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Association between district-level safety and self-rated health: a multilevel study in an urban setting

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Abstract

Objectives: Several studies have reported the relationship between resident's perceived neighborhood safety and their health outcomes. However, those studies suffered from unreliability of neighborhood safety measure and potential residual confounding related to crime rates. In this study, using multilevel analysis to account for the hierarchical structure of the data, we examined associations between district-level safety and self-rated health after adjusting for potential confounders including individual-level perceived neighborhood safety and district-level crime rate.

Design: Cross-sectional study

Setting: We used the 1st wave of Seoul Welfare Panel Study, which has 7,761 individuals from 3,665 households in 25 administrative districts in Seoul, South Korea. District-level safety was obtained by aggregating responses from the residents that are representative samples for each administrative district in Seoul. We controlled objective district-level crime rate, individual-level perceived neighborhood safety and socio-demographic factors as well. To examine an association between district-level safety and residents' self-rated health, we used mixed effects logistic regression.

Results: Our results showed that higher district-level perceived safety, an aggregated measure of district residents' responses on neighborhood safety, was significantly associated with poor self-rated health after controlling for demographic influences and SES (OR: 0.87, 95% CI: 0.78-0.97). Notably, this association was still robust even when we additionally adjusted for district-level crime rate and individual-level perceived neighborhood safety (OR: 0.86, 95% CI: 0.77-0.96).

Conclusions: Our study highlights the importance of improving neighborhood safety to enhance resident health.

Keywords: perceived neighborhood safety, self-rated health, neighborhood crime rate, Seoul Welfare Panel Study, multilevel analysis

Strengths and limitations of this study

- Multilevel analytic frame was used to examine an association between district-level safety and residents' self-rated health using representative samples of metropolis, Seoul, South Korea.
- We succeed in adjusting for potential confounders such as individual-level perceived neighborhood safety and district-level crime rate in our analytic model, which past studies have failed.
- Causal relationships cannot be inferred from the cross-sectional data.

INTRODUCTION

Crime is one of the major problems in many metropolitan areas across countries. Although city crime rates have dropped globally since the mid-1990s,[1] there are still large variations and dramatic fluctuations across cities.[2] Past criminological studies revealed that variations in crime rates were explained by characteristics of metropolitan areas, such as population sizes, ethnic heterogeneity, geographic mobility, economic segregation, unemployment rate, poverty level and degree of social integration and control.[2-4] Thus, many governments have made great efforts to reduce the crime rates especially in metropolitan areas by intervening in those characteristics to ensure the safety of their residents.

Safety from crime is not only an essential human need in daily life, but also a prerequisite to human health.[5] A body of past studies has reported the relationship between residents' perceptions of neighborhood safety and their health outcomes.[6,7] For example, one UK survey with 407 adults reported that fear of crime was significantly associated with self-rated health and mental well-being.[8] Ziersch and Baum[10] showed that perceived neighborhood safety was related to physical and mental health among 2,400 residents in western suburbs of Adelaide, Australia.

However, these earlier studies suffer from the following limitations. First is the potential measurement error of the perceived neighborhood safety. The individual perception can be influenced by several factors such as prior individual experience of victimization, or individual health conditions other than neighborhood-level safety.[11,12] This could be particularly a critical issue in previous cross-sectional studies because of the potential reverse causation, meaning that the sick are more likely to perceive their neighborhood as unsafe.[7,13] The second

limitation is lack of representativeness of samples within the operationalized definition of neighborhood. The sample size or the sample size within neighborhood of previous studies was too small to be representative for each neighborhood.[6, 8,14] Unless the responses are obtained from a representative sample of participants within each neighborhood, aggregated perceived neighborhood measures can potentially be prone to measurement errors. Also, unavailability in appropriate neighborhood measure may explain why there is scant hierarchical or multilevel analysis which allows for estimating the influence of neighborhood measures on residents' health outcomes. The final limitation is that previous studies did not adjust for district-level crime rate as a potential confounder although crime-rate has been reported to influence perception of neighborhood safety as well as residents' health outcomes.

In this study, we assessed the district-level safety, which was obtained by aggregating responses from the residents that are representative samples for each administrative district in Seoul, the capital of South Korea. Then, using multilevel analysis to account for the hierarchical structure of the data, we examined associations between district-level safety and self-rated health after adjusting for potential confounders including individual-level perceived neighborhood safety and district-level crime rate.

METHODS

Study population

Data were obtained from the Seoul Welfare Panel Study (SWPS), which tracked a representative sample of households residing in 25 administrative districts in Seoul, South Korea. The SWPS was launched in 2008 by the Seoul Welfare Foundation. The 1st wave of the survey was

conducted in 2008 and its supplementary survey targeting the low-income households was implemented in 2009. The SWPS was suspended after the 2nd wave of the survey was conducted in 2010 September. The survey employed a two-stage stratified cluster sampling approach where a representative sample of census tracts for each district was first drawn, and then households were randomly selected within those sampled census tracts at baseline. A household representative answered household survey and all members of a household whose age is 15 or older were interviewed. A total of 7,761 individuals completed the interviews in Wave 1. The SWPS have been publicly released [http://panel.welfare.seoul.kr]. Because there was no observation with missing variables, the final sample used in the data analysis of this research consists of 7,761 individuals from 3,665 households from 25 administrative districts in Seoul. This research received IRB exemption from Division of Research Affairs at the San Diego State University.

