2023 AAG Annual Meeting

Post COVID-19 and the Healthy City

: Post COVID-19 and the Healthy City: Spatial distribution of health inequalities and differences before and during the pandemic

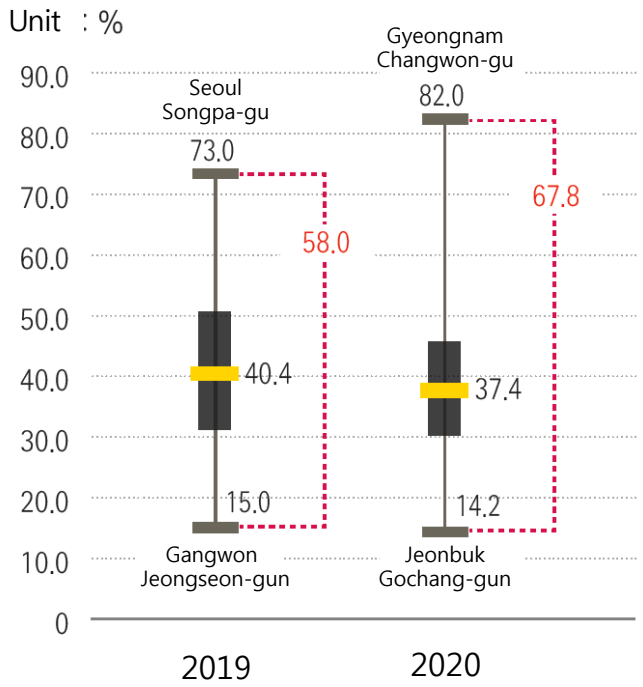
Chaeryun Lee

Seoul National University

1. Background and Purpose

Changes in life due to COVID-19

- Changes in daily life due to social distancing policies such as city lock-down, telecommuting, and etc.
- According to the 2020 Community Health Survey, 52.6% of respondents said physical activity decreased due to the COVID-19 pandemic. Walking rate[1)]decreased by an average of 3.0%p, and the gap between regions calculated the maximum and minimum differences increased by 9.8%p(KDCPA, 2021)



<Fig. 1> The average gap between regions in the walking rate

Intensifying Health Inequality Between Regions

- Physical and mental health problems caused by direct health effects such as infection and death, as well as decreased social activities (Cullen et al., 2020; Shanbehzadeh et al., 2021).
- Worldwide, studies have shown that the existing health gap between regions has widened due to COVID-19, worsening health inequality, and especially the gap between regions according to social classes (Okonkwo et el., 2020; Abedi et al., 2021; Okoi et al., 2020)

1) Walking rate : Percentage of respondents who walk for at least 30 minutes once in the last week and at least 5 days a week for at least 30 minutes a day (지역사회건강조사, 2021)

1. Background and Purpose

Necessity

- The importance of healthy cities and the analysis of health inequality after the pandemic have emerged as global urban issues
- Lack of research on changes in health inequality between regions after COVID-19 and urgent to discuss the patterns of health levels.

Purpose

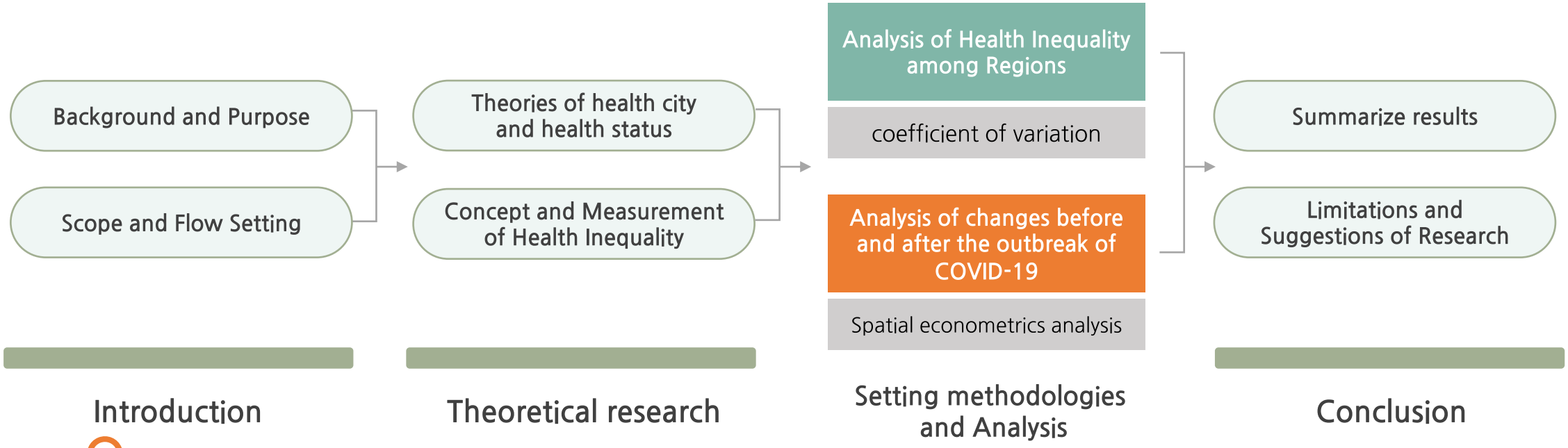
- To identify whether changes in health inequality exist between regions due to COVID-19
- To analyze changes in health inequality between regions before and after the outbreak of the pandemic.

