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Association between area deprivation index and concerns to COVID-19: A multi-level analysis of individual and area factors

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ABSTRACT

Background: The coronavirus disease 2019 (COVID-19) pandemic has been one of the most serious global threats to public health recently. The present study examined whether area deprivation is associated with concerns related to COVID-19 using large nationwide data across South Korea.

Methods: We used nationwide 2020 Korea Community Health Survey and official government database. Of the 225,680 included participants, 123,324 (54.6%) were women, and the mean age was 54.9 [17.8] years old. We classified the Area deprivation index (ADI) into Quartile 1 (Least deprived); Quartile 2; Quartile 3; and Quartile 4 (Most deprived). Our primary outcome was the concerns related to COVID-19 (0–16 scores). Multilevel regression analysis was conducted.

Results: The mean score of concerns related to COVID-19 was 11.3 [3.2] in the total population. 13.5% of the variability in the scores of concerns related to COVID-19 was accounted for by district areas. Area with Q4 of ADI were associated with an increased score of concerns related to COVID-19 (Q1: reference; Q2: $\beta = 0.218$, $SE = 0.119$, *FDR adj.p-value = 0.085*; Q3: $\beta = 0.235$, $SE = 0.133$, *FDR adj.p-value = 0.094*; Q4: $\beta = 0.252$, $SE = 0.109$, *FDR adj.p-value = 0.029*). 19–49 groups in area with Q4 of ADI were associated with an increase in scores of concerns related to COVID-19 than other age groups in area with Q4 of ADI. Area with Q4 of ADI were associated with a score of concern of being criticized if getting infected compared to area with Q1 of ADI.

Conclusion: We found that the highest quartile ADI was associated with greater concerns related to COVID-19. By identifying vulnerable population to concerns related to COVID-19, health systems may consider preventive intervention to mitigate mental health issues.

1. Introduction

The coronavirus disease 2019 (COVID-19) pandemic has been one of the most serious global threats to public health recently. As of August 2023, 1 out of 10 people in the world has had COVID-19, and 1 out of 100 people have died due to COVID-19 ("WHO Coronavirus (COVID-19) Dashboard,"). In particular, South Korea is one of the countries most affected by COVID-19, with about 66% of the total population getting COVID-19 as of August 2023. COVID-19 affected people's mental health as well as their physical health ("Mental Health During the COVID-19 Pandemic,"; Wu et al., 2020). COVID-19 has unprecedently suffered humanity while infringing on personal freedoms and provoking financial loss due to the government's strict quarantine policies (Cullen, Gulati, & Kelly, 2020; Kumar & Nayar, 2021; O'Connor et al., 2021). Consequently, policies such as lockdown, social distancing, and its economic consequences have affected individuals' mental health and increased the risk of suicide (Cullen et al., 2020; Kumar & Nayar, 2021; McKibbin & Fernando, 2020; O'Connor et al., 2021).

Individuals might encounter various concerns about COVID-19, including the risk of contracting the virus, COVID-19-related death, the stigma, and the economic impact brought by the pandemic. Concerns about COVID-19 may increase vigilance to protect themselves and those they care about from infection and death, which can cause anxiety, and panic in some people (Wu et al., 2020). COVID-19 may also result in

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stigma such as discrimination, racism, and judgmental attitudes to those who have been quarantined or who were from COVID-19 affected regions (Ganesan et al., 2021). Furthermore, economic loss, economic hardship and unemployment, and employment transitions triggered by the pandemic may have a strain on mental health with increasing financial difficulties and economic pressure (Lu & Lin, 2021).

Certain groups may be more vulnerable to the psychological impacts of the pandemic than others (Pfefferbaum & North, 2020). A systematic literature review summarized that several mental health outcomes are worse in deprived areas, and other studies have shown that people are more likely to have poor mental health in deprived areas than in other regions during COVID-19 (Hubbard, den Daas, Johnston, & Dixon, 2021; Rehkopf & Buka, 2006). Therefore, it may be necessary to identify mental health vulnerable people considering area factors during COVID-19.

Several studies have examined the association between the concerns of the COVID-19 pandemic and area factors such as area deprivation score (Hubbard et al., 2021) and socio-demographic factors of 31 European countries (Sannigrahi, Pilla, Basu, Basu, & Molter, 2020); however, these studies have utilized datasets of relatively limited scope, often focusing on specific populations or regions. To bridge this knowledge gap, the present study examined whether area deprivation is associated with concerns related to COVID-19 using a large nationwide sample of data across South Korea.

2. Material and methods

2.1. Data source and study population

We used the 2020 Korea Community Health Survey (KCHS) from the Korea Disease Control and Prevention Agency, which employed a multi-stage, stratified, and random sampling method to represent the nationwide Korean population (Kang et al., 2015). The 2020 KCHS was conducted from October 16, 2020 to December 31, 2020. Trained interviewers conducted one-to-one interviews with individuals aged 19 or older across the 255 local districts, which are all administrative districts in South Korea. “Districts” (or “Gu”) in South Korea are key administrative units within cities, akin to boroughs or neighborhoods elsewhere. Their geographic sizes and population densities vary, especially in larger cities where districts are smaller but more populous. Each district autonomously manages local matters such as urban planning, education, and public services. They play a vital role in local policy-making, tailored to the specific needs of their residents. Overall, districts are central to daily life and governance in South Korean cities. Within 255 districts, KCHS yielded about 230,000 representative population. Detailed information on the study design and aims of the KCHS has been previously reported (Kang et al., 2015). In the 2020 KCHS, new questionnaires regarding COVID-19 were added, including types of concerns related to COVID-19. Of the 229,269 participants, we excluded those who 1) did not answer at least one question regarding concerns related to COVID-19 (n = 482), and 2) who had any missing value of covariates considered in our study (n = 3107) (Fig. 1). We included 225,680 participants for our final study population.

