**Effect of anti-S antibody titers on newly confirmed cases of COVID-19 in Korea: A community-based longitudinal seroprevalence survey on COVID-19 (K-SEROSMART Wave 2)**

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**Abstract**

**Background:** COVID-19 continues to impact populations globally, raising concerns about immunity levels and risks to high-risk groups despite the lifting of the global health emergency in May 2023. While studies have tracked seroprevalence, few have comprehensively assessed long-term antibody persistence and COVID-19 risk, particularly regarding immunity changes due to vaccination and infection.This study aimed to estimate the population prevalence of severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) antibodies and assess the risk of newly confirmed coronavirus disease 2019 (COVID-19) infections in Korea in December 2022. We conducted a follow-up survey and blood testing of 9,945 participants in the Korea Seroprevalence Study of Monitoring of SARS-CoV-2 Antibody Retention and Transmission (K-SEROSMART) Wave 1.

**Methods:** The K-SEROSMART Wave 2 study employed a staged approach through public health centers nationwide, using mobile web, telephone, and face-to-face surveys. Participants self-reported sociodemographic characteristics and health status and provided blood samples for the analysis of anti-spike (anti-S) and anti-nucleocapsid (anti-N) antibodies via electrochemiluminescence immunoassay. Population prevalence estimates were weighted for demographic data. Multivariate Cox proportional hazards regression was used to assess the relationship between anti-S antibody titers from Wave 1 and new COVID-19 cases, adjusting for age and sex.

**Results:** A total of 7,528 individuals participated, yielding a follow-up rate of 74.9%. The population-adjusted prevalence rates of anti-S and anti-N antibodies were 98.5% and 70.0%, respectively. The percentage of newly confirmed COVID-19 cases was significantly higher in individuals with anti-S antibody titers below 2,000 U/mL, 2,000–3,999 U/mL, 4,000–5,999 U/mL, 6,000–7,999 U/mL, and 8,000–9,999 U/mL than in those with titers above 18,000 U/mL (hazard ratio [HR]= 9.9, 95% confidence interval [CI] = 7.2–13.5; HR = 8.1, 95% CI = 5.8–11.3; HR = 7.1, 95% CI = 5.0–10.1; HR = 4.2, 95% CI = 2.8–6.3; HR = 2.0, 95% CI = 1.2–3.3, respectively).

**Conclusions:** This study demonstrated the feasibility of conducting a seroepidemiological longitudinal survey on COVID-19 using a nationally representative sample. Additionally, this study quantified anti-S antibody titer levels that are associated with reduced risk of new infections within a community.

**Keywords:** COVID-19, Seroepidemiologic study, Antibody titer, Longitudinal study, Community

**Background**

The coronavirus disease 2019 (COVID-19) has significantly impacted the global population since the World Health Organization (WHO) declared it a Public Health Emergency of International Concern in January 2020 [1, 2]. Although COVID-19 was no longer considered a global health emergency as of May 2023 [3], the disease continues to be reported in many countries, with complications persisting, particularly in high-risk groups. Furthermore, concerns persist among public health experts regarding the decline in herd immunity acquired from vaccination and natural infection [1].

A longitudinal approach is essential to evaluate the long-term impact of post-COVID-19 symptoms and the effect of the pandemic on population immunity levels [4-7]. This approach is also crucial for assessing COVID-19 risks based on antibody titers acquired through natural infection or vaccination. The results may provide crucial insights into predicting the spread of COVID-19 based on community immunity levels and inform prevention and control measures.

Several countries have initiated long-term follow-up studies to track seroprevalence rates in community settings. For example, medical professionals [4], residents [5-6], confirmed cases, symptomatic individuals [8], and students [9] have participated in follow-up surveys since the early stages of the pandemic. These surveys have tracked changes in seroprevalence, seroconversion rates, mental health status, and other relevant parameters. Recently, countries such as Switzerland and India have established monitoring systems to track and observe large populations for at least 2 years [1, 10].

In August 2022, a nationwide community-based COVID-19 serosurvey, known as the Korea Seroprevalence Study of Monitoring of SARS-CoV-2 Antibody Retention and Transmission (K-SEROSMART), was conducted to assess the scale of COVID-19 infections, including undiagnosed cases, within local communities [11]. The study confirmed that most individuals possess antibodies to severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) and identified a significant number of unreported cases, laying the groundwork for an ongoing surveillance system to monitor transmission and enhance COVID-19 response at the community level.

Repeated measurements within the same population are essential for understanding antibody prevalence and also the effectiveness of COVID-19 vaccinations, reinfection rates, and changes in immunity. In this study, we conducted follow-up surveys targeting participants of the K-SEROSMART study to estimate the seroprevalence rate in South Korea 4 months after the initial survey in December 2022. Additionally, we aimed to evaluate the risk of COVID-19 during the follow-up period based on antibody titers acquired through either vaccination or natural infection.

**Methods**

**Fieldwork and participants**

***Baseline seroepidemiology survey of COVID-19: K-SEROSMART Wave 1***

The details of the baseline study were provided in our initial investigation [11]. In brief, we used a two-stage random sampling method to select a representative sample of 5,000 households within the community. Face-to-face household surveys were conducted, with all household members aged 5 years and older providing serum samples and completing a questionnaire. The serum samples were analyzed for SARS-CoV-2 antibodies using the Elecsys Anti-SARS-CoV-2 test (Roche). The fieldwork for K-SEROSMART Wave 1 was conducted between August 12 and September 5, 2022, with a total of 9,945 individuals from 5,041 households participating.

***Follow-up seroepidemiology survey of COVID-19: the K-SEROSMART Wave 2***

This study was a follow-up survey conducted in December 2022, involving serial sampling of the same individuals from K-SEROSMART Wave 1. We aimed to reach all 9,945 individuals using a multi-step engagement process to increase the follow-up rate, including web-based, telephone, and face-to-face surveys: (1) Between December 2 and 6, invitation emails for K-SEROSMART Wave 2 were sent to 5,041 households. Following this, a multimedia messaging service (MMS) was sent to all 9,945 individuals who completed the initial survey. The MMS included the URL for the mobile web survey, an introduction to the secondary survey, informed consent form, consent to participate form, personal questionnaire form, and blood draw reservation form. (2) Participants who did not respond to the mobile web survey or who only provided a landline phone number were contacted by telephone surveyors. If participants expressed interest in the follow-up survey, consent was obtained over the phone, and a telephone survey was conducted between December 7 to December 27. (3) Individuals who did not respond to the web or phone survey or who requested a home visit were contacted by trained interviewers for face-to-face surveys. These visits occurred between December 7 and 19. During the visit, participants provided informed consent, and the survey was conducted in-person. Following each interview, participants were instructed to schedule blood sample collection. For further details on the survey questions, please refer to the Supplementary 1.

