions/causes of death reported except COVID-19	5.5% - 37%	Range based on three estimates for the proportion of deaths attributed to COVID-19 without underlying conditions or other causes of death: ● 5.5% of reported US deaths in 2020 [7] ● 28.5% of reported deaths in Australia during the Omicron wave [8] ● 37% of deaths in 7 French hospitals [9]
$I_{tot}(t)$	Proportion of the population newly infected at time *t*	Daily positive rate between December 16, 2022 to January 19, 2023, shown in Figure A below	Extracted from Figure 1-5 in Ref. [1]
$C^i_a(t)$	Age-specific vaccine coverage of the i-th dose (first, second, and booster) from December 2020 to September 2022 in China	See Figure B below.	We assume the cumulative vaccination rates of the first, second, and booster doses before March 1, 2022 follows the published values in Ref. [4]. For adults < 60 years, cumulative vaccination

			coverage hardly changes between March and December of 2022. For adults ≥ 60 years, cumulative vaccination rates for first, second, and booster doses are reported as 90.68%, 86.42%, and 68.8%, respectively, as of November 28, 2022 [10], and 96%, 96%, and 92% as of January 20, 2023 [1]. We assume a constant daily rate of vaccine administration during this period.
$VE(j,t)$	Vaccine effectiveness (VE) against mortality for an individual with most recent dose of type *j* administered at time *t*, as of December 2022 in China	First dose: after two weeks 53.0%; after six months 53.0% Second dose: after two weeks 66.3%; after six months 59.7% Booster dose: after two weeks 79.2%; after six months 76.3%	Ref. [4]
$VE_{extreme}$	Vaccine effectiveness (VE) against mortality in two extreme scenarios — maximimum and minimum protection	*maximum*: entire population with VE of 98.1% *minimum*: entire population with VE of 0%	*maximum*; Ref. [4] assumes VE of boosters after six months can be as high as 98.1%. *minimum*: Ref. [11] suggests vaccines given over eight months ago have minimal efficacy.
IFR_a	Age-specific infection-fatality (IFR) without vaccination or antiviral treatment	Age 0-9: 0.0005% (95% CI: 0.0004%, 0.0008%) Age 10-19: 0.0005% (95% CI: 0.0003%, 0.0008%) Age 20-29: 0.0005% (95% CI: 0.0004%, 0.0008%) Age 30-39: 0.023% (95% CI: 0.016%, 0.034%)	Mean values are based on estimates in Ref. [3]. 95% confidence intervals are derived from Ref. [2] which estimates age-specific IFR's at 10 year intervals (ages 5,

		Age 40-49: 0.023% (95% CI: 0.016%, 0.036%) Age 50-59: 0.126% (95% CI: 0.088%, 0.196%) Age 60-69: 0.126% (95% CI: 0.087%, 0.198%) Age 70-79: 2.00% (95% CI: 1.38%, 3.15%) Age ≥ 80: 8.70% (95% CI: 6.12%, 13.01%)	15, 25 …) between April 15, 2020 and January 1, 2021, prior to broad vaccination and the emergence of the Delta and Omicron variants. Specifically, we use the ratios of the lower and upper CI's to the mean in Ref. [2] to scale the estimates in Ref. [3]. For example, consider the 70-79 age group. The estimate of 4.84% (95% CI: 3.33%, 7.63%) given in Ref. [2] for 75 year olds yields ratios of 0.69 to 1.58. We use these values to scale the mean for 70-79 year olds in Ref. [3] to obtain 2.00% (95% CI: 1.38%, 3.15%).

Figures

Figure A. Graph reproduced from a Chineses CDC report published on January 26, 2023 entitled *COVID-19 Clinical and Surveillance Data — December 9, 2022 to January 23, 2023, China*[1]. The reported trends are based on (1) infection surveillance — community-based monitoring of nucleic acid and antigen testing and sentinel community surveillance of nucleic acid and antigen testing; (2) clinical visits and hospitalizations — daily COVID-19 visits to all fever clinics; mild to severe COVID-19 infections and COVID-19 fatalities in all hospitals, and outpatient clinics (emergency) COVID-19 visits in sentinel hospitals; (3) molecular surveillance (sequencing) of samples from sentinel hospitals.