Questions

1. "Did COVID-19 affect health inequality among regions?"
2. "If health inequality exists, what about the spatial distribution and the pre-pandemic changes in spatial distribution?"

2. Scope and Flow

- Spatial scope: National or national city, county, and district units (*Sigungu*; Korean admin unit)
- Time Range: 2019, 2020 (2-year)



Significance of research

- Available to help create a healthy city and derive a system to alleviate health inequality as well as when urban issues related to citizens' health such as COVID-19 occur

1. Healthy Cities and Health Status

Definition of a Healthy City

- WHO, "a city that continuously creates and improves the physical and social environment and expands the resources of the community to enable interaction with each other so that citizens can enjoy life to the fullest"
- Can be explained as “a city in which all citizens enjoy health-related public services fairly and have well equipped policies or administrative systems” (Duhl and Hancock, 1988)

Concepts and measurement tools of health status

- WHO describes 'health' as one of the basic rights of everyone regardless of economic or social conditions, not just the absence of disease, but the state of physical, mental, and social well-being (WHO, 1949)
- As a health level measurement tool, not only output indicators such as mortality and chronic diseases, but also input indicators such as walking volume, physical activity, depression, and self-cognitive health are used (Seong et al., 2014; Kim and Jeong, 2020; Zhang et al., 2019; Yim and Kwon, 2021).

✓ As a health level measurement tool, this paper intends to conduct individual, regional analysis using the indicators of "obesity rate," "subjective health status rate," "stress level rate," "depression experience rate," and "walking rate"

2. Concept and Measurement of Health Inequalities

Concept of Health Inequalities

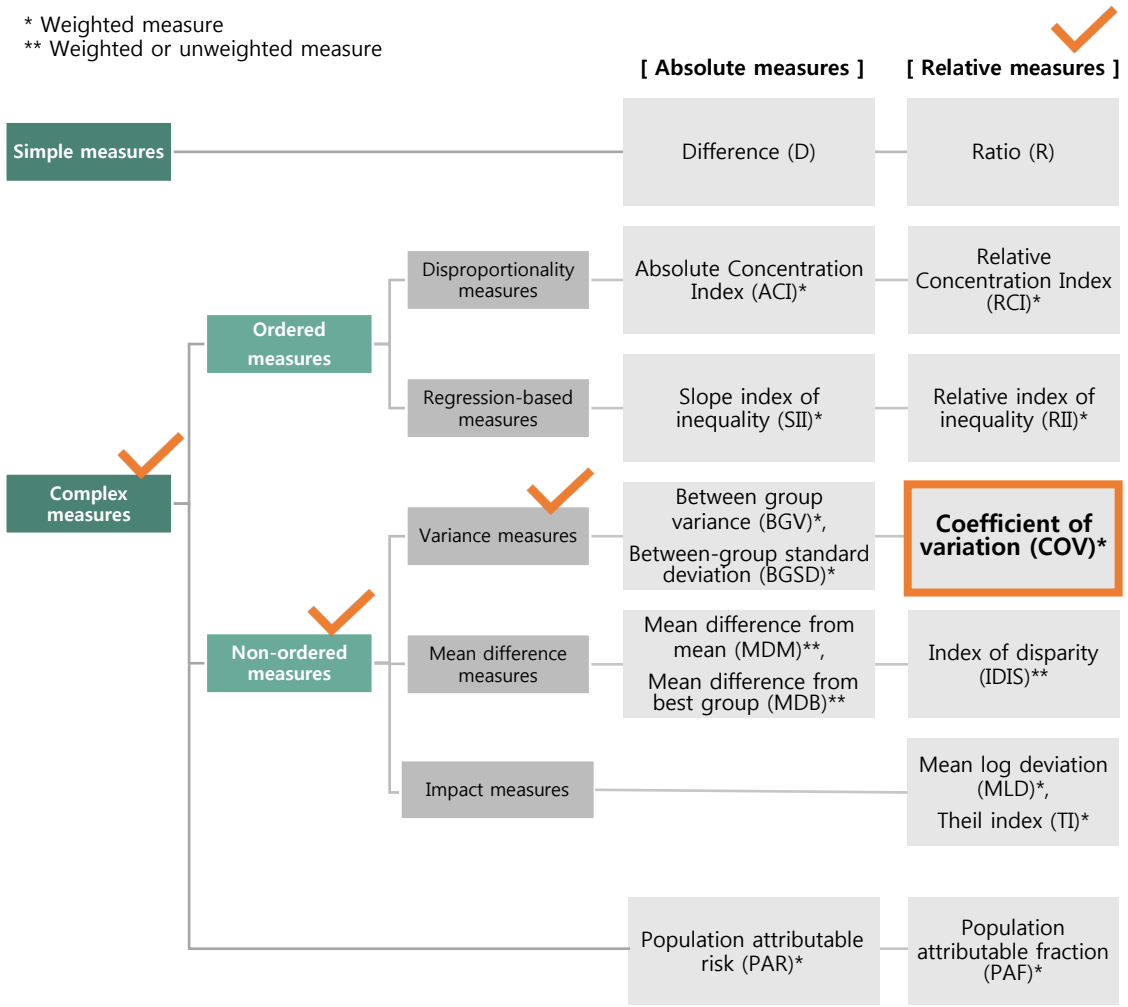
- "Difference in health between individuals or groups that is preventable and unfair"(Corburn, 2005)
- "Unfair health differences according to socioeconomic position, not just variation between individuals in terms of health status."(Lee, 2016)
- Through his book Toward the Healthy City, Corburn (2009) conveys cases of regional health inequality due to race, income, and drinking rates in U.S. cities and emphasizes public practical roles such as improving the physical environment and providing health services for healthy and equal cities.

✓ aims to measure health inequality by analyzing the distribution of observations and the presence of spatial clusters based on the difference in the average personal health status between regions

Measurement of Health Inequalities

- **(Statistical measurement)** A method to examine the distribution and distribution of health indicator observations
  - Total linearity measure: Lorentz curves and Gini coefficients are classically used, but socioeconomic dimensions cannot be considered through individual analysis - Social linear quality measure: Summary measures, a technical statistical method, can be analyzed
- **(Spatial measurement)** A method to examine spatial autocorrelation between regions of health indicator observations
  - Moran (1948) devised Moran's I, a spatial autocorrelation index that can overcome the spatial analysis convenience of traditional linear regression models (OLS)

2. Concept and Measurement of Health Inequalities



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〈Fig. 2〉 Health Inequality Statistical Measurement Methodology (Source: Schlotheuber & Hosseinpoor, 2022)

2. Concept and Measurement of Health Inequalities

〈Table 1〉 Previous Studies on the Analysis of Health Inequality Between Regions

Researchers	Title	Result	Methodologies
Avedi et al. (2021)	Racial, economic, and health inequality and COVID-19 infection in the United States. Journal of racial and ethnic health disparities	Low population, high poverty rate, and high death rate in counties with high number of disabled people were derived	Bivariate linear regression, stepwise regression
Rocha et al. (2021)	Effect of socioeconomic inequalities and vulnerabilities on health-system preparedness and response to COVID-19 in Brazil	Health inequality between regions is largely derived according to socioeconomic vulnerability	Linear regression
Jun and Kang (2021)	Spatial Distribution of Local Health Inequities : An Analysis of Local Mortality	The existence of regional differences in health level and mortality between metropolitan and non-metropolitan areas	Moran's I, LISA
Jay et al. (2020)	Neighbourhood income and physical distancing during the COVID-19 pandemic in the United States	The physical activity of citizens living in low-income areas was low, which was caused by health inequality	Difference in Differences
Kim and Jeon (2020)	The Differences in the Level of Physical Activity and its Determinants between Gangnam and Gangbuk Areas in the City of Seoul	Analysis of physical activity levels in the three Gangnam districts are higher than in the three Gangbuk 3 districts	Chi-square, t-test
Mee sook Lee (2005)	Health Inequalities Among Korean Adults	Apart from social class factors, the results are derived as variables that structure health differences in residential areas	Binomial logistic regression
Jinhui Lee (2016)	The Regional Health Inequity, and Individual and Neighborhood Level Health Determinants	Although the degree of influence of regional characteristics was smaller than that of individual characteristics, the likelihood of health inequality caused by the neighborhood environment was derived	Hierarchical Linear Model

3. Differentiation of Research

3. Double analysis of health inequality through statistical and spatial analysis

Diversified analysis is conducted by studying not only statistical inequality measurement but also health inequality measurement considering **spatial autocorrelation**

2. Analysis of health inequality in situations such as naturally occurring quasi-experimental environments

1. Analysis of various health status types

Comprehensive health variables are **measured by analyzing three types of health status**; physical health, mental health, and physical activity level

Analysis of health inequality before and after the COVID-19 outbreak is expected to contribute socially and economically to the creation of a healthy city and the preparation of policies to alleviate health inequality in the future

1. Data and Subjects

Characteristics of research data and subjects

- Research data: Using raw data from the annual community health survey conducted by Korea Disease Control and Prevention Agency(KDCPA)
  - Spatial range: 239 cities, counties, and districts nationwide
  - Survey Method: Interviews with Households Selected with an Average of 900 Samples per region(Sigungu)
  - Limitations and Significance: Although causal analysis is not possible due to cross-sectional surveys, time series changes in phenomena by region and time point are easy to grasp
- Subject of study: Adults aged 19 or older living in nationwide of Korea ($n_{2019} = 232,688$, $n_{2020} = 229,099$)