***Participants and study populations***

A total of 8,826 individuals were contacted, of whom 7,528 completed K-SEROSMART Wave 2. Participants were excluded from the analysis to estimate the population prevalence of SARS-CoV-2 antibodies if they did not consent to participate in the survey (n = 406) or did not have their blood drawn (n = 892) due to reasons such as refusal, scheduling conflicts, or health issues (Figure 1). The association between anti-spike protein (anti-S) antibody titers and newly confirmed COVID-19 infection cases was analyzed in a cohort of 6,837 individuals. Among the 7,528 participants who completed K-SEROSMART Wave 2, we excluded 136 individuals who could not be matched with their Korea Disease Control and Prevention Agency (KDCA) data, 493 individuals who had a history of confirmed infection after vaccination between Waves 1 and 2 (due to potential fluctuations in anti-S antibody titers prior to new confirmed cases), and 62 individuals with an anti-S antibody titer of less than 0.8 U/ml, which is the established cut-off for the presence of anti-S antibodies.

**Measurement**

***Laboratory method for blood samples: COVID-19 anti-nucleocapsid protein (anti-N) and anti-S antibody titers***

Blood samples were collected according to a standardized protocol. Tablet personal computers and blood collection tools were provided to 258 public health centers and 130 medical clinics that participated in K-SEROSMART Wave 2. Additionally, medical staff received training to ensure standardized blood collection procedures. For all participants, 4 mL of blood was collected from adults and 2 mL from children. The samples were transported to regional laboratory centers on the same day, centrifuged at 3,000 rpm for 10 min, stored in refrigerators, and then transported to the central laboratory. The following morning, the samples were analyzed for the presence of anti-S and anti-N antibodies via electrochemiluminescence immunoassay. Additional details regarding the laboratory methods can be found in a previous article [11].

***Newly confirmed cases of COVID-19***

All public health centers and medical institutions in Korea are required to report the results of expert rapid antigen tests and emergency reverse transcription polymerase chain reaction (RT-PCR) screening tests for newly confirmed COVID-19 cases to the COVID-19 information management system of the KDCA within 24 hours. For participants in the survey, the names, sex, dates of birth, and home addresses of those who consented to the use of their personal information were used to link the survey data with their COVID-19 confirmation and vaccination history information provided by the KDCA. A newly confirmed case was defined as any individual with a history of COVID-19 confirmation, including reinfections, occurring between K-SEROSMART Waves 1 and 2, based on the COVID-19 confirmation history data provided by the KDCA.

***General characteristics***

Baseline sociodemographic factors of the participants included sex, age group (5–18 years, 19–34 years, 35–49 years, 50–64 years, 65 years or older), education level (for participants aged 19 years and older: primary school, middle or high school, postsecondary), annual household income (in 1,000 KRW: less than 20,000; 20,000–39,999; 40,000–59,999; 60,000–79,999; 80,000 or more). Additional characteristics included generational household composition (single person, first generation, second generation, or third generation), occupation (for participants aged 19 years and older: white collar, pink collar, blue collar, unskilled workers, unemployed), employment type (for participants aged 19 years and older: employers, full-time worker, non-regular worker), and city of residence (one of the 17 metropolitan cities). Health behavior factors included smoking status, body mass index (BMI) (for participants aged 19 years and older, kg/m2: low: <18.5, normal: 18.5–24.9, obesity: ≥25), and number of diagnosed diseases (none, 1, 2, ≥3).

**Statistical analysis**

The PROC SURVEYFREQ procedure, designed for complex sample analysis, was employed to estimate the prevalence of anti-S and anti-N antibodies among participants in K-SEROSMART Wave 2 as of December 2022. The Rao–Scott chi-square test was applied to assess differences among participants based on their general characteristics. Survey data were weighted for age and sex using final individual weights benchmarked against the November 2022 population estimates for Korea. These weights were calculated by multiplying three components: sampling design weight, nonresponse correction weight, and poststratification correction weight [11].

We examined the relationship between anti-S antibody titers measured during K-SEROSMART Wave 1 and newly confirmed COVID-19 cases during the follow-up period. Baseline anti-S antibody titers were categorized into 10 groups of 2,000 U/mL, with the ≥18,000 U/mL group serving as the reference. Multivariate Cox proportional hazards regression analysis was used to estimate the hazard ratios (HRs) for newly confirmed COVID-19 cases, adjusting for age and sex. Person-days were calculated based on the date of blood collection in Wave 1. The log-rank test validated the proportional hazards assumption, and no violations were detected. All statistical analyses were conducted using the SAS package (version 9.4; SAS Institute, Cary, NC, USA), with a p-value <0.05 considered statistically significant.

**Ethical approval**

The Institutional Review Board of the KDCA exempted this survey from review in accordance with Article 36 of the Bioethics Act, Article 33 of the Enforcement Rules, and Article 2 of the Bioethics Act. The study was deemed necessary for urgent public health action and was conducted directly or commissioned by the state or local government to review and evaluate public welfare or service programs (2022-11-02-PE-A). We provided all participants with the purpose and process of the study and obtained written consent.

**Results**

Table 1 compares the characteristics of participants who completed follow-up with those of participants lost to follow-up in K-SEROSMART Wave 2. Follow-up rates were higher among women (75.9%), individuals aged 50–64 years (80.5%), those with higher education and income levels, first-generation households (77.1%), residents of Jeju (83.2%), and participants with a history of two types of diagnosed diseases (79.4%).

**Insert Table 1 here**

Table 2 presents the prevalence of antibodies against SARS-CoV-2 by demographic characteristics in Wave 2. The prevalence of anti-S antibodies was 98.5% (95% confidence interval [CI], 98.2–98.9). By age group, the prevalence was the lowest among 5–18-year-olds at 93.8% (95% CI, 91.8–95.8) and increased with age, peaking at 99.4% (95% CI, 99.0–99.7) in individuals aged 65 years and older.

The prevalence of anti-N antibodies was 70.0% (95% CI, 68.8–71.2), with rates of 68.1% (95% CI, 66.3–69.9) in males and 71.8% (95% CI, 70.3–73.3) in females. By age group, the highest prevalence of anti-N antibodies was observed among 5–18-year-olds at 84.5% (95% CI, 81.5–87.4), decreasing with age to a low of 58.2% (95% CI, 56.0–60.4) in individuals aged 65 years and older.

The prevalence of anti-N antibodies tended to be higher among individuals with higher education and income levels, in second-generation households (72.9%; 95% CI, 71.2–74.6), and residents of Sejong (80.5%; 95% CI, 72.2–88.8). However, it decreased with an increasing number of diagnosed diseases.