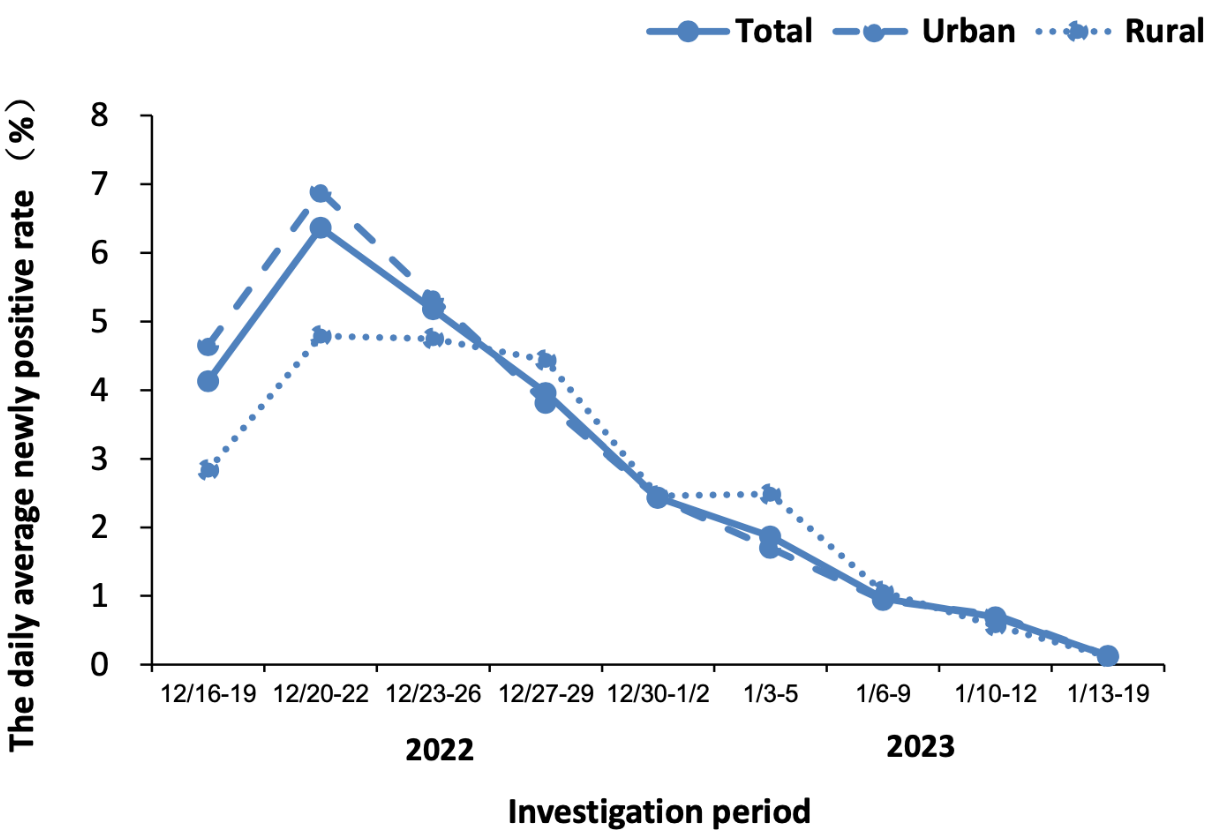
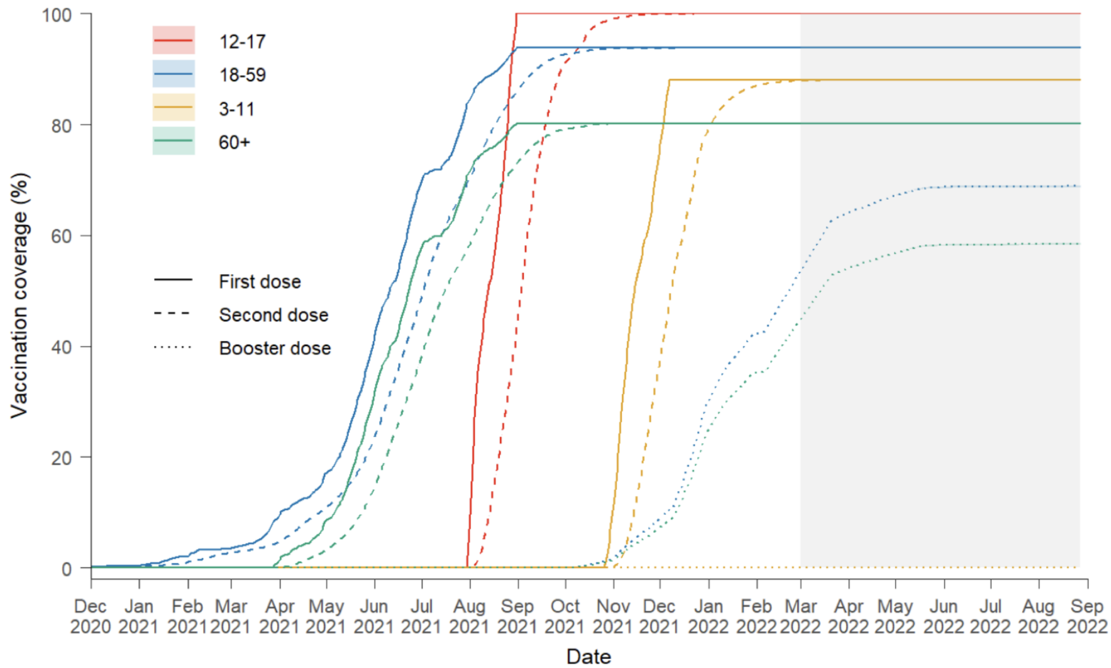


Figure.1-5 Trends of the average daily positive rate in each surveillance round.（%）

Figure B. Graph reproduced from Ref. [4] estimating age-specific uptake of primary and booster doses in China.



Supplementary Fig. 7 | Cumulative vaccine coverage by age in China shown for the first (solid lines), second (dashed lines), and booster (dotted lines) doses administered in the baseline scenario. The observed data until March 1, 2022 are presented, while the forward data are projected until August 31, 2022, in which period the booster vaccination rate is competing against the Omicron variant transmission.

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