→ In this study, the original data of individual responses are analyzed by city, county, and district (Sigungu)

Variables		Before		After	
		Freq.	Percent	Freq.	Percent
Sex	Male	102,572	44.77	103,894	45.32
	Female	126,527	55.23	125,375	54.68
	Sub-total	229,099	100	229,269	100
Age	19~44	66,290	28.94	67,701	29.53
	45~64	88,262	38.53	88,756	38.71
	65~74	39,104	17.07	38,593	16.83
	75 and above	35,443	15.47	34,219	14.93
	Sub-total	229,099	100	229,269	100
Economical Activities	economically active population	141,960	61.99	138,970	60.63
	Non-active	87,056	38.01	90,236	39.37
	Sub-total	229,016	100	229,206	100
primary beneficiary	Yes	7,574	3.31	9,109	3.97
	Yes In the past	1,486	0.65	1,598	0.7
	No	219,845	96.04	218,511	95.33
	Sub-total	228,905	100	229,218	100
education level	No schooling	23,038	10.07	20,701	9.04
	Primary	34,861	15.23	33,105	14.46
	Lower secondary	25,505	11.14	24,976	10.91
	Upper secondary	75,409	32.95	78,225	34.16
	Bachelor's	63,397	27.70	65,089	28.42
	Master's and above	6,663	2.91	6,901	3.01
	Sub-total	228,873	100	228,997	100

〈Table 2〉 Demographic and social characteristics of the study subjects

2. Methodologies

1) Research questions and methodologies

Q1 : "Did COVID-19 affect health inequality among regions?"

Q2 : "If health inequality exists, what about the spatial distribution and the pre-pandemic changes in spatial distribution?"

Methodology 1_ Coefficient of Variance

- A statistical method that uses how distributed missing values are compared to the overall mean, and is widely used to identify intercluster inequality
- The larger the coefficient of variation, the larger the gap
- Suitable for variable conditions that analyze nominal variables and weight values, but if the missing value is a small value close to 0, the coefficient of variation is derived high, so care must be taken when analyzing

Methodology 2_ Moran's I, LISA

- Method of analyzing spatial autocorrelation according to Tobler (1979)'s first law of geography
- Moran's I : ranging from -1 to 1 and constructing a space-weighted matrix using the Queen method in this study
- LISA : Deriving statistically significant local clusters

2. Methodologies

2) Health Inequality Measurement and Change Analysis

Cross-progress of statistical and spatial analyses to diversify health inequality reviews

- **Statistical Measurement**

Coefficient of Variance : $\widehat{CV} = \frac{s}{\bar{x}} \times 100$

- **Spatial Measurement**

Moran's I: $I = \frac{N}{W} \frac{\sum_{i=1}^{N} \sum_{j=1}^{N} w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^{N}(x_i - \bar{x})^2}$

LISA(Local Moran's I):

$$I_i = \frac{(Z_i - Z)}{S_z^2} \cdot \sum_{j=1}^{n} [w_{ij}(Z_j - \overline{Z})]^{*}$$

〈Table 3〉 Health inequality measurement variables

Type		Variables	Explanation
Dep. Var.	Physical health level	Obesity rate	Percentage of persons with a self-reported body mass index (kg/m2) of 25 or higher
		Health Cognitive Rate**	Percentage of people who usually say their health is "very good" or "good"
	Mental health level	Stress Cognitive Rate	Percentage of people who feel "very much" or "very much" of stress in their daily lives
		Depression Experience Rate	Percentage of people who have experienced depression that interferes with their daily lives for more than two consecutive weeks in the past
	Physical activity level	Walking rate**	Percentage of persons who have practiced walking for at least 30 minutes once in the past week and for at least 5 days a week for at least 30 minutes a day

* Sz^2 is the variance, w_{ij} is the property variable of the region, and Z is the spatial weight matrix. The local peony index (I_i) refers to the standardization value for the difference between the adjacent area (Z_j) and the corresponding area (Z_i)(Lee and Sim, 2011).

** The larger the value, the healthier, and the smaller the value, the healthier the other variables.

1. Basic Statistical Analysis of Variables

Basic statistics of individual and regional units of dependent variables

- As dependent variables for personal data analysis, "obesity" (self-reported BMI), "subjective health level" and "stress level" and "depression experience" that can measure mental health level, and "walking" that can measure health life level are used.
- Personal data should be estimated and standardized for regional analysis, such as "obesity rate," "health cognitive rate," "stress cognitive rate," "depression experience rate," and "walking rate," (KCDC, 2021).

$$\hat{V}(\widehat{\overline{Y}_g}) = \sum_{h=1}\sum_{j=1} \frac{n_{ghj}(1-f_{ghj})}{n_{ghj}-1} \sum_{k=1}^{n_{ghj}} (e_{ghjk} - \overline{e_{ghj.}})^2$$

g : Public health center, h : region, j : sample points, k : household, l : household member,
n_{ghj} : the number of sample points of 'g' public health center,
N_{ghj} : the number of regions under the jurisdiction of 'g' public health center

$$f_{ghj} = \frac{n_{ghj}}{N_{ghj}}, \quad e_{ghjk} = \frac{(\sum_{l=1} W_{ghjkl}(y_{ghjkl} - \widehat{\overline{Y}_g}))}{W_{g....}}, \quad \overline{e_{ghj..}} = (\sum_{k=1} e_{hjk})/n_{ghj}$$

Source: Guidelines for Using Raw Data for 2020 Community Health Survey (KDCPA, 2021)

Red : Decreased health status
Green : Increased health status

〈Table 4〉 Basic statistics of individual unit

Type	Variable	Year	Obs	Mean	Std. Dev.	Min	Max
Physical health level	Obesity	2017	219,778	23.377	3.230	10.3	49.6
		2020	224,185	**23.587**	3.298	10.4	49.9
	subjective health level	2019	229,082	2.869	0.895	1	5
		2020	229,261	**2.581**	0.902	1	5
Mental health level	Stress level*	2019	228,974	2.995	0.743	1	4
		2020	229,199	**3.004**	0.753	1	4
	Depression experience*	2019	229,009	1.939	0.240	1	2
		2020	229,210	**1.944**	0.230	1	2
Physical activity level	Walking amount* (minutes per week)	2019	229,032	245.889	386.874	0	7140
		2020	229,170	**246.157**	392.773	0	6480

〈Table 5〉 Basic statistics of regional unit

Type	Variable	Year	Obs	Mean	Std. Dev.	Min	Max
Physical health level	Obesity rate	2017	239	28.605	3.274	18.3	39.0
		2020	239	**31.327**	3.487	20.1	43.5
	Health cognitive rate*	2019	239	42.675	7.195	29.7	68.3
		2020	239	**56.280**	6.466	38.6	79.4
Mental health level	Stress cognitive rate	2019	239	24.888	4.382	10.0	36.4
		2020	239	**25.712**	4.919	6.2	36.1
	Depression experience rate	2019	239	5.553	2.104	0.1	10.7
		2020	239	**5.532**	2.193	0.4	11.8
Physical activity level	Walking rate*	2019	239	40.813	12.809	15.0	73.0
		2020	239	**37.995**	11.019	14.2	82.0

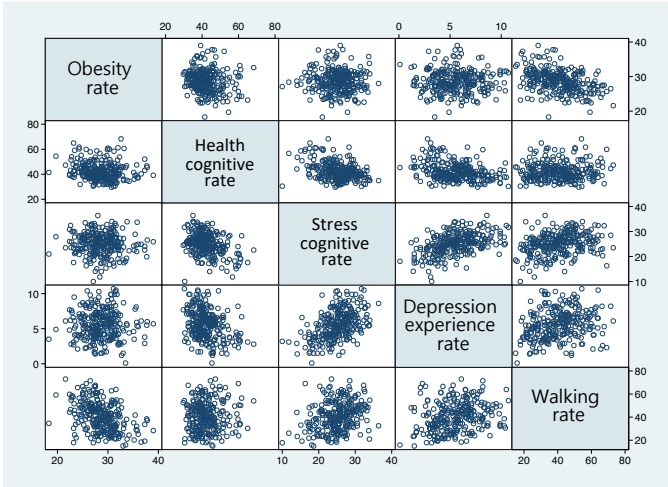
* Larger values are healthier; other variables show smaller values are healthier.

1. Basic Statistical Analysis of Variables

〈Table 6〉 Results of correlation analysis of dependent variables in regions before the outbreak

Type	Variable	(a)	(b)	(c)	(d)	(e)
Physical health level	Obesity rate (a)	1				
	Health cognitive rate (b)	-0.138*	1			
Mental health level	Stress cognitive rate (c)	-0.038	-0.380***	1		
	Depression experience rate (d)	0.007	-0.335***	0.497***	1	
Physical activity level	Walking rate (e)	-0.401***	0.047	0.287***	0.250***	1

Note: *p<.05, **p<.01, ***p<.001.

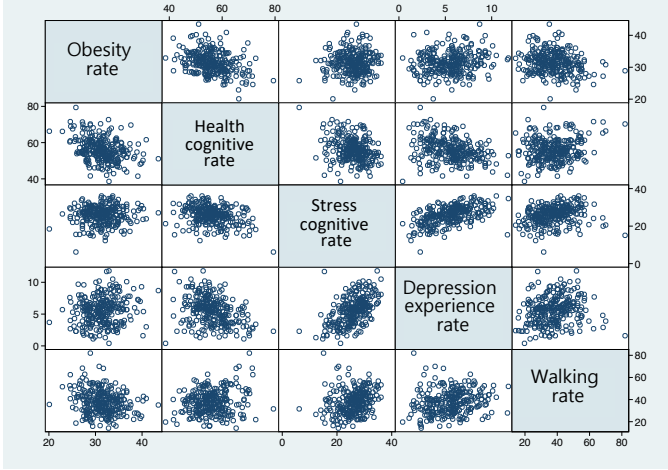


〈Fig. 3〉 Scatterplot between dependent variables before COVID-19

〈Table 7〉 Results of correlation analysis of dependent variables in regions after the outbreak

Type	Variable	(a)	(b)	(c)	(d)	(e)
Physical health level	Obesity rate (a)	1				
	Health cognitive rate (b)	-0.345*	1			
Mental health level	Stress cognitive rate (c)	0.062	-0.287***	1		
	Depression experience rate (d)	0.158***	-0.337***	0.542***	1	
Physical activity level	Walking rate (e)	-0.203***	0.178**	0.232***	0.173**	1

Note: *p<.05, **p<.01, ***p<.001.