**Insert Table 2 here**

Table 3 presents the characteristics of newly confirmed COVID-19 cases among participants of K-SEROSMART Wave 2. Among the 6,837 participants, 712 (10.4%) were newly confirmed COVID-19 cases. The prevalence of COVID-19 was significantly higher among females (11.6%) and individuals aged 35–49 years (11.5%). Additionally, the prevalence was notably elevated among participants with a history of COVID-19 (18.1%). The percentage of confirmed cases demonstrated an inverse relationship with anti-S antibody titers, decreasing as antibody levels increased (Table 3).

**Insert Table 3 here**

Figure 2 illustrates the results of the Cox proportional hazards model for newly confirmed COVID-19 cases. The HR for COVID-19 infection was significantly higher in individuals with anti-S antibody titers in the lowest four categories, less than 2,000 U/mL (HR = 9.9, 95% CI = 7.2–13.5), 2000–3999 U/mL (HR = 8.1, 95% CI = 5.8–11.3), 4000–5,999 U/mL (HR = 7.1, 95% CI = 5.0–10.1), 6,000–7,999 U/mL (HR = 4.2, 95% CI = 2.8–6.3), than that of those in the highest category, above 18,000 U/mL. Individuals in the 8,000–9,999 U/mL category also exhibited moderately increased risk (HR = 2.0, 95% CI = 1.2–3.3).

**Discussion**

This follow-up study, conducted in December 2022, targeted 9,945 participants from K-SEROSMART Wave 1, which was conducted in August 2022. Of these, 7,528 participants (74.9%) completed the survey and blood collection. Data collection was carried out through mobile web, telephone, and face-to-face methods, while blood-sample collection was conducted at public health centers or medical institutions.

The estimated seroprevalence of anti-S and anti-N antibodies in Korea in December 2022 was 98.5% and 70.0%, respectively. These findings represent increases of 0.9 percentage points for anti-S antibodies and 12.9 percentage points for anti-N antibodies compared to those in August 2022, when the prevalence was 97.6% and 57.1%, respectively [11]. As of December 2022, the highly transmissible BA.5 Omicron subvariant was rapidly becoming dominant in Korea. The cumulative number of reported COVID-19 cases in Korea was approximately 29.06 million, with an estimated cumulative infection rate of 56%, including reinfections [12]. Meanwhile, the COVID-19 vaccination completion rate was 86.3% [13].

This follow-up survey coincided with the seventh peak of infections in Korea, marked by a rise in both new infections and reinfections [14, 15]. Additionally, recommendations for bivalent mRNA COVID-19 vaccination for individuals who had completed the primary vaccination series [16] contributed to fluctuating immunity levels within the community [17].

This study evaluated the risk of COVID-19 based on immunity levels acquired through infection or vaccination, measured by antibody titers. No significant difference in the risk of new infection was observed in the group with anti-S antibody titers of 10,000 U/mL or higher compared to that in the group with anti-S antibody titers of 18,000 U/mL or higher at the initial survey. However, a significant increase in the risk of new infection was noted for titers below 10,000 U/mL, ranging from 2.0 times (95% CI: 1.2–3.3) for 8,000–9,999 U/mL to 9.9 times (95% CI: 7.2–13.5) for titers less than 2,000 U/mL.

Antibody titers are widely used as surrogate markers for immunity, with declining titers indicating a reduction in collective protective immune effects [18, 19]. A case-control study reported that a two-fold increase in anti-S antibody titers after the second vaccine dose was associated with a 29% reduction in the risk of Delta infections (95% CI 14–42; p = 0.001) [20]. Similarly, an analysis comparing serological differences between reinfected individuals and uninfected controls found that higher anti-S antibody titers significantly lowered reinfection risk (odds ratio [OR]: 0.63, CI 0.47–0.85), while anti-N antibody titers showed no significant association (OR: 0.88, CI 0.73–1.05) [21]. Another study demonstrated that SARS-CoV-2 spike RBD antibody titers in individuals previously infected with SARS-CoV-2 are associated with protection against Omicron BA.1/BA.2 variants. Specifically, the risk of Omicron BA.1/BA.2 infection was reduced by up to threefold when antibody levels were 800 IU/mL or higher [22].

The waning of antibodies over time is inevitable [23-26]. Given that immunity acquired through infection or vaccination may diminish and that individual antibody levels vary, achieving sustained herd immunity at the population level is challenging. This study established quantitative thresholds for anti-S antibody titers to mitigate the risk of new infections in a community population, providing evidence to support long-term COVID-19 vaccination strategies.

This large-scale study, which represents the entire population, demonstrated a high follow-up rate of 74.9%. The high follow-up rate can be attributed to the implementation of the governance structure established by the Korean Epidemiological Society, the Korea Disease Control and Prevention Agency/National Health Research Institute, the Metropolitan City and Provincial Health Authorities, and the District Health Centers for the execution of the K-SEROSMART study. Given the results, the strategy of actively leveraging public and private resources within local communities, based on the administrative organization of health centers in each region, proved effective. Additionally, by considering the characteristics of the participants and their survey preferences, the study enhanced engagement by offering surveys through various methods such as online, via telephone, and in-person formats.

Similar to other tracking studies, males, younger and older age groups, and residents from certain areas had significantly lower follow-up rates. Many participants found it challenging to visit designated health centers or medical institutions for blood collection at scheduled times. For future long-term tracking studies, methods such as self-sampling kits or blood collection during household visits could improve participation rates [27].

Antibody prevalence surveys are time-sensitive [28]. A community-based surveillance system enabling real-time monitoring [29, 30] is essential to predict future pandemic crises. Tailored strategies, based on sociodemographic characteristics and health status, are crucial to understanding disease spread and guiding medical resource allocation and risk management for emerging infectious diseases. In this study, we addressed the limitations of existing paper-based survey methods by establishing a comprehensive survey management system encompassing participant recruitment, survey administration, blood sample reservation, and specimen management.

Additionally, a long-term surveillance system is necessary to track changes in nationwide COVID-19 immunity levels and antibody titers. This requires collaboration among multidisciplinary research teams, including experts in epidemiology, preventive medicine, infectious diseases, diagnostic laboratory medicine, statistics, pediatric, and adolescent medicine. In the current study, these teams monitored and provided feedback on the survey process, interpreted the results, and conducted a comprehensive analysis.

Our study had some limitations. First, there was variation in participation rates for the follow-up survey based on sociodemographic characteristics. To address this, we applied sampling processes, non-response correction, and post-stratification correction weights to all participants who completed the follow-up survey. Second, the standard serological tests for SARS-CoV-2, which only detect binding antibodies, cannot distinguish between binding and neutralizing antibodies. While neutralizing antibodies are critical for virus neutralization, binding antibodies induced by vaccination help produce neutralizing antibodies. Previous studies have reported a correlation between binding and neutralizing antibodies [31-33].

**Conclusions**

This study established a comprehensive and sustainable longitudinal survey protocol based on the local community, enabling the measurement of immune status across the entire population and identifying sociodemographic factors that influence infectious disease response policies. In addition to providing representative seroprevalence rates within a limited timeframe, this study demonstrated the feasibility of conducting follow-up surveys within local communities to assess COVID-19 risk based on anti-S antibody titers.

**List of abbreviations**

* Anti-N – Anti-nucleocapsid protein
* Anti-S – Anti-spike protein
* CI – Confidence interval
* COVID-19 – Coronavirus disease 2019
* HR – Hazard ratio
* K-SEROSMART – Korea Seroprevalence Study of Monitoring of SARS-CoV-2 Antibody Retention and Transmission
* KDCA – Korea Disease Control and Prevention Agency
* OR – Odds ratio
* SARS-CoV-2 – Severe acute respiratory syndrome coronavirus 2

**Declarations**

**Ethical approval and consent to participate**

The Institutional Review Board of the KDCA exempted this survey from review, in accordance with Article 36 of the Bioethics Act, Article 33 of the Enforcement Rules, and Article 2 of the Bioethics Act. The study was deemed necessary for urgent public health action and was conducted directly or commissioned by the state or local government to review and evaluate public welfare or service programs (2022-11-02-PE-A). All participants provided informed consent.

**Consent for publication**

Not applicable.

**Availability of data and materials**

Data are available on reasonable request.

**Competing Interests**

The authors declare that they have no competing interests.

**Funding**

This work was supported by the National Institutes of Health of the Korea Disease Control and Prevention Agency grant number 2022-ER2603-00.

**Author Contributions**

JH, SYL and DHK conceptualized the study. JH, JAK, HJB, and EN conducted the literature search, performed the data collection and analysis. JH, KOL and EN had directly accessed and verified the underlying data. DHK supervised the project administration. JH, JAK, SYL completed the first draft of the manuscript. KOL, JWL, ARK and HND interpreted the results and critically revised the manuscript. KOL, JWL, ARK, HND and DHK read and approved the submitted version, had full access to all the data in the study and accepted responsibility to submit for publication.

**Acknowledgments**

Not applicable.

**References**

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| 1 | Baysson, H., Pennacchio, F., Wisniak, A., Zaballa, M. E., Pullen, N., Collombet, P., ... & Stringhini, S. (2022). Specchio-COVID19 cohort study: a longitudinal follow-up of SARS-CoV-2 serosurvey participants in the canton of Geneva, Switzerland. BMJ open, 12(1), e055515. |
| 2 | Ayouni, I., Maatoug, J., Dhouib, W., Zammit, N., Fredj, S. B., Ghammam, R., & Ghannem, H. (2021). Effective public health measures to mitigate the spread of COVID-19: a systematic review. BMC public health, 21(1), 1-14. |
| 3 | World Health Organization. "Statement on the fifteenth meeting of the IHR (2005) Emergency Committee on the COVID-19 pandemic." World Heal Organ (2023). https://www.who.int/news/item/05-05-2023-statement-on-the-fifteenth-meeting-of-the-international-health-regulations-(2005)-emergency-committee-regarding-the-coronavirus-disease-(covid-19)-pandemic |
| 4 | Korth, J., Wilde, B., Dolff, S., Frisch, J., Jahn, M., Krawczyk, A., ... & Anastasiou, O. E. (2021). SARS-CoV-2 seroprevalence in healthcare workers in Germany: a follow-up study. International Journal of Environmental Research and Public Health, 18(9), 4540. |
| 5 | Radon, K., Bakuli, A., Pütz, P., Le Gleut, R., Guggenbuehl Noller, J. M., Olbrich, L., ... & Fuchs, C. (2021). From first to second wave: follow-up of the prospective COVID-19 cohort (KoCo19) in Munich (Germany). BMC infectious diseases, 21, 1-15. |
| 6 | Berry AA, Tjaden AH, Renteria J, Friedman-Klabanoff D, Hinkelman AN, Gibbs MA, Ahmed A, Runyon MS, Schieffelin J, Santos RP, Oberhelman R, Bott M, Correa A, Edelstein SL, Uschner D, Wierzba TF; COVID-19 Community Research Partnership. Persistence of antibody responses to COVID-19 vaccines among participants in the COVID-19 Community Research Partnership. Vaccine X. 2023 Aug 11;15:100371. |
| 7 | Mahase, E. (2020). Covid-19: What do we know about “long covid”?. bmj, 370. |
| 8 | Wang, D., Zhao, J., Zhai, S., Chen, H., Liu, X., & Fan, F. (2022). Trajectories of mental health status during the early phase pandemic in China: A longitudinal study on adolescents living in the community with confirmed cases. Psychiatry Research, 314, 114646. |
| 9 | Arnold, C. R., Srinivasan, S., Rodriguez, S., Rydzak, N., Herzog, C. M., Gontu, A., ... & Ferrari, M. J. (2022). A longitudinal study of the impact of university student return to campus on the SARS-CoV-2 seroprevalence among the community members. Scientific reports, 12(1), 8586. |
| 10 | Madhavan R, Paul JS, Babji S, Kumar D, Prabhu SB, Pulleri HK, Annadorai R, Gowda SR, John J, Kang G. Risk of COVID-19 re-infection and its predictors (CORES): protocol for a community-based longitudinal cohort study in Vellore, India. BMJ Open. 2022 May 24;12(5):e059869 |
| 11 | Han, J., Baek, H. J., Noh, E., Yoon, K., Kim, J. A., Ryu, S., ... & Kim, D. H. (2023). Korea Seroprevalence Study of Monitoring of SARS-COV-2 Antibody Retention and Transmission (K-SEROSMART): findings from national representative sample. Epidemiology and health, 45. |
| 12 | STATISTA. Cumulative monthly number of coronavirus (COVID-19) confirmed and death cases in South Korea from January 20, 2020 to July 3, 2023. [cited 2023 Dec 28]. Available from: https:// https://www.statista.com/statistics/1098721/south-korea-coronavirus-confirmed-and-death-number/ |
| 13 | STATISTA. Percentage of population in select countries and territories worldwide that had received a COVID-19 vaccination as of December 23, 2022. [cited 2023 Dec 28]. Available from: https:// www.statista.com/statistics/1202074/share-of-population-vaccinated-covid-19-by-county-worldwide/ |
| 14 | Jang, E. J., Choe, Y. J., Yun, G. W., Wang, S., Cho, U. J., Yi, S., ... & Park, Y. J. (2022). Reinfection with SARS‐CoV‐2 in general population, South Korea; nationwide retrospective cohort study. Journal of Medical Virology, 94(11), 5589-5592. |
| 15 | Shim, J. A., Park, E., Kim, R. K., Lee, K. H., & Kwon, D.(2023). The Suspected COVID-19 Reinfection Cases and Vaccine Effectiveness in KOREA. PHWR, 16, 1512-1520. |
| 16 | Korea Disease Control and Prevention Agency. Due to the suspension of the 3rd and 4th vaccinations, additional vaccinations after basic vaccination are unified as the bivalent mRNA COVID-19 vaccination. [cited 2022 Dec 8]. Available from: https:// https://ncov.kdca.go.kr/tcmBoardView.do?brdId=3&brdGubun=31&dataGubun=&ncvContSeq=7019&contSeq=7019&board\_id=312&gubun=BDJ (Korean) |
| 17 | Yunoki, M., Kubota-Koketsu, R., Imada, T., Furuyama, K., Sasaki, T., Ohashi, S., & Shioda, T. (2023). Changes in Anti–SARS-CoV-2 Antibody Titers of Pooled Plasma Derived From Donors in Japan: A Potential Tool for Mass-Immunity Evaluation. The Journal of Infectious Diseases, jiad178. |
| 18 | Asamoah-Boaheng, M., Goldfarb, D. M., Karim, M. E., O’Brien, S. F., Wall, N., Drews, S. J., ... & Grunau, B. (2023). The relationship between anti-spike SARS-CoV-2 antibody levels and risk of breakthrough COVID-19 among fully vaccinated adults. The Journal of Infectious Diseases, 227(3), 339-343. |
| 19 | Goldberg, Y., Mandel, M., Bar-On, Y. M., Bodenheimer, O., Freedman, L. S., Ash, N., ... & Milo, R. (2022). Protection and waning of natural and hybrid immunity to SARS-CoV-2. New England Journal of Medicine, 386(23), 2201-2212. |
| 20 | Atti, A., Insalata, F., Carr, E. J., Otter, A. D., Foulkes, S., Wu, M. Y., ... & SIREN Study Group. (2023). Antibody correlates of protection against Delta infection after vaccination: A nested case-control within the UK-based SIREN study. *Journal of Infection*, *87*(5), 420-427. |
| 21 | Atti, A., Insalata, F., Carr, E. J., Otter, A. D., Castillo-Olivares, J., Wu, M., ... & Crick COVID Immunity Pipeline Consortium. (2022). Antibody correlates of protection from SARS-CoV-2 reinfection prior to vaccination: A nested case-control within the SIREN study. *Journal of Infection*, *85*(5), 545-556. |
| 22 | Perez-Saez, J., Zaballa, M. E., Lamour, J., Yerly, S., Dubos, R., Courvoisier, D. S., ... & Azman, A. S. (2023). Long term anti-SARS-CoV-2 antibody kinetics and correlate of protection against Omicron BA. 1/BA. 2 infection. Nature Communications, 14(1), 3032. |
| 23 | Yamamoto, S., Oshiro, Y., Inamura, N., Nemoto, T., Horii, K., Okudera, K., ... & Ohmagari, N. (2023). Durability and determinants of anti-SARS-CoV-2 spike antibodies following the second and third doses of mRNA COVID-19 vaccine. Clinical Microbiology and Infection. |
| 24 | Pooley, N., Abdool Karim, S. S., Combadière, B., Ooi, E. E., Harris, R. C., El Guerche Seblain, C., ... & Shaikh, N. (2023). Durability of vaccine-induced and natural immunity against COVID-19: a narrative review. Infectious Diseases and Therapy, 12(2), 367-387. |
| 25 | Hamady, A., Lee, J., & Loboda, Z. A. (2022). Waning antibody responses in COVID-19: what can we learn from the analysis of other coronaviruses?. Infection, 1-15. |
| 26 | Ferrari, D., Clementi, N., Criscuolo, E., Ambrosi, A., Corea, F., Di Resta, C., ... & Banfi, G. (2021). Antibody titer kinetics and SARS-CoV-2 infections six months after administration with the BNT162b2 vaccine. Vaccines, 9(11), 1357. |
| 27 | Yoon, K., Kim, J., Peck, K. R., Kim, H. S., Lee, H., Hwang, Y. S., ... & Kim, D. H. (2022). Seroprevalence of severe acute respiratory syndrome coronavirus 2 antibodies during the third wave of coronavirus disease in the Seoul metropolitan area of Korea. Epidemiol Health, e2022085-e2022085. |
| 28 | Dean, N. E., Howard, D. H., & Lopman, B. A. (2023). Serological Studies and the Value of Information. American Journal of Public Health, 113(5), 517-519. |
| 29 | Elliott, P., Ward, H., & Riley, S. (2023). Population Monitoring of SARS-CoV-2 Infections via Random Sampling During the COVID-19 Pandemic. American Journal of Public Health, 113(5), 514-516. |
| 30 | Bendavid, E. (2023). Seroprevalence Studies Are Critical Early Pandemic Tools, and They Were Underappreciated During COVID-19. American Journal of Public Health, 113(5), 523-524. |
| 31 | Earle, K. A., Ambrosino, D. M., Fiore-Gartland, A., Goldblatt, D., Gilbert, P. B., Siber, G. R., ... & Plotkin, S. A. (2021). Evidence for antibody as a protective correlate for COVID-19 vaccines. *Vaccine*, *39*(32), 4423-4428. |
| 32 | Goldblatt, D., Fiore-Gartland, A., Johnson, M., Hunt, A., Bengt, C., Zavadska, D., ... & Ambrosino, D. (2022). Towards a population-based threshold of protection for COVID-19 vaccines. *Vaccine*, *40*(2), 306-315. |
| 33 | Takahashi, T., Ai, T., Saito, K., Nojiri, S., Takahashi, M., Igawa, G., ... & Tabe, Y. (2023). Assessment of antibody dynamics and neutralizing activity using serological assay after SARS-CoV-2 infection and vaccination. *Plos one*, *18*(9), e0291670. |

**Figure legends**

**Figure 1.** Follow-up process for K-SEROSMART Wave 2

K-SEROSMART – Korea Seroprevalence Study of Monitoring of SARS-CoV-2 Antibody Retention and Transmission

**Figure 2.** Association between anti-S antibody titer levels at baseline and newly confirmed cases of COVID-19. The hazard ratios were adjusted for sex and age.

Anti-S – Anti-spike protein; COVID-19 – Coronavirus disease 2019

**Table 1.** Comparison of participants who completed follow-up and those lost to follow-up in K-SEROSMART Wave 2

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Characteristics in the K-SEROSMART WaveⅠ | | N | Losses to follow-up | | Follow-up participants | | P-value\* |
| N | Weighted % | N | Weighted % |  |
|  | Total | 9945 | 2417 | 25.1 | 7528 | 74.9 |  |
| Sex | Male | 4474 | 1104 | 26.2 | 3367 | 73.8 | 0.039 |
| Female | 5471 | 1313 | 24.1 | 4161 | 75.9 |  |
| Age-group | 5-18 | 987 | 283 | 28.0 | 704 | 72.0 | <0.001 |
| 19-34 | 1361 | 470 | 34.2 | 891 | 65.8 |  |
| 35-49 | 1864 | 413 | 22.7 | 1451 | 77.3 |  |
| 50-64 | 2672 | 517 | 19.5 | 2155 | 80.5 |  |
| +65 | 3061 | 734 | 24.0 | 2327 | 76.0 |  |
| Education  (≥19years) | Primary school | 1555 | 506 | 33.1 | 1049 | 66.9 | <0.001 |
| Middle/High school | 3702 | 808 | 24.8 | 2894 | 75.2 |  |
| Postsecondary | 3582 | 792 | 23.1 | 2790 | 76.9 |  |
| Annual household income (1,000 KRWa) | <20,000 | 1940 | 556 | 28.5 | 1384 | 71.5 | <0.003 |
| 20,000-39,999 | 2391 | 586 | 27.2 | 1805 | 72.8 |  |
| 40,000-59,999 | 1369 | 298 | 23.1 | 1071 | 76.9 |  |
| 60,000-79,999 | 1565 | 356 | 24.2 | 1209 | 75.8 |  |
| ≥80,000 | 1286 | 262 | 21.4 | 1024 | 78.6 |  |
| Generational household | Single person | 1234 | 385 | 32.1 | 849 | 67.9 | <0.001 |
| First-generation | 2802 | 595 | 22.9 | 2207 | 77.1 |  |
| Second-generation | 4195 | 998 | 24.0 | 3197 | 76.0 |  |
| Third generation | 526 | 146 | 30.5 | 380 | 69.5 |  |
| Occupation | White collar | 1411 | 324 | 23.5 | 1087 | 76.5 | 0.398 |
| Pink collar | 1137 | 289 | 26.5 | 848 | 73.5 |  |
| Blue collar | 435 | 116 | 26.1 | 319 | 73.9 |  |
| Unskilled workers | 792 | 191 | 25.3 | 601 | 74.7 |  |
| Unemployed | 3795 | 854 | 23.6 | 2941 | 76.4 |  |
| Type of  employment | Employers | 962 | 244 | 26.4 | 718 | 73.6 | 0.637 |
| Full-time worker | 1755 | 424 | 24.6 | 1331 | 75.4 |  |
| Non-regular worker | 1067 | 255 | 24.7 | 812 | 75.3 |  |
| Region | Seoul | 1399 | 309 | 23.6 | 1090 | 76.4 | <0.001 |
| Busan | 636 | 135 | 21.7 | 501 | 78.3 |  |
| Daegu | 382 | 69 | 18.0 | 313 | 82.0 |  |
| Incheon | 485 | 135 | 29.9 | 350 | 70.1 |  |
| Gwangju | 228 | 58 | 27.1 | 170 | 72.9 |  |
| Daejeon | 230 | 50 | 22.9 | 180 | 77.1 |  |
| Ulsan | 192 | 51 | 28.8 | 141 | 71.2 |  |
| Sejong | 100 | 23 | 23.8 | 77 | 76.2 |  |
| Gyeonggi | 2173 | 574 | 27.6 | 1599 | 72.4 |  |
| Gangwon | 495 | 115 | 26.4 | 380 | 73.6 |  |
| Chungbuk | 431 | 98 | 25.9 | 333 | 74.1 |  |
| Chungnam | 513 | 133 | 21.5 | 380 | 78.5 |  |
| Jeonbuk | 440 | 88 | 19.7 | 352 | 80.3 |  |
| Jeonnam | 611 | 204 | 33.2 | 407 | 66.8 |  |
| Gyeongbuk | 738 | 188 | 27.3 | 550 | 72.7 |  |
| Gyeongnam | 710 | 154 | 22.8 | 556 | 77.2 |  |
| Jeju | 182 | 33 | 16.8 | 149 | 83.2 |  |
| Current | Yes | 1049 | 281 | 27.4 | 768 | 72.6 | 0.082 |
| smoke | No | 7371 | 1740 | 24.5 | 5,631 | 75.5 |  |
| BMI | Low | 1906 | 482 | 26.4 | 1,424 | 73.6 | 0.228 |
|  | Normal | 4828 | 1133 | 24.4 | 3,694 | 75.6 |  |
|  | Obesity | 2225 | 519 | 24.0 | 1,706 | 76.0 |  |
| Number of disease history | None | 5431 | 1386 | 26.7 | 4,045 | 73.4 | <0.001 |
| 1 | 2047 | 461 | 22.6 | 1,586 | 77.7 |  |
| 2 | 1329 | 292 | 21.7 | 1,037 | 79.4 |  |
| ≥3 | 958 | 234 | 23.2 | 724 | 76.9 |  |

\*p-value estimated using the Rao–Scott chi-square test.

a 1,000 KRW = 0.76 USD (January 14, 2024)

K-SEROSMART – Korea Seroprevalence Study of Monitoring of SARS-CoV-2 Antibody Retention and Transmission; BMI – Body mass index

**Table 2**. Prevalence of antibodies against SARS-CoV-2 based on general characteristics in K-SEROSMART Wave 2

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | | N | Seroprevalence of anti-S1) antibody | | | Seroprevalence of anti-N1) antibody | | |
| Weighted % (95% CI) | RSE | p-value\* | Weighted % (95% CI) | RSE | p-value\* |
| Total | | 7528 | 98.5 (98.2 - 98.9) | 0.2 |  | 70.0 (68.8 - 71.2) | 0.9 |  |
| Sex | Male | 3367 | 98.3 (97.7 - 98.8) | 0.3 | 0.095 | 68.1 (66.3 - 69.9) | 1.4 | 0.002 |
| Female | 4161 | 98.8 (98.4 - 99.2) | 0.2 |  | 71.8 (70.3 - 73.3) | 1.1 |  |
| Age-group | 5-18 | 704 | 93.8 (91.8 - 95.8) | 1.1 | <0.001 | 84.5 (81.5 - 87.4) | 1.8 | <0.001 |
| 19-34 | 891 | 99.3 (98.7 - 100.0) | 0.3 |  | 71.4 (68.1 - 74.7) | 2.3 |  |
| 35-49 | 1451 | 99.2 (98.6 - 99.7) | 0.3 |  | 73.8 (71.3 - 76.3) | 1.7 |  |
| 50-64 | 2155 | 99.2 (98.7 - 99.6) | 0.2 |  | 66.2 (64.0 - 68.4) | 1.7 |  |
| +65 | 2327 | 99.4 (99.0 - 99.7) | 0.2 |  | 58.2 (56.0 - 60.4) | 2.0 |  |
| Education  (≥19years) | Primary school | 1049 | 99.6 (99.3 - 100.0) | 0.2 | 0.186 | 56.8 (53.2 - 60.3) | 3.2 | <0.001 |
| Middle/High school | 2894 | 99.0 (98.5 - 99.5) | 0.2 |  | 66.5 (64.5 - 68.5) | 1.5 |  |
| Postsecondary | 2790 | 99.4 (99.1 - 99.7) | 0.2 |  | 70.2 (68.3 - 72.1) | 1.4 |  |
| Annual household income  (1,000 KRWa) | <20,000 | 1384 | 98.4 (97.5 - 99.3) | 0.5 | 0.655 | 56.2 (53.0 - 59.3) | 2.9 | <0.001 |
| 20,000-39,999 | 1805 | 98.8 (98.1 - 99.4) | 0.3 |  | 69.9 (67.4 - 72.4) | 1.8 |  |
| 40,000-59,999 | 1071 | 97.8 (96.6 - 99.0) | 0.6 |  | 71.6 (68.4 - 74.7) | 2.3 |  |
| 60,000-79,999 | 1209 | 98.3 (97.4 - 99.2) | 0.5 |  | 72.1 (69.3 - 75.0) | 2.0 |  |
| ≥80,000 | 1024 | 98.5 (97.5 - 99.4) | 0.5 |  | 73.7 (70.7 - 76.6) | 2.0 |  |
| Generational household | Single person | 849 | 99.0 (98.2 - 99.8) | 0.4 | 0.003 | 58.0 (54.1 - 62.0) | 3.5 | <0.001 |
| First-generation | 2207 | 99.5 (99.2 - 99.8) | 0.2 |  | 66.9 (64.6 - 69.2) | 1.8 |  |
| Second-generation | 3197 | 98.0 (97.4 - 98.5) | 0.3 |  | 72.9 (71.2 - 74.6) | 1.2 |  |
| Third generation | 380 | 96.3 (93.3 - 99.3) | 1.6 |  | 68.9 (63.4 - 74.4) | 4.1 |  |
| Occupation | White collar | 1087 | 98.8 (97.9 - 99.7) | 0.5 | 0.539 | 67.1 (63.8 – 70.4) | 2.5 | 0.974 |
| Pink collar | 848 | 94.4 (98.8 - 99.9) | 0.3 |  | 68.2 (64.5 – 71.9) | 2.7 |  |
| Blue collar | 319 | 98.7 (97.1 - 100.3) | 0.8 |  | 67.2 (61.2 – 73.2) | 4.6 |  |
| Unskilled workers | 601 | 99.2 (98.4 - 100.1) | 0.5 |  | 66.6 (62.1 – 71.1) | 3.4 |  |
| Unemployed | 2924 | 99.4 (99.1 - 99.7) | 0.2 |  | 67.9 (66.0 - 69.9) | 1.5 |  |
| Type of  employment | Employers | 718 | 99.6 (99.2 – 100.1) | 0.2 | 0.092 | 65.5 (61.6 – 69.5) | 3.1 | 0.117 |
| Full-time worker | 1331 | 99.2 (98.6 - 99.7) | 0.3 |  | 66.2 (63.2 – 69.2) | 2.3 |  |
| Non-regular worker | 812 | 98.3 (97.1 - 99.6) | 0.6 |  | 70.6 (66.9 – 74.3) | 2.7 |  |
| Region | Seoul | 1090 | 99.3 (98.7 - 99.8) | 0.3 | -\*\* | 73.1 (70.3 - 75.8) | 1.9 | 0.005 |
| Busan | 501 | 98.6 (97.6 - 99.6) | 0.5 |  | 75.2 (71.3 - 79.1) | 2.6 |  |
| Daegu | 313 | 96.3 (94.0 - 98.6) | 1.2 |  | 63.5 (58.0 - 69.1) | 4.5 |  |
| Incheon | 350 | 98.1 (96.1 - 100.2) | 1.1 |  | 65.6 (59.7 - 71.5) | 4.6 |  |
| Gwangju | 170 | 100.0 (100.0 - 100.0) | 0.0 |  | 65.0 (57.5 - 72.5) | 5.9 |  |
| Daejeon | 180 | 98.5 (96.9 - 100.0) | 0.9 |  | 72.5 (65.6 - 79.3) | 4.8 |  |
| Ulsan | 141 | 92.3 (85.9 - 98.7) | 3.5 |  | 65.2 (55.3 - 75.1) | 7.8 |  |
| Sejong | 77 | 99.4 (98.2 - 100.6) | 0.6 |  | 80.5 (72.2 - 88.8) | 5.3 |  |
| Gyeonggi | 1599 | 99.0 (98.5 - 99.6) | 0.3 |  | 70.3 (68.0 - 72.7) | 1.7 |  |
| Gangwon | 380 | 98.8 (96.7 - 100.8) | 1.1 |  | 72.6 (66.8 - 78.5) | 4.1 |  |
| Chungbuk | 333 | 97.5 (95.1 - 100.0) | 1.3 |  | 70.0 (63.6 - 76.4) | 4.7 |  |
| Chungnam | 380 | 97.4 (95.3 - 99.4) | 1.1 |  | 65.4 (60.1 - 70.7) | 4.2 |  |
| Jeonbuk | 352 | 100.0 (100.0 - 100.0) | 0.0 |  | 66.1 (58.5 - 73.7) | 5.9 |  |
| Jeonnam | 407 | 99.9 (99.6 - 100.1) | 0.1 |  | 68.7 (63.6 - 73.9) | 3.8 |  |
| Gyeongbuk | 550 | 97.6 (95.8 - 99.5) | 1.0 |  | 68.4 (63.6 - 73.2) | 3.6 |  |
| Gyeongnam | 556 | 97.8 (96.1 - 99.5) | 0.9 |  | 68.2 (63.5 - 72.9) | 3.5 |  |
| Jeju | 149 | 100.0 (100.0 - 100.0) | 0.0 |  | 78.3 (71.2 - 85.5) | 4.6 |  |
| Current smoke | Yes | 768 | 99.8 (99.5-100.0) | 0.1 | <0.001 | 70.8 (67.1-74.5) | 2.7 | 0.621 |
| No | 5631 | 98.3 (97.9-98.7) | 0.2 |  | 69.8 (68.4-71.2) | 1.0 |  |
| BMI | Low | 1424 | 99.5 (99.1-99.9) | 0.2 | 0.565 | 68.1 (65.3-70.9) | 2.1 | 0.951 |
| Normal | 3694 | 99.2 (98.8-99.6) | 0.2 |  | 67.6 (65.8-69.3) | 1.3 |  |
| Obesity | 1706 | 99.2 (98.7-99.7) | 0.3 |  | 67.9 (65.3-70.5) | 2.0 |  |
| Number of disease history | None | 4045 | 98.5 (98.0-98.9) | 0.2 | 0.557 | 73.7 (72.2-75.3\_ | 1.1 | <0.001 |
| 1 | 1586 | 98.3 (97.6-99.1) | 0.4 |  | 64.7 (62.0-67.5) | 2.2 |  |
| 2 | 1037 | 98.9 (98.0-99.7) | 0.4 |  | 60.7 (57.3-64.1) | 2.9 |  |
| ≥3 | 724 | 99.2 (98.4-99.9) | 0.4 |  | 59.8 (55.7-63.9) | 3.5 |  |
| \*p-value estimated using the Rao–Scott chi-square test.  \*\* Chi-square test cannot be performed for the data on province by prevalence of anti-S antibodies because at least one table cell has 0 frequency.  K-SEROSMART – Korea Seroprevalence Study of Monitoring of SARS-CoV-2 Antibody Retention and Transmission; SARS-CoV-2 – Severe acute respiratory syndrome coronavirus 2; RSE – Relative Standard Error | | | | | | | | |

**Table 3.** Characteristics of newly confirmed COVID-19 cases among those who participated in K-SEROSMART Wave 2

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Variable | | N | Newly confirmed cases | Weighted % | P-value\* |
| Total | | 6837 | 712 | (10.4) |  | |
| Sex | Male | 3048 | 275 | (9.1) | 0.005 | |
|  | Female | 3789 | 437 | (11.6) |  | |
| Age-group | 5-18 | 595 | 69 | (10.6) | 0.049 | |
| 19-34 | 867 | 82 | (9.6) |  | |
| 35-49 | 1406 | 155 | (11.5) |  | |
| 50-64 | 1997 | 179 | (8.7) |  | |
| +65 | 1972 | 227 | (12.2) |  | |
| Education  (≥19years) | Primary school | 853 | 101 | (12.1) | 0.480 | |
| Middle/High school | 2644 | 276 | (10.4) |  | |
| Postsecondary | 2663 | 260 | (10.2) |  | |
| Annual household income (1,000 KRWa) | <20,000 | 1149 | 122 | (11.0) | 0.126 | |
| 20,000-39,999 | 1659 | 163 | (9.6) |  | |
| 40,000-59,999 | 978 | 97 | (9.4) |  | |
| 60,000-79,999 | 1126 | 143 | (12.3) |  | |
| ≥80,000 | 973 | 82 | (9.1) |  | |
| Generational household | Single person | 717 | 76 | (11.3) | 0.618 | |
| First-generation | 1985 | 208 | (10.7) |  | |
| Second-generation | 2965 | 293 | (9.8) |  | |
| Third generation | 5392 | 42 | (11.3) |  | |
| Occupation | White collar | 1004 | 121 | (12.7) | 0.182 | |
| Pink collar | 765 | 73 | (9.8) |  | |
| Blue collar | 287 | 30 | (10.5) |  | |
| Unskilled workers | 563 | 59 | (10.5) |  | |
| Unemployed | 2700 | 260 | (9.5) |  | |
| Type of  employment | Employers | 650 | 64 | (10.4) | 0.466 | |
| Full-time worker | 1226 | 146 | (12.1) |  | |
| Non-regular worker | 747 | 73 | (10.2) |  | |
| Region | Seoul | 1008 | 112 | (10.4) | 0.071 | |
| Busan | 466 | 31 | (6.8) |  | |
| Daegu | 283 | 28 | (9.4) |  | |
| Incheon | 314 | 35 | (9.1) |  | |
| Gwangju | 152 | 21 | (12.7) |  | |
| Daejeon | 166 | 19 | (12.7) |  | |
| Ulsan | 117 | 14 | (15.0) |  | |
| Sejong | 72 | 13 | (23.3) |  | |
| Gyeonggi | 1497 | 153 | (10.4) |  | |
| Gangwon | 351 | 39 | (11.8) |  | |
| Chungbuk | 288 | 31 | (10.7) |  | |
| Chungnam | 335 | 34 | (10.4) |  | |
| Jeonbuk | 305 | 33 | (9.0) |  | |
| Jeonnam | 368 | 30 | (6.6) |  | |
| Gyeongbuk | 471 | 46 | (10.5) |  | |
| Gyeongnam | 510 | 63 | (13.1) |  | |
| Jeju | 134 | 10 | (6.8) |  | |
| Current smoke | Yes | 693 | 80 | (12.6) | 0.074 | |
|  | No | 5133 | 519 | (10.0) |  | |
| BMI | Low | 1302 | 136 | (9.6) | 0.663 | |
|  | Normal | 3372 | 350 | (10.7) |  | |
|  | Obesity | 1568 | 157 | (10.2) |  | |
|  | None | 3767 | 392 | (10.5) | 0.997 | |
| Number of disease history | 1 | 1407 | 143 | (10.6) |  | |
|  | 2 | 900 | 93 | (10.3) |  | |
|  | ≥3 | 637 | 75 | (10.7) |  | |
| Titer of anti-S antibody | <2,000 | 1582 | 327 | (20.0) | <0.001 | |
| <4,000 | 772 | 141 | (18.0) |  | |
| <6,000 | 562 | 93 | (17.1) |  | |
| <8,000 | 448 | 45 | (9.8) |  | |
|  | <10,000 | 417 | 20 | (4.7) |  | |
| <12,000 | 364 | 13 | (3.1) |  | |
|  | <14,000 | 286 | 13 | (3.7) |  | |
| <16,000 | 265 | 7 | (2.3) |  | |
|  | <18,000 | 256 | 7 | (2.9) |  | |
|  | ≥18,000 | 1885 | 46 | (2.3) |  | |

\*p-value estimated using the Rao–Scott chi-square test.

K-SEROSMART – Korea Seroprevalence Study of Monitoring of SARS-CoV-2 Antibody Retention and Transmission; BMI – Body mass index; Anti-S – Anti-spike protein; COVID-19 – Coronavirus disease 2019