Exposure: district-level perceived neighborhood safety

Perceived neighborhood safety was assessed through the household survey using a question about how much a household representative agrees with the following statement: 'My current residential environment is unsafe". Respondents answered in a five ordinal scale from "very agree" (coded as 1) to "very disagree" (coded as 5). The answer was then dichotomized into "unsafe" (coded as 0) for the response, 1-3 and "safe" (coded as 1) for the response, 4-5. The binary responses from household representatives were aggregated to calculate an administrative district-level perceived neighborhood safety by taking a weighted average within each district with the household size used as weight. Such aggregation implies that the district-level perceived

neighborhood safety is essentially a sample proportion of individuals who answered "safe" within each district.

Outcome: self-rated health

Poor self-rated health was assessed through the individual interview using the question "How would you rate your overall health?" Respondents answered within a five ordinal scale ranging from "Very good" (coded as 1) to "very poor" (coded as 5). The response was then dichotomized into "good health" (coded as 0) for response, 1-3 and "poor health" (coded as 1) for response, 4-5. Although self-rated health cannot assess multi-dimensional aspects of health conditions, it is known to be a reliable predictor of life-expectancy after adjusting for other health indicators.[15]

Covariates

We included several confounders in the data analysis. For individual-level confounders, we have sex, age group (15-19 yrs, 20-29 yrs, 30-39 yrs, 40-49 yrs, 50-59 yrs, 60-69 yrs, and 70 years or more), education level (elementary or less, junior high school, high school, college graduate, university graduate, and graduate school or more), marital status(married or cohabiting vs. others), and job status (employed vs. unemployed), household with six categories (1,000,000 KRW or less, 1,010,000-2,000,000 KRW, 2,010,000-3,000,000 KRW, 3,010,000-4,000,000 KRW, 4,010,000-5,000,000 KRW, and Above 5,000,000 KRW), and individual-level neighborhood safety (unsafe vs. safe). Because neighborhood safety was assessed solely from the household survey, we assigned the value of perceived neighborhood safety measured from each household representative to all members of the household.

We considered district-level crime rate as a potential covariate at district-level because it can influence residents' health as well as perceived safety. District-level crime rates for each of 25 administrative district ('Gu') in Seoul were collected from the 'Analytical report on crimes (2008)' that is annually published by supreme prosecutors' office in South Korea.[16] Crime rate was calculated by dividing the total number of crimes by the total number of residents in each district (Expressed in number/year/1000persons). Using an administrative district identifier in the SWPS, we linked the official crime rate of each administrative district to our final dataset of the SWPS.

Data analysis

Mixed effects logistic regression was used to investigate the association between district-level safety and self-rated health. Because of the hierarchical structure in our data (i.e., individuals are nested in households, which in turn are nested in districts), within-household and within-district correlations were incorporated using household-specific and district-specific random intercepts. We made stepwise adjustments of potential confounders in the data analysis. First, we adjusted for potential confounders including sex, age, education level, job status, marital status, and household-level income. Second, we added individual-level perceived neighborhood safety to the previously listed confounders for adjustment. Finally, we examined the association after adjusting for district-level crime rate in addition to all of the previously mentioned confounders. All of the confounders were included as categorical variables and the district-level safety was included after standardization for simple interpretation in the model. All computations were done using R statistical software.

RESULTS

Table 1 presents the distribution of the study population and the prevalence of poor self-rated health by each of the individual-level, household-level, and district-level characteristics. Overall, self-rated health was reported at 20.9% (1,620 out of 7,761 participants). The proportion was higher for women and showed an increasing pattern with age. Lower proportions were observed for participants in lower education levels. The unemployed and the group of people in an unsafe neighborhood exhibited higher prevalence of poor self-rated health compared to the employed and the group in a safe neighborhood. Household income were fairly equally distributed in the SWPS. As to the district-level safety and crime rate, given the overall mean of each variable, relative size of each standard deviation shows that there are considerable variations among the 25 districts.

District-level safety was significantly associated with poor self-rated health while different sets of confounders being step-wisely adjusted (Table 2). Living in a district where its safety level is 1 standard deviation (0.08) higher resulted in 13% lower odds of reporting self-rated poor health status (OR: 0.87, 95% CI: 0.78, 0.97) after adjusting for sex, age, education level, job status, marital status, and household-level income. When adjusted for individual-level safety, this association was slightly attenuated but still significant (OR: 0.88, 95% CI: 0.79, 0.98). When we controlled for district-level crime, the magnitude of this association was slightly increased and remained significant (OR: 0.86, 95% CI: 0.77, 0.96).

DISCUSSION

Evidence from our study indicated that district-level safety, as assessed by aggregating responses from district residents, was significantly associated with poor self-rated health even after controlling for demographