Presumed population immunity to SARS-CoV-2 in South Korea, April 2022

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ABSTRACT

Objectives: We estimated the overall and age-specific percentages of the Korean population with presumed immunity against severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) as of April 2022 using the national registry.

Methods: We used the national coronavirus disease 2019 (COVID-19) infection and vaccination registry from South Korea, as described to define individuals with a previous history of COVID-19 infection, vaccination, or both, as persons with presumed immunity.

Results: Of a total of 53,304,627 observed persons, 24.4% had vaccination and infection, 58.1% had vaccination and no infection, 7.6% had infection and no vaccination, and 9.9% had no immunity. The SARS-CoV-2 Omicron variant emerged at a time when the presumed population immunity ranged from 80% to 85%; however, nearly half of the children were presumed to have no immunity.

Conclusion: We report a gap in population immunity, with lower presumed protection in children than in adults. The approach presented in this work can provide valuable informed tools to assist vaccine policy-making at a national level.

Keywords: COVID-19; Immunity; Population; SARS-CoV-2; Vaccines

Introduction

The level of population immunity is essential to guide the public health response against coronavirus disease 2019 (COVID-19) [1]. While most studies have estimated the level of population immunity primarily using sampled data or simulation models [2,3], these methods have intrinsic limitations in terms of the generalizability of the data. In this study, we attempted to use real-world numbers to calculate the population immunity level in a robust manner using a centralized, standardized dataset in South Korea. We estimated the overall...
and age-specific percentage of the Korean population with presumed immunity against severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) due to natural infection, vaccination, or both.

Materials and Methods

In South Korea, as of May 2022, more than 17 million COVID-19 confirmed cases had been reported (33% of total population), while 85% of its population had received at least 2 doses of COVID-19 vaccines [4]. We used the national COVID-19 infection and vaccination registry from South Korea, as described in a previous study, to define individuals with a previous history of COVID-19 infection, vaccination, or both, as persons with presumed immunity [5]. We excluded 141,690 persons who had more than 2 reports of infection, errors in vaccination records, and those who received vaccines outside of the country. We classified age groups as 0 to 4 years, 5 to 11 years, 12 to 17 years, 18 to 59 years, 60 to 74 years, and ≥75 years to perform descriptive analyses investigating the percentage of the population that could be presumed immune because of vaccination and/or infection. From the COVID-19 infection and vaccination registry spanning from February 26, 2021 to April 30, 2022, 4 mutually exclusive composites were constructed: (1) no immunity (i.e., uninfected, unvaccinated, or 1 dose of vaccination for the Pfizer-BioNTech, Moderna, and AstraZeneca vaccines); (2) infection and no vaccination (including 1 dose of vaccination); (3) vaccination (1 dose for the Janssen vaccine and 2 or more doses for other vaccines) and no infection, and; (4) vaccination (1 dose for the Janssen vaccine and 2 or more doses for other vaccines) and infection.

In addition, we calculated age-specific proportions with each composite by surveillance weeks from January 1, 2022, to April 30, 2022. The proportion of vaccination in each age group for 2 weeks previously was assigned to the cumulative vaccination coverage of a given week. The group with no immunity was defined as the sum of those without a history of vaccination and/or infection with COVID-19. We calculated the cumulative density of no immunity by week and age group. To assess the association of the age-specific weekly incidence of COVID-19 with the cumulative density of no immunity and vaccination coverage, we used Poisson regression models.

The statistical analysis was performed using R package (ver. 4.0.2; R Foundation for Statistical Computing, Vienna, Austria). This study was conducted as a legally mandated public health investigation under the authority of the Infectious Diseases Control and Prevention Act (No. 12444 and No. 13392) and was reviewed by the Institutional Board Review of Korea Disease Control and Prevention Agency (IRB No: 2021-12-03-PE-A).

Results

Of a total of 53,304,627 observed persons, 13,014,902 (24.4%) had vaccination and infection, 30,955,551 (58.1%) had vaccination and no infection, 4,068,131 (7.6%) had infection and no vaccination, and 5,266,043 (9.9%) had no immunity as of April 2022 (Figure 1). The percentages of adults aged 18 to 59 years, 60 to 74 years, and ≥75 years with no immunity were 6.6%, 4.4%, and 6.7%, respectively, whereas the percentages of children and adolescents aged 0 to 4 years, 5 to 11 years, and 12 to 17 years with no immunity were 54.0%, 40.5%, and 16.9%, respectively. The proportion of infection and no vaccination was highest in children aged 5 to 11 years (59.5%), followed by those aged 0 to 4 years (46.0%) and 12 to 17 years (19.7%).

Between January 1 and April 30, 2022, the percentage of people with no immunity decreased from 20.5% to 9.9% in the entire population (Table 1). In all age groups, the incidence rate of COVID-19 peaked at surveillance week 11, when the percentage of no immunity reached 13.1% (Table 1; Figure S1). The proportion of no immunity decreased in the adult population from 11.8% to 6.6% (18–59 years), from 6.6% to 4.4% (60–74 years), and from 10.0% to 6.7% (≥75 years); whereas in children and adolescents, the decrease was from 91.6% to 54.0% (0–4 years), from 98.3% to 40.5% (5–11 years), and from 65.0% to 16.9% (12–17 years).

Adults aged 18 to 59 years, 60 to 74 years, and ≥75 years, in whom less than 25% of the population had no immunity, displayed a smaller peak and shorter duration of COVID-19 incidence per 100,000 than children aged 12 to 17 years, 5 to 11 years, and 0 to 4 years (Figure S2). Table S1 shows the association of age-specific COVID-19 incidence with the proportion of children with no immunity in the age groups of 0 to 4 years, 5 to 11 years, and 12 to 17 years, as relative risk (RR) and 95% confidence intervals. A higher RR was found in children aged 12 to 17 years than in children aged 0 to 4 years and 5 to 11 years.

Discussion

In South Korea, the SARS-CoV-2 Omicron variant emerged and spread at a time when the presumed population immunity ranged from 80% to 85%; however, there were significant discrepancies between age groups. Following the surge in cases due to the spread of the Omicron variant in early 2022, the number of new incident cases has decreased dramatically since April 2022 [6]. During week 1 of 2022, the percentages of adults presumed to have no immunity were...
11.8% (18–59 years), 6.6% (60–74 years), and 10.0% (≥75 years), while these percentages were higher in children, at 91.6% (0–4 years), 98.2% (5–11 years), and 65.0% (12–17 years). Vaccination in the adult population started in February 2021, whereas the vaccines have been offered to the age groups of 12 to 17 years and 5 to 11 years since October 2021 and March 2022, respectively, which partly explains the population susceptibility in children [5]. The disproportionate distribution of COVID-19 vaccination between age groups likely resulted in the observed discrepancy in population immunity, as demonstrated in a previous study [7]. Nevertheless, our findings showed widespread population immunity among persons aged 60 years and above, largely obtained through vaccination. The high population immunity among this at-risk age group, primarily induced by vaccination, may have resulted in relatively low death rates among this population [8].

It is imperative to recognize that SARS-CoV-2 infection-induced immunity and vaccine-induced immunity may offer different levels of protection. Previous studies indicate that immunity from natural infection is not as predictable as vaccine-induced immunity, and booster vaccination significantly enhances protection from severe illness. We found that with a higher population immunity level in a given age group, a lower peak of COVID-19 incidence can be expected, as seen in Figures S1 and S2. The contact mixing pattern between different age groups widely varies across countries and settings [1]. In Korea, the contact number in school-aged children was found to be this age group had the highest contact number of all [9], suggesting that the improved population immunity in this age group may have substantially reduced the community transmission of SARS-CoV-2.

This study has a number of limitations. First, we did not take into account primary and secondary vaccine failures, or the waning of immunity, in estimating the level of population immunity. Second, differences in the types of vaccines, the interval since the last vaccination, and the number of doses may have confounded the results of this study. Second, the observed period spans before and after school opening, which limits the generalizability of our results. Third, following the cases of reinfections after the introduction of the Omicron variant, the assumption of “presumed immunity” from previous infection may not be applicable. Despite these limitations, our results present a rapid assessment of population immunity, which was quickly translated into policy-making in the national vaccination campaign. The results support continual recommendations to vaccinate children and adolescents, who could be the main source of transmission in the next
COVID-19 outbreak.
Herein, we report a gap in population immunity, with lower presumed protection in children than in adults. The approach presented in this work can provide valuable informed tools to assist vaccine policy-making at a national level.

Supplementary Material

Figure S1. Age-specific percentage of the population in each category of presumed immunity due to natural infection, vaccination, both, or neither, by surveillance week between January 1, 2022 and April 30, 2022; Figure S2. Proportion of no immunity and COVID-19 incidence by age group; Table S1. Association of age-specific COVID-19 incidence with the proportion of children with no immunity. Supplementary data are available at https://doi.org/10.24171/j.phrp.2022.0209.

Notes

Ethics Approval
This study was approved by the Institutional Review Board of Korea Disease Control and Prevention Agency (No: 2021-12-03-PE-A) and performed in accordance with the principles of the Declaration of Helsinki. The informed consent was waived because of the retrospective nature of this study.

Conflicts of Interest
The authors have no conflicts of interest to declare.

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None.

Availability of Data
The datasets are not publicly available but are available from the corresponding author upon reasonable request.

Authors’ Contributions
Conceptualization: EJJ, YJC, YJP; Data curation: EJJ, YYK, RKK; Formal analysis: EJJ, JK, DSL, JHL, SY; Investigation: EJJ, YJC, JHL, SY, SL; Methodology: EJJ, JK, SY; Project administration: RKK, DSL, JHL; Resources: SL, YJP; Software: EJJ, SAC; Supervision: SL, YJP; Validation: EJJ; SAC; Visualization: EJJ; SAC; Writing—original draft: EJJ, YJC; Writing—review & editing: all authors.

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Table 1. Number and percentage of the population in each category, by surveillance week between January 1, 2022 and April 30, 2022

| Surveillance week | No immunity | Infection and no vaccination | Vaccination and no infection | Vaccination and infection |
|-------------------|-------------|-----------------------------|----------------------------|--------------------------|
| 1                 | 10,905,513 (20.5) | 374,645 (0.7) | 41,680,379 (78.2) | 207,676 (0.4) |
| 2                 | 10,635,974 (20.0) | 385,279 (0.7) | 41,924,075 (78.6) | 224,239 (0.4) |
| 3                 | 10,155,681 (19.1) | 397,744 (0.7) | 42,364,812 (79.5) | 252,807 (0.5) |
| 4                 | 9,674,052 (18.1) | 421,461 (0.8) | 42,753,499 (80.2) | 322,827 (0.6) |
| 5                 | 9,350,688 (17.5) | 463,118 (0.9) | 42,897,727 (80.5) | 460,981 (0.9) |
| 6                 | 9,104,593 (17.1) | 541,346 (1.0) | 42,813,001 (80.3) | 721,637 (1.4) |
| 7                 | 8,854,503 (16.6) | 694,472 (1.3) | 42,462,836 (79.7) | 1,177,594 (2.2) |
| 8                 | 8,516,735 (16.0) | 946,857 (1.8) | 41,782,045 (78.4) | 1,952,045 (3.7) |
| 9                 | 8,280,203 (15.5) | 1,288,935 (2.4) | 40,581,153 (76.1) | 3,064,374 (5.7) |
| 10                | 7,636,354 (14.3) | 1,751,893 (3.3) | 39,385,520 (73.9) | 4,702,319 (8.8) |
| 11                | 6,992,694 (13.1) | 2,386,982 (4.5) | 37,245,703 (69.9) | 6,872,281 (12.9) |
| 12                | 6,406,646 (12.0) | 2,953,122 (5.5) | 35,194,383 (66.0) | 8,710,922 (16.3) |
| 13                | 5,950,033 (11.2) | 3,389,758 (6.4) | 33,617,782 (63.1) | 10,304,739 (19.3) |
| 14                | 5,652,728 (10.6) | 3,700,644 (6.9) | 32,475,772 (60.9) | 11,456,348 (21.5) |
| 15                | 5,454,046 (10.2) | 3,888,444 (7.3) | 31,718,183 (59.5) | 12,233,027 (22.9) |
| 16                | 5,337,503 (10.0) | 3,999,925 (7.5) | 31,256,300 (58.6) | 12,706,071 (23.8) |
| 17                | 5,266,043 (9.9) | 4,068,131 (7.6) | 30,955,551 (58.1) | 13,014,902 (24.4) |

Data are presented as n (%).
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