〈Fig. 4〉 Scatterplot between dependent variables after COVID-19

2. Changes in the Health Status between Regions

Result of statistical analysis

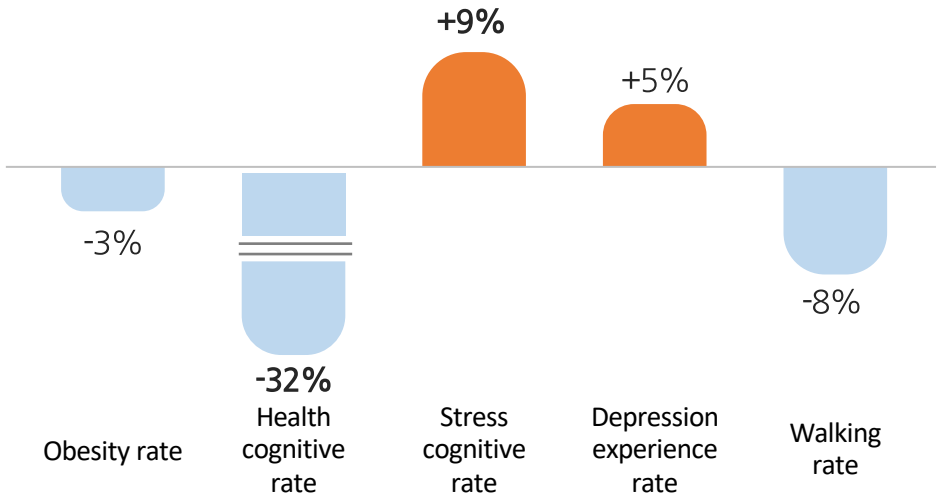
Changes in Coefficient of Variance

Result

- The CV in physical health level and physical activity levels decreased after the outbreak, but the stress cognitive rate and depression experience rate that explain mental health level has increased.
- In the case of this decrease in the coefficient of variation, health inequality in physical health and physical activity levels, such as walking rates, has been alleviated due to the pandemic-related social distancing policy, but inequality in mental health levels has been strengthened due to differences in the number of infections and deaths by region.

〈Table 8〉 Result of CV analysis

Type	Variable	Year	CV	Diff.(ratio)
Physical health level	Obesity rate	2017	11.4445	Reduced (-2.74%)
		2020	11.1304	
	Health cognitive rate	2019	16.8596	Reduced (-31.86%)
		2020	11.4887	
Mental health level	Stress cognitive rate	2019	17.6053	Increased (8.68%)
		2020	19.1327	
	Depression experience rate	2019	37.8898	Increased (4.61%)
		2020	39.6372	
Physical activity level	Walking rate	2019	31.3841	Reduced (-7.60%)
		2020	29.0003	



〈Fig. 5〉 Changes of CV before and after the outbreak

2. Changes in the Health Status between Regions

Result of spatial analysis

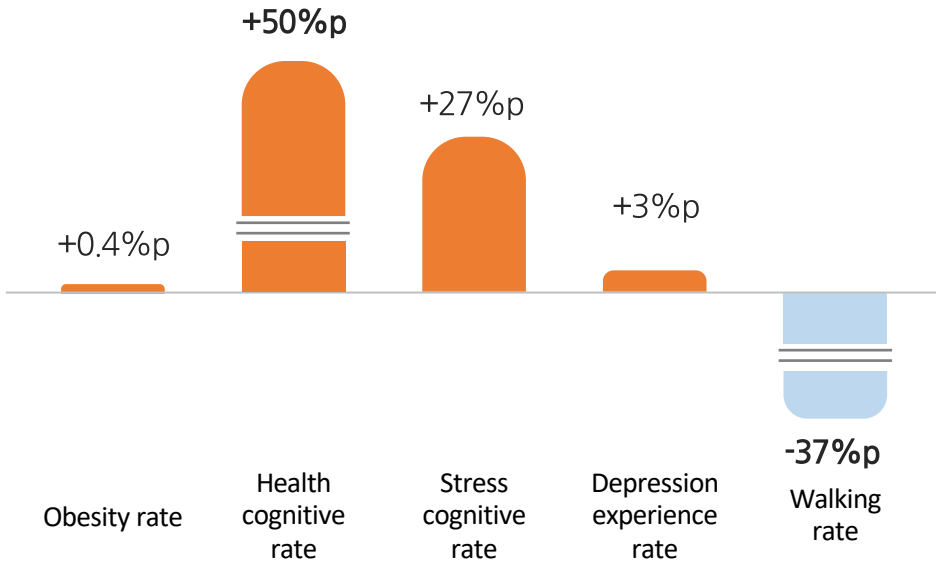
Changes in Moran's I

Result

- All five health level indicators are not randomly distributed between regions, and health inequality exists as high and low health level regions form clusters, respectively.
- In particular, spatial health inequality has worsened in all variables except for the walking practice rate, which can be interpreted as a further increase in clustering due to differences in the number of COVID-19 infections by region.

〈Table 9〉 Result of Moran's I analysis

Type	Variable		Before	After	Diff. (ratio)
Physical health level	Obesity rate	Moran's I:	0.279	0.280	Increased
		p-value:	0.000	0.000	(0.39%p)
	Health cognitive rate	Moran's I:	0.213	0.321	Increased
		p-value:	0.000	0.000	(50.39%p)
Mental health level	Stress cognitive rate	Moran's I:	0.254	0.324	Increased
		p-value:	0.000	0.000	(27.48%p)
	Depression experience rate	Moran's I:	0.146	0.150	Increased
		p-value:	0.000	0.000	(3.27%p)
Physical activity level	Walking rate	Moran's I:	0.525	0.329	Reduced
		p-value:	0.000	0.000	(-37.41%p)



〈Fig. 6〉 Changes of Moran's I before and after the outbreak

3. Spatial Distribution of Health Inequality

Spatial Analysis Results

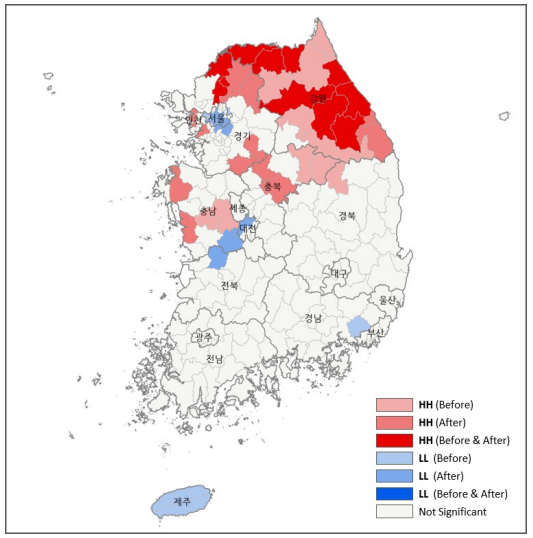
Changes in Local Moran's I (LISA)

Result

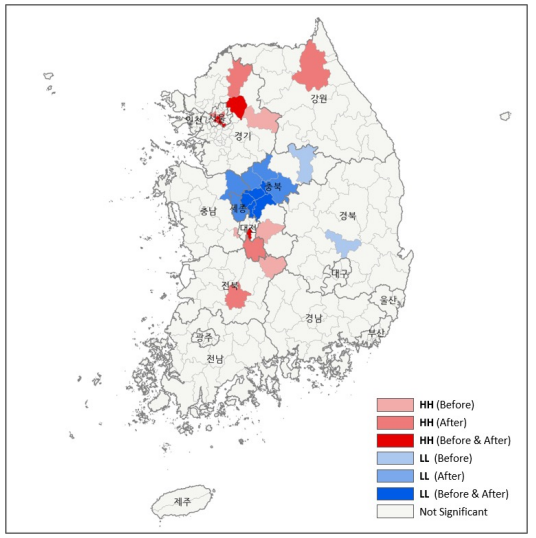
- Although the size and number of the cluster have changed in both HH and LL types before and after the pandemic, the cluster area of mental health level shows a significant difference.
- However, in most variables, the difference between the metropolitan area and the non-metropolitan area is noticeable, making it difficult to interpret that health inequality between regions has been greatly alleviated.

〈Table 10〉 the number of cities in the cluster

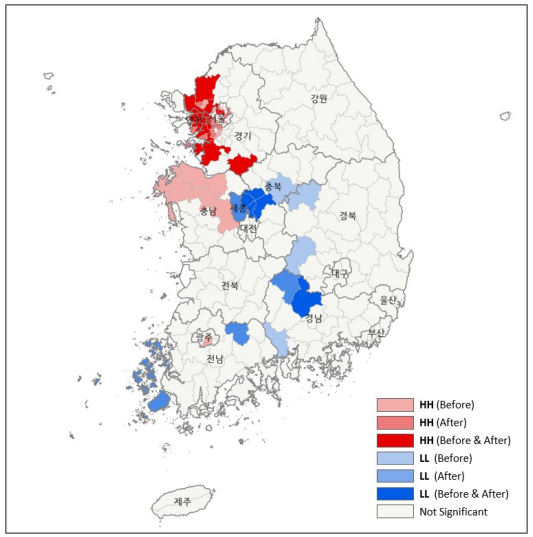
Type	Variable	Cluster	Before	After
Physical health level	Obesity rate	HH	23	26
		LL	6	24
	Health cognitive rate	HH	9	14
		LL	7	10
Mental health level	Stress cognitive rate	HH	33	33
		LL	9	10
	Depression experience rate	HH	14	14
		LL	15	12
Physical activity level	Walking rate	HH	46	31
		LL	34	26



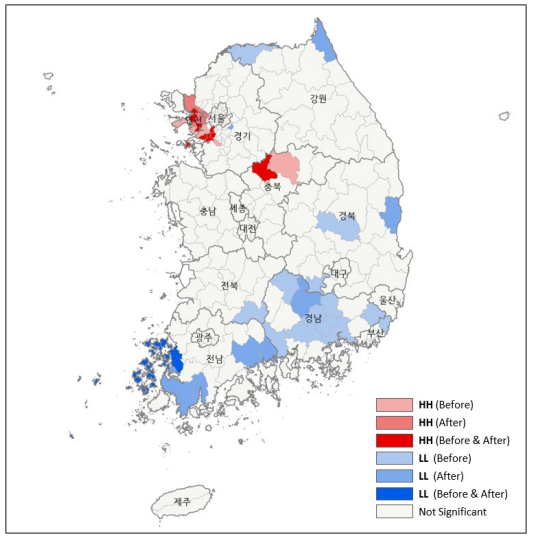
〈Fig.7〉 LISA Map of Obesity rate



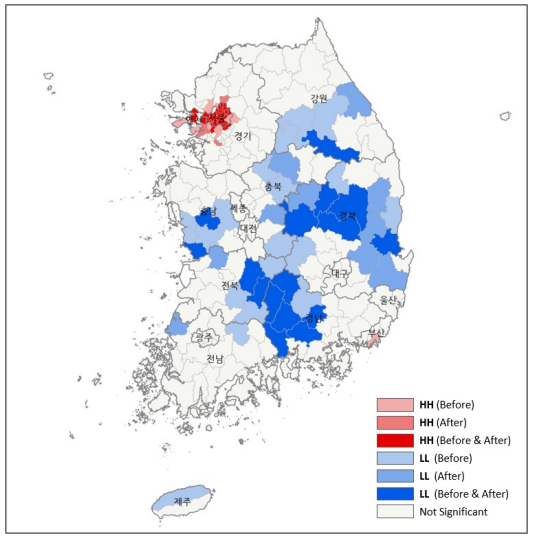
〈Fig.8〉 LISA Map of Health Cognitive rate



〈Fig.9〉 LISA Map of stress cognitive rate



〈Fig.10〉 LISA Map of depression experience rate



〈Fig.11〉 LISA Map of walking rate

Summary of Research Results

〈Table 11〉 Summary of analysis results

Type	Variable	Mean Health Status	CV Statistical Inequality	Moran's I Spatial Inequality
Physical health level	Obesity rate	Reduced	Alleviated (-2.74%)	Worsen (+0.39%)
	Health cognitive rate	Increased	Alleviated (-31.86%)	Worsen (+50.39%)
Mental health level	Stress cognitive rate	Reduced	Worsen (+8.69%)	Worsen (+27.48%)
	Depression experience rate	Increased	Worsen (+4.61%)	Worsen (+3.27%)
Physical activity level	Walking rate	Reduced	Alleviated (-7.60%)	Alleviated (-37.41%)

Shows differences in health inequality between regions after the pandemic

Since the outbreak of COVID-19, social distancing has reduced the statistical distribution of physical health levels and physical activity levels. On the other hand, health inequality of mental health level have worsened.

Increasing spatial autocorrelation and strengthening inequality

All health level variables were spatially clustered, and after the pandemic, health inequality worsened due to strong clusters in all variables except the walking rate. The difference in H-H and L-L clusters between the metropolitan area and the non-metropolitan area.

Differences exist in health inequality after the pandemic occurred

As there are regional differences in health inequality between individual health level variables, suggesting the need to analyze what regional characteristics will affect health after COVID-19

Limitation and Discusses

The characteristics of the region have been excessively averaged by conducting regional analysis across the country

Reasons why some cities have particularly large health inequality could not be examined in detail

Discusses

- After the pandemic, **health inequality worsened** statistically or spatially in all variables **except for walking rate** due to social distancing
- Differences in health levels **between metropolitan and non-metropolitan areas** were derived
- A more in-depth interpretation would have been possible if qualitative research had been accompanied as well as quantitative analysis
- Expected to be used as basic data for urban planning policies and follow-up research in consideration of citizens' health in the post-pandemic and new normal era

Reference

Abedi, Vida, Oluwaseyi Olulana, Venkatesh Avula, Durgesh Chaudhary, Ayesha Khan, Shima Shahjouei, Jiang Li, and Ramin Zand. "Racial, economic, and health inequality and COVID-19 infection in the United States." Journal of racial and ethnic health disparities 8 (2021): 732-742.

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Thank you