We deployed data of cumulated infection rate of COVID-19 regional from the initial occurrence date (January 20, 2020) to the last survey date of KCHS (December 31, 2020), from open data source of Public Data Portal managed by the Ministry of the Interior and Safety. Thus, our study reflects the COVID-19 experience of the study population in KCHS as possible. We also used 2020 Korean population census data to calculate area deprivation index (ADI) in the context of material and social deprivation (MicroData Integrated Service (MDIS), 2021). All data used in this study are publicly accessible as noted in section of

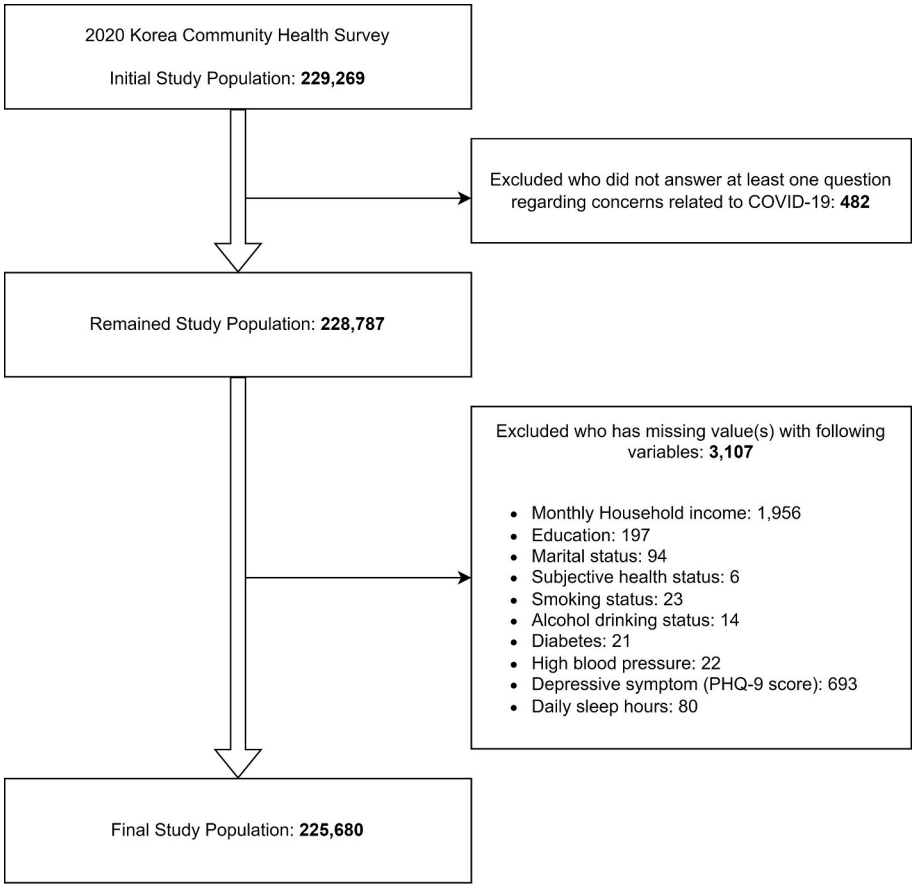

Fig. 1. Flowchart of the study population.

'Availability of Data and Materials'. All personal information in this data was de-identified before its distribution; therefore, the institutional review board of Yonsei University confirmed that this study is eligible for exemption from full institutional review board review.

2.2. Variables

2.2.1. Dependent variable: concerns related COVID-19 score (0–16 score)

With COVID-19 emerging as one of the most impactful and devastating pandemics in recent history, there's an increasing urgency to comprehend its societal repercussions and understand the depth of people's fears regarding the pandemic. Numerous studies have aimed to gauge the perceived risks and concerns associated with COVID-19 (Beaudoin & Hong, 2021; Fujii, Suzuki, & Niimi, 2021; Rayani, Rayani, & Najafi-Sharjabad, 2021). In response to this demand, KCHS formulated five questionnaires probing into respondents' concerns about the unintended consequences spurred by COVID-19. These questionnaires have been frequently employed in both published research and ongoing studies (Hyun, Son, & Jung, 2022; W. Kim, Ju, & Lee, 2022; H. Shin, Kim, & Lee, 2023).

To determine the COVID-19 concerns score, we used four questionnaire items: Type 1) "I am concerned I might become infected with COVID-19" (99.9% response rate; 229,029 out of 225,269 respondents), Type 2) "I am concerned I might die if I become infected" (99.9% response rate; 229,077 out of 229,269 respondents), Type 3) "I am concerned I may face criticism if I get infected" (99.9% response rate; 229,007 out of 229,269 respondents), Type 4) "I am concerned the outbreak could result in economic losses for me or my family" (99.9% response rate; 229,145 out of 229,269 respondents).

Although the item "I am concerned that my family members vulnerable to poor health might get infected" was included in the data, this specific question targeted only participants with family members at higher risk, such as the elderly, infants, or those with underlying health conditions. To ensure consistency in our evaluation of the association between ADI and the COVID-19 concerns score across the entire study population, we excluded this particular item. Each of the retained items was assigned a score of 0 (least concerned) or 4 (most concerned). The overall COVID-19 concerns score was the cumulative total of these individual scores, ranging between 0 and 16, with higher scores representing greater levels of concern related to COVID-19.

2.2.2. Independent variable: area deprivation index (ADI)

The ADI serves as a composite measure, signifying the extent of material and social deprivation within a geographical region. It is formulated based on several standardized and weighted variables (Jarman, Townsend, & Carstairs, 1991). Previous research has proven that the ADI can be useful for uncovering geographically-based differences in a community's health (V, 1995).

The South Korean version of the ADI, developed by the Korea Institute for Health and Social Affairs (D. Kim et al., 2013). Considering South Korea's unique socio-geographical dynamics, this ADI has been crafted drawing inspiration from earlier established indices like the Townsend and Carstairs indexes (H.-S. Shin, Lee, & Chu, 2009). It offers a continuous metric, quantifying regional socioeconomic disparities by incorporating eleven distinct determinants. This version of the ADI has gained traction in past studies for its efficacy in delineating variations in local environments (Hwang et al., 2022; D. W. Lee et al., 2022; S. E. Lee, Yeon, Kim, & Yoon, 2016; Youn, Lee, & Park, 2020).

The ADI used in our study was calculated based on the 2020 Korean population census data driven from 10% of the sample survey, along with district-level data (MicroData Integrated Service (MDIS), 2021). Eleven variables were included for the overall degree of area deprivation across 13 regional states and four metropolitan cities, which are the entire geographical area of South Korea. These variables are 1) proportion of people aged 25–64 with no high school diploma, 2) proportion of households not owning their own house, 3) proportion of households living in a monthly/yearly rental house, 4) proportion of households with overcrowded living conditions (> one person/room), 5) proportion of the population aged 65 or over, 6) proportion of households with a woman as head of the household, 7) proportion of separated, divorced, or widowed individuals aged ≥15 years, 8) proportion of households living below the minimum housing standard (house without separate kitchen, bathroom, hot-water supply system, and heating apparatus), 9) proportion of households without a motor vehicle, 10) proportion of people living alone, and 11) proportion of the population with occupational lower social class. These occupations include a) agriculture, forestry, and fishing workers; b) device, operation, and assembly workers; and c) simple labour workers. Each variable was standardized using a Z-score, combined to calculate the district-specific deprivation score, and linked with a participant's residential area code. We manually classified the ADI into quartile groups: Quartile 1 (least deprived, 1–25%, z-score < −3·67); Quartile 2 (26–50%, −3·67 < z-score ≤ −0·15); Quartile 3 (51–75%, −0·15 < z-score ≤3·61); Quartile 4 (most deprived, 76–100%, 3·61 < z-score).

2.2.3. Covariates

Incorporating with the study objective of understanding how concerns of COVID-19 were related with socioeconomic and health aspect, we included following individual- and area-level covariates. Included individual-level covariates were sex, age groups (19–29, 30–39, 40–49, 50–59, 60–69, or ≥ 70), monthly household income (<₩2,000,000, ₩2,000,000–2,999,999, ₩3,000,000–3,999,999, ₩4,000,000–4,999,999, or ≥ ₩ 5,000,000; ₩1000 almost equal $0·921), education (elementary school graduated or below, middle school graduated, high school graduated, or college graduated or above), marital status (single, married living together, or separated, divorced, or bereaved), subject health status (good, fair, or bad), smoking status (every day, occasionally, past, or never), alcohol drinking status (more than 4 times/a week, 2–3 times/a week, 2–4 times/a month, once or less than once/a month, or never), diabetes (no, or yes), high blood pressure (no, or yes), depressive symptom (Patient Health Questionnaire 9 items [PHQ-9] score; ranges from 0 to 27], and daily sleep hours. Included area-level covariates were COVID-19 infection rate by region and region type (capital city, metropolitan areas, or others).

2.3. Statistical analysis

We used a multilevel regression model to estimate the regression coefficient, with individual-level factors nested within 255 district areas in South Korea (area-level). Given that the dependent variable was continuous, ranging from 0 to 16, and had a fairly normal distribution (Supplementary Table 1), we selected the model with the identity link.

To ensure the correct specification of our multilevel model, we first conducted preliminary analyses to assess the functional relationship between the ADI (z-score) for 255 district areas and the mean concern scores related to COVID-19. We confirmed linearity through both visual and analytical means, using scatter plots with linear regression line (Supplementary Fig. 2).

Secondly, we conducted a univariate exploratory spatial data analysis (ESDA) to identify any spatial autocorrelation in concerns related to COVID-19 in South Korea, using both the global Moran's I and Geary's C statistic (Supplementary Fig. 3). Testing residuals for spatial autocorrelation means checking if a residual at one location correlates with residuals at nearby locations more than would be expected randomly. In essence, it checks if observations that are spatially close have similar values, indicating similar values are clustered together within the neighbouring areas.

Multilevel modelling begins with a null model analysis. This null model differentiates variances of the dependent variable, like within-area and between-area variances (Snijders & Bosker, 2011). We calculated the intraclass correlation coefficient (ICC) to test between-area variability. The ICC is the ratio between the between-area variance

and the sum of both within-area and between-area variances. In other words, the ICC reports on the amount of variation unexplained by any predictors in the model that can be attributed to the grouping variable, as compared to the overall unexplained variance (within and between variance). A high ICC indicates that between-area variance is not negligible, and thus a multilevel model should be employed to explain the inter-area dynamics. ICC equation is expressed as follows:

$$\mathrm{ICC} = \frac{\sigma^2_{u_0}}{\sigma^2_{u_0} + \sigma^2_e}$$

where $\sigma^2_{u_0}$ is the variance of the level-2 (area-level) residuals and σ^2_e is the variance of the level-1 (individual-level) residuals.

Following the basic association analysis (null model), we incorporated area-level deprivation (Model 1). In Model 2, we introduced individual-level characteristics. Finally, in Model 3, we integrated both individual- and area-level characteristics for the main analyses. This analysis used a two-level random intercept where individuals are nested within their residential areas. The main analyses used a two-level random intercept with the individuals (i), nested within their residential areas (j). Its equation is expressed as follows:

$$Y_{ij} = \beta_0 + \beta_{1j}X_{ij} + \left(\mathrm{u}_{0j} + e_{0ij}\right)$$

$$\left[u_{0\mathrm{j}}\right] \sim N\left(0, \sigma^2_{u0}\right)$$

$$\left[e_{0\mathrm{j}}\right] \sim N\left(0, \sigma^2_{e0}\right)$$

Here, Y_{ij} represents the value of the dependent variable of the i th individual in area j, while adjusting for a vector, X_{ij} of independent variables of individuals. Random effects inside the bracket are residual differentials specific for individuals ($u_{0\mathrm{j}}$) and area ($e_{0\mathrm{j}}$)-level.

We also performed stratified analysis with independent variables by sex, age, and monthly household income. Further we tested which type of concerns related COVID-19 had stronger association with ADI.

Furthermore, as the multiple comparison in the analyses may increases the likelihood of type I errors (false positive), we calculated different types of adjusted p-value such as Bonferroni adjusted p-value, Benjamini-Hochberg adjusted p-value, and false discovery rate (FDR) adjusted p-value (Supplementary Table 1). As FDR adjusted p-value is a balance between being too conservative (and potentially missing true effects) and allowing a controlled rate of false positives, we take it as a main p-value in the study (Benjamini & Hochberg, 1995).

All the statistical tests were two-tailed and performed using Stata (15·1, StataCorp LLC, College Station, TX), and SAS version 9·4 software (Cary, North Carolina, USA).

3. Results

COVID-19 infection rate per 1000 people varied by area from 0.06 to 9.50 (Fig. 2). ADI ranges from −13.1 to 16.7. The Capital region (Seoul and Gyeonggi) presented a higher COVID-19 infection rate per 1000 people along with a lower ADI compared to other areas.

The mean (standard deviation) score of concerns related to COVID-19 was 11.3 (3.2) in the total population (Table 1). Of the 225,680 included participants, 123,324 (54.6%) were women, and mean age was 54.4 [17.8]. Those with a higher score of concerns related to COVID-19 were more likely to be women (men: 10.81 [3.30]; women: 11.73 [3.11]), be aged 70 years or over (19–29 to ≥70: 10.20 [3.18] to 11.97 [3.36]; *p-value* < *0.001*), and received less than ₩ 2,000,00 monthly household income (<₩ 2,000,00 to ≥ ₩ 5,000,000: 11.78 [3.33] to 10.80 [3.12]; *p-value* < *0.001*). Area in quartile 4 of ADI showed higher scores of concerns related to COVID-19 compared to area in quartile 1 of ADI (Q1: 10.96 [3.17]; Q2: 11.31 [3.15]; Q3: 11.46 [3.24]; Q4: 11.70 [3.28]; *p-value* < *0.001*). Other area showed higher scores of concerns related to COVID-19 compared to capital city regions (capital city: 10.99 [3.15]; metropolitan areas: 11.07 [3.13]; others: 11.58 [3.29]; *p-value* < *0.001*).

Further, the result of the global univariate Moran's I and Geary's c tests for autocorrelation in score of concerns related to COVID-19 showed a significant value of positive spatial autocorrelation, indicating similar values are clustered together within the neighbouring areas (Moran's I: 0.0223; Geary's c: 0.9446, both p-values: <0.0001) (Supplementary Fig. 3).

In the null model, the random effect covariance was 0.510 (standard error [*SE*]: 0.047; *p-value* < *0.001*), and ICC value was 0.135. In ADI adjusted model, the random effect covariance was 0.4178 (standard error [*SE*]: 0.038; *p-value* < *0.001*), and ICC value was 0.113 (Table 2). Each indicates that 13.5% and 11.3% of the variability in the scores of concerns related to COVID-19 was accounted for by district areas. Accordingly, we can infer that 2.3% variability in concerns about COVID-19 was attributed to ADI. Model 3 considered both individual- and area-level characteristics presents the best fitting with the lowest −2 Log-likelihood and Akaike Information Criterion. In model 1, area with the highest quartile ADI scores was associated with the higher scores of concerns related to COVID-19 referenced with the least deprived area (Q1: reference; Q2: $\beta = 0.317$, $SE = 0.122$, *FDR adj.p-value* = 0.013; Q3: $\beta = 0.395$, $SE = 0.136$, *FDR adj.p-value* = 0.009; Q4: $\beta = 0.539$, $SE = 0.111$, *FDR adj.p-value*<0.001). In model 3, regarding individual-level characteristics, women were significantly associated with an increased score of concerns related to COVID-19 (women: $\beta = 0.705$, $SE = 0.019$, *FDR adj.p-value*<0.001). Regarding area-level characteristics, area of COVID-19 infection rate was not related to an increased score of concerns related to COVID-19 ($\beta = -0.032$, $SE = 0.052$; *FDR adj.p-value* =

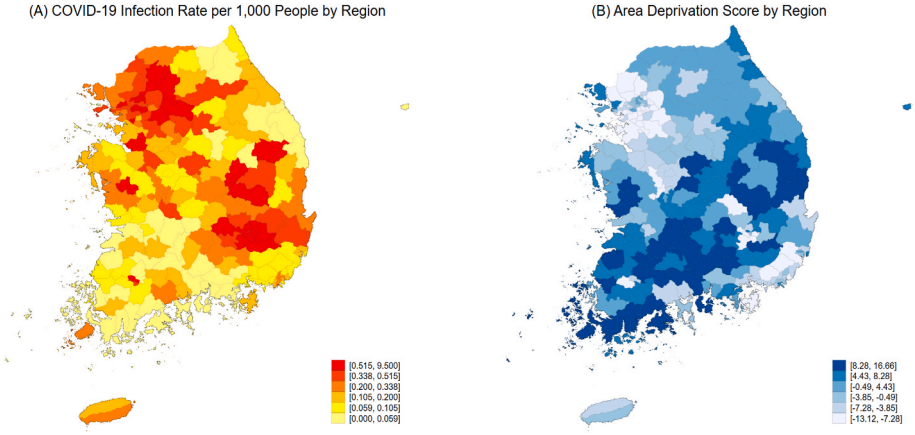

Fig. 2. COVID-19 infection rate (A) and area deprivation score (B) for 255 administrative districts that classified in 2020 Korea Community Health Survey.

Table 1
General characteristics of study population.

Characteristics	Total	%	Concerns related to COVID-19 (0–16 score)		
			Mean	SD	*p-value*
Individual level					
Sex	225,680	100.0	11.3	3.2	
Men	102,356	45.4	10.81	3.30	<0.0001
Women	123,324	54.6	11.73	3.11	
Age (mean: 54.5, SD: 17.8)					
19-29	25,821	11.4	10.20	3.18	<0.0001
30-39	25,012	11.1	10.87	3.09	
40-49	35,440	15.7	10.89	3.04	
50-59	43,912	19.5	11.29	3.12	
60-69	44,335	19.6	11.83	3.16	
≥70	51,160	22.7	11.97	3.36	
Monthly Household income					
< ₩ 2,000,000	72,049	31.9	11.78	3.33	<0.0001
₩ 2,000,000–2,999,999	35,203	15.6	11.46	3.19	
₩ 3,000,000–3,999,999	31,176	13.8	11.26	3.17	
₩ 4,000,000–4,999,999	24,421	10.8	11.11	3.11	
≥ ₩ 5,000,000	62,831	27.8	10.80	3.12	
Education					
Primary school grad., or below	49,639	22.0	12.22	3.25	<0.0001
Middle school grad.	25,257	11.2	12.01	3.13	
High school grad.	79,718	35.3	11.13	3.21	
College, or above	71,066	31.5	10.65	3.08	
Marital status					
Single	39,732	17.6	10.23	3.19	<0.0001
Married, live together	141,473	62.7	11.50	3.15	
Separated, divorced, bereaved	44,475	19.7	11.71	3.32	
Subjective health status					
Good	108,438	48.0	10.98	3.28	<0.0001
Fair	87,022	38.6	11.44	3.08	
Bad	30,220	13.4	12.17	3.27	
Smoking status					
Smoke every day	32,971	14.6	10.72	3.30	<0.0001
Smoke occasionally	3855	1.7	10.77	3.26	
Past smoker	41,275	18.3	11.08	3.26	
Never smoked	147,579	65.4	11.53	3.18	
Alcohol drinking status					
More than 4 times/a week	12,651	5.6	10.89	3.42	<0.0001
2–3 times/a week	27,794	12.3	10.92	3.13	
2–4 times/a month	40,208	17.8	10.95	3.09	
Once or less than once/a month	90,257	40.0	11.36	3.20	
Never drinked	54,770	24.3	11.81	3.31	
Diabetes					
No	199,319	88.3	11.24	3.22	<0.0001
Yes	26,361	11.7	11.86	3.29	
High blood pressure					
No	162,783	72.1	11.11	3.21	<0.0001
Yes	62,897	27.9	11.84	3.23	
Depressive symptom (PHQ-9 score), mean ± SD	1.96		±2.95		
Daily sleep hours, mean ± SD	6.68		±1.27		
Area level					
COVID-19 infection rate per 1000 by region [a], mean ± SD	0.39		±0.79		
Area deprivation score					
Quartile 1 (least): z-score < −3.67	89,312	39.6	10.96	3.17	<0.0001
Quartile 2: 3.67 ≤ z-score < −0.15	36,761	16.3	11.31	3.15	
Quartile 3: 0.15 ≤ z-score <3.61	26,563	11.8	11.46	3.24	
Quartile 4: (most): 3.61 ≤ z-score	73,044	32.4	11.70	3.28	
Region					
Capital city	63,132	28.0	10.99	3.15	<0.0001
Metropolitan areas	44,141	19.6	11.07	3.13	
Others	118,407	52.5	11.58	3.29	

PHQ-9, Patient Health Quastionnaire 9 items, SD, standard deviation.

[a] 255 administrative districts that classified in 2020 Korea Community Health Survey.

0.584). Area with Q4 of ADI were associated with an increased score of concerns related to COVID-19 (Q1: reference; Q2: $\beta = 0.218$, $SE = 0.119$, *FDR adj.p-value* = 0.085; Q3: $\beta = 0.235$, $SE = 0.133$, *FDR adj.p-value* = *0.094*; Q4: $\beta = 0.252$, $SE = 0.109$, *FDR adj.p-value* = 0.029).

In subgroup analyses, it was observed that men exhibited slightly higher concerns related to COVID-19, when stratified by ADI (Table 3). Concerning age groups, individuals aged 19–49 in areas with Q4 of ADI demonstrated a higher increase in concern scores related to COVID-19 compared to other age groups in the same ADI quartile.

Subgroup analysis for each detailed concern related to COVID-19 items showed that area with Q4 of ADI were associated with a score of concern of being criticized if getting infected compared to area with Q1 of ADI (Q1: reference; Q2: $\beta = 0.069$, $SE = 0.032$, *FDR adj.p-value* = *0.042*; Q3: $\beta = 0.066$, $SE = 0.036$, *FDR adj.p-value* = *0.084*; Q4: $\beta = 0.091$, SE = 0.029, *FDR adj.p-value* = *0.003*) (Table 4). Moreover, concerns of economic burdens due to infection were significantly associated with ADI, albeit its statistical significance is marginal in Q3 and Q4 (Q1: reference; Q2: $\beta = 0.088$, $SE = 0.033$, *FDR adj.p-value* = *0.012*; Q3: $\beta = 0.074$, $SE = 0.037$, *FDR adj.p-value* = *0.064*; Q4: $\beta = 0.063$, SE = 0.030, *FDR adj.p-value* = *0.057*). The result was in line with the respective analysis where the included population did not answer a corresponding question (Supplementary Table 2).

4. Discussion

We found that the highest quartile ADI was associated with greater concerns related to COVID-19. While explaining 13.5% of the concerns on COVID-19 at area-level, which is somewhat noticeable where the majority of previous research populated in South Korea indicated little explanation of regional variation to health-related outcomes (around 3%). (Kong & Cho, 2021; J. H. Lee & Heo, 2014; M, 2012; Park & Kim, 2014). Furthermore, we found that 2.3% variability in concerns about COVID-19 was attributed to ADI. Additionally, when stratified by sex, men exhibited a greater increase in COVID-19-related concern scores than women within the same ADI quartiles. In the highest ADI quartile, individuals aged 19–49 showed a more significant increase in these concern scores compared to other age groups within the same quartile. When stratified by type of concerns, "Concerns being criticized if getting infected" and "Concerns of economic burdens due to the infection" had significantly associated with ADI.

Firstly, it is noteworthy that the variability in concerns about COVID-19 is largely attributed to regional factors. Public health strategies and policies targeting larger clustered groups, like the 255 government district areas, could be beneficial. Understandably, living in a more deprived area was associated with greater concerns related to COVID-19 since the more deprived areas had a higher rate of poorer mental health, and thus higher vulnerability to concerns related to COVID-19. Environmental factors of an individual's dwelling area such as demographic profile, economic status, educational status, housing status and employment rate are critical factors to suicide, anxiety, and depression since they are indirectly associated with each other (O'Farrell, Corcoran, & Perry, 2016; Rehkopf & Buka, 2006; Walters et al., 2004). Indeed, areas with greater deprivation in South Korea showed higher rates of suicide and mental illness such as depression and anxiety, moderated by a higher proportion of the elderly and poorer economic status (Cheong et al., 2012; C. Kim, Chang, E. J., & Kim, C. Y, 2021). Furthermore, those who already had mental illness showed a greater risk of developing its severity (Pfefferbaum & North, 2020).

Moreover, deprived areas would be more likely to have a lower educational and socioeconomic level; thus, they may have less opportunity to acquire appropriate information about COVID-19 at the proper time. Therefore, people living in deprived areas have fewer COVID-19 preventive behaviours and greater fear of COVID-19. It is important to

Table 2
Association of individual and area characteristics to individuals' concerns related to COVID-19.

Characteristics	Concerns related to COVID-19 (0–16 score)											
	Null Model			Model 1 (Area)			Model 2 (Individual)			Model 3 (Both)		
	β	SE	FDR adj.p-value	β	SE	FDR adj.p-value	β	SE	FDR adj.p-value	β	SE	FDR adj.p-value
Individual level												
Sex												
Men							Reference			Reference		
Women							0.704	0.019	<0.001	0.705	0.019	<0.001
Age												
19-29							Reference			Reference		
30-39							0.466	0.036	<0.001	0.343	0.031	<0.001
40-49							0.163	0.032	<0.001	0.167	0.032	<0.001
50-59							0.293	0.033	<0.001	0.297	0.033	<0.001
60-69							−0.240	0.032	<0.001	−0.241	0.032	<0.001
≥70							0.326	0.040	<0.001	0.330	0.040	<0.001
Monthly Household income												
< ₩ 2,000,000							Reference			Reference		
₩ 2,000,000–2,999,999							0.127	0.021	<0.001	0.129	0.021	<0.001
₩ 3,000,000–3,999,999							0.057	0.023	0.016	0.060	0.023	0.015
₩ 4,000,000–4,999,999							−0.007	0.025	0.8	−0.004	0.025	0.903
≥ ₩ 5,000,000							−0.170	0.021	<0.001	−0.167	0.021	<0.001
Education												
Primary school grad., or below							0.759	0.026	<0.001	0.755	0.026	<0.001
Middle school grad.							0.769	0.026	<0.001	0.767	0.026	<0.001
High school grad.							0.332	0.017	<0.001	0.330	0.017	<0.001
College, or above							Reference			Reference		
Marital status												
Single							Reference			Reference		
Married, live together							0.727	0.026	<0.001	0.722	0.026	<0.001
Separated, divorced, bereaved							0.370	0.030	<0.001	0.365	0.030	<0.001
Subjective health status												
Good							Reference			Reference		
Fair							−0.259	0.022	<0.001	−0.259	0.022	<0.001
Bad							−0.433	0.023	<0.001	−0.433	0.023	<0.001
Smoking status												
Smoke every day							−0.130	0.023	<0.001	−0.130	0.023	<0.001
Smoke occasionally							−0.101	0.051	0.055	−0.101	0.051	0.065
Past smoker							−0.001	0.022	0.975	−0.001	0.022	0.980
Never smoked							Reference			Reference		
Alcohol drinking status												
More than 4 times/a week							−0.240	0.032	<0.001	0.080	0.021	<0.001
2–3 times/a week							0.010	0.025	0.753	0.009	0.025	0.775
2–4 times/a month							0.069	0.022	0.003	0.068	0.022	0.003
Once or less than once/a month							0.040	0.018	0.026	0.040	0.018	0.032
Never drinked							Reference			Reference		
Diabetes												
No							Reference			Reference		
Yes							0.080	0.021	<0.001	0.080	0.021	<0.001
High blood pressure												
No							Reference			Reference		
Yes							0.113	0.017	<0.001	0.114	0.017	<0.001
Depressive symptom (PHQ-9 score)							0.040	0.002	<0.001	0.040	0.002	<0.001
Daily sleep hours							0.021	0.005	<0.001	0.021	0.005	<0.001
Area level												
COVID-19 infection rate per 1000 by region							−0.030	0.053	0.573	−0.032	0.052	0.584
Area deprivation score												
Quartile 1 (least): z-score < −3.67							Reference			Reference		
Quartile 2: 3.67 ≤ z-score < −0.15							0.317	0.122	0.013	0.218	0.119	0.085
Quartile 3: 0.15 ≤ z-score <3.61							0.395	0.136	0.009	0.235	0.133	0.094
Quartile 4 (most): 3.61 ≤ z-score							0.539	0.111	<0.001	0.252	0.109	0.029
Region												
Capital city							Reference			Reference		
Metropolitan areas							−0.075	0.124	0.573	−0.110	0.122	0.412
Others							0.311	0.1121	0.011	0.125	0.11	0.298
Between area variance (SE)	0.510 (0.047) *		0.391 (0.036) *	0.408 (0.037) *		0.377 (0.035) *						
Model Fitness												
2 Log Likelihood	1,159,212		1,159,146	1,145,270		1,145,251						

(*continued on next page*)

Table 2 (*continued*)

Area level												
AIC	1,159,218	1,159,164	1,145,332	1,145,325								
Intraclass correlation coefficient	Unadjusted: 13.5%/Area deprivation score adjusted: 10.2% [b]											

FDR, False Discovery Rate, SE, standard error, AIC, Akaike Information Criterion.
*p < 0.0001.
[a] 255 administrative districts that classified in 2020 Korea Community Health Survey.
[b] 13.5% of the variability in the scores of concerns related to COVID-19 is accounted for by the areas in the study.

acquire relevant and updated information about COVID-19, as it guides an individual to practice preventive behaviours, such as hand hygiene, avoiding close contact with the sick, staying home when suspicious of being ill, using a facemask, cleaning and disinfecting contact objects and surfaces (Basch et al., 2020; Chang et al., 2020). Accordingly, relevant information about COVID-19 played an important role in reducing the fear of COVID-19 while preventive behaviours were mediated (Chang, Strong, Pakpour, Griffiths, & Lin, 2020).

While there is no definitive evidence explaining why men residing in socioeconomically deprived areas exhibit greater concerns about COVID-19 compared to women, a plausible inference can be drawn. It is likely that men in these areas are more frequently employed in occupations that cannot be performed remotely, such as manual labor or factory work. These types of jobs typically have a higher risk of exposure to COVID-19, potentially contributing to their increased concerns regarding the virus. Those aged 19–49 living in deprived areas had greater concerns due to COVID-19. This is interpreted that they are socially or economically active but environmentally aggravated, thus more likely to be frightened of the negative consequences related to COVID-19, such as being infected, criticized by others due to infection of COVID-19, financially disadvantaged, or death.

Our study showed the highest quartile deprivation was associated with greater concerns about being criticized if they got infected. Fear of interpersonal relationships may lead to social isolation and further psychological problems (Leigh-Hunt et al., 2017; Pietrabissa & Simpson, 2020; Rogers et al., 2020). This might be especially distinctive during the COVID-19 outbreak (Pietrabissa & Simpson, 2020; Rogers et al., 2020). Furthermore, we can infer that in deprived areas, significant concerns arise from economic burdens potentially caused by infection, such as decreased or suspended earnings due to job disruptions or loss.

Table 3
Association between area deprivation and individuals' concerns related to COVID-19, according to individuals' characteristics (sex, age group, and monthly income group).

Characteristic	Concerns related to COVID-19 (0–16 score)									
	Area deprivation score [a] : Q1 (least)	Area deprivation score [a] : Q2			Area deprivation score [a] : Q3			Area deprivation score [a] : Q4 (most)		
	β	β	SE	FDR adj.p-value	β	SE	FDR adj.p-value	β	SE	FDR adj.p-value
Sex										
Men	Reference	0.247	0.128	0.072	0.260	0.143	0.087	**0.285**	**0.117**	**0.022**
Women	Reference	0.182	0.117	0.156	0.211	0.130	0.150	0.214	0.107	0.068
Age										
19-29	Reference	0.267	0.149	0.180	0.300	0.132	0.063	**0.433**	**0.125**	**0.004**
30-39	Reference	0.174	0.130	0.260	**0.349**	**0.148**	**0.044**	**0.430**	**0.123**	**<0.001**
40-49	Reference	0.202	0.126	0.189	0.214	0.142	0.218	**0.328**	**0.117**	**0.013**
50-59	Reference	0.210	0.123	0.137	0.075	0.138	0.704	0.191	0.113	0.138
60-69	Reference	0.195	0.130	0.223	0.171	0.144	0.336	0.143	0.119	0.336
≥70	Reference	0.188	0.155	0.295	0.247	0.172	0.206	0.167	0.142	0.301

Adjusted for sex, age, monthly household income, education, marital status, subjective heatlh status, alcohol drinking status, smoking status, depressive symptom score (PHQ-9), daily sleep duration, diabetes, high blood pressure, regional infection rate of COVID-19, and region type.
[a] 255 administrative districts that classified in 2020 Korea Community Health Survey.

Table 4
Association between area deprivation and each type of concerns related to COVID-19.

	Concern Type 1: Concerns about infection			Concern Type 2: Concerns of dying by infection			Concern Type 3: Concerns of being blamed by others of infection			Concern Type 4: Concerns of economic burdens due to infection		
	β	SE	FDR adj.p-value	β	SE	FDR adj.p-value	β	SE	FDR adj.p-value	β	SE	FDR adj.p-value
Area deprivation score [a]												
Quartile 1 (least): z-score < −3.67	Reference			Reference			Reference			Reference		
Quartile 2: 3.67 ≤ z-score < −0.15	0.017	0.029	0.566	0.046	0.048	0.356	**0.069**	**0.032**	**0.042**	**0.088**	**0.033**	**0.012**
Quartile 3: 0.15 ≤ z-score <3.61	0.029	0.032	0.406	0.066	0.053	0.245	0.066	0.036	0.084	0.074	0.037	0.064
Quartile 4 (most): 3.61 ≤ z-score	0.015	0.027	0.566	0.082	0.044	0.078	**0.091**	**0.029**	**0.003**	**0.063**	**0.030**	**0.057**

Abbreviations: SE, standard error.
Adjusted for sex, age, monthly household income, education, marital status, subjective heatlh status, alcohol drinking status, smoking status, depressive symptom score (PHQ-9), daily sleep duration, diabetes, high blood pressure, regional infection rate of COVID-19, and region type.
[a] 255 administrative districts that classified in 2020 Korea Community Health Survey.

Interestingly, we can deduce that people have greater fears about the social/psychological and economic impacts arising from COVID-19 than about clinical outcomes such as being infected or dying from the infection. This finding aligns with previous research indicating that concerns over the pandemic's consequences adversely affect mental health, stemming from psychological distress and economic burdens (Blix, Birkeland, & Thoresen, 2021).

Several strategies may be explored to address concerns related to COVID-19 in deprived areas. The government may consider enhancing providing accurate information and mental health support related to COVID-19 to deprived areas where it is difficult to access timely appropriate information related to COVID-19. It may be considered to reduce the stress of the COVID-19 situation by increasing the public's understanding and reliability of COVID-19 related policies. In addition, policies and programs aiming at increasing neighbourhood safety and cleanliness might potentially lead to better mental health (Mohan & Barlow, 2023). Moreover, given access to services and amenities related to better mental health, efforts to enhance services like public transportation and establish high-quality open spaces may benefit the mental health of the community (Mohan & Barlow, 2023). Community social capital was associated with reduced psychological distress during the COVID-19 pandemic, serving as a buffer against the negative effects of pandemic-induced mobility restrictions (Laurence & Kim, 2021; McKenzie & Harpham, 2006; Mohan & Barlow, 2023). Participating in social groups and engaging in community activities might yield positive impacts on mental health by alleviating adverse outcomes.

Our study had several limitations. First, even after adjusting for various individual and area-level characteristics, the observed associations may still be influenced by residual confounding and potential bias from excluding individuals with missing values. We suggest investigating other factors that could influence concerns related to COVID-19. Future research should also explore potential mediators and moderators in the connection between area deprivation and COVID-19 concerns. Furthermore, it would be pertinent to examine the role of other area-based social determinants of health that might be relevant to this relationship. Second, the study relied on self-reported data, making it susceptible to measurement errors, recall bias, and social desirability bias. These limitations could introduce attenuation bias, underestimating the true effect of the independent variables. Third, the study's cross-sectional nature inhibits causal inferences. Longitudinal designs are needed for a more nuanced understanding of the relationship between area deprivation and COVID-19 concerns. Fourth, due to the limitation of data availability, we could not reflect frequent changes in the COVID-19 infection rate and involved government regulations, raising limited generalizability of the result. Subsequent research might consider the effect of government regulations on COVID-19 on individuals' behavioural changes and concerns. Fifth, we did not include worries about susceptible family members among the concerns related to COVID-19 items to understand the entire population's concerns related to COVID-19. It might lead to an incomplete understanding of the relationship between area deprivation and COVID-19 concerns. Sixth, our findings may not be generalizable to other countries with different environments. Nevertheless, given the severe effect of COVID-19 on Korea, where approximately two-thirds of the entire Korean population has experienced infection, this research may provide valuable insights into the association between the pandemic and mental health (Taylor, 2019). Seventh, even though we conducted a normality test on the outcome, as required by the multilevel regression model which assumes a normal distribution of the outcome, the results are somewhat ambiguous. Graphically, the distribution appears roughly normal, but statistically, it does not align perfectly with this (Supplementary Fig. 2). According to the Central Limit Theorem, normality tests with large sample sizes can be sensitive to even minor deviations from a perfect normal distribution (Kwak & Kim, 2017). Thus, given the current context of COVID-19 concerns and the potential influence of our large study population on the observed non-normality, it might be more prudent to emphasize the real-world significance of our findings rather than a slight deviation from normality in the outcome. Finally, ADI used was based on 255 predefined geographic districts, which may not align with residents' perceived neighbourhoods. This could result in discrepancies between administrative boundaries and actual areas affecting residents' lifestyles (Raudenbush & Bryk, 2002). However, using these 255 administrative districts in South Korea was our best option to classify the areas to capture social and economic characteristics using accessible data. These limitations notwithstanding, our study offers comprehensive information about factors associated with concerns related to COVID-19 including more than 200,000 individuals based on large nationwide representative data.

5. Conclusion

By identifying vulnerable population to concerns related to COVID-19, health systems may consider preventive intervention to mitigate mental health issues. Our research outcomes shed light on that regional deprivation is associated with higher concerns about COVID-19, potentially serving as valuable insights to address mental health issues during public health emergencies.

Availability of data and materials

The datasets generated and/or analysed during the current study are available in the repository of Korea Disease Control and Prevention Agency [https://chs.kdca.go.kr/chs/rdr/rdrInfoProcessMain.do], Ministry of the Interior and Safety [https://www.data.go.kr/en/index.do], and Statistics Korea [https://kostat.go.kr/portal/eng/index.action].

Ethics approval and consent to participate

The data used in the study are publicly accessible and all methods were carried out in accordance with relevant guidelines and regulations in the declaration. All personal information in this data was de-identified before its distribution; therefore, the institutional review board of Yonsei University confirmed that this study is eligible for exemption from full institutional review board review.

Consent for publication

Not applicable.

Authors' contributions

Doo Woong Lee: Conceptualization; Methodology; Formal analysis; Data curation; Writing – original draft; Writing – review and editing; Visualization.

Jieun Jang: Conceptualization; Methodology; Writing – review and editing; Visualization;

Jaeyong Shin: Conceptualization; Validation; Supervision.

All authors gave final approval.

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Declaration of competing interest

Dr. Shin reported receiving grant funding from the Korea Health Industry Development Institute during the conduct of the study and

being the chief executive officer and founder of Evertri, a company unrelated to the work that was submitted. Dr. Lee reported receiving grant funding from the Korea Health Industry Development Institute during the conduct of the study. Dr. Jang reported receiving grant funding from the Korea Health Industry Development Institute during the conduct of the study. No other disclosures were reported.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ssmph.2023.101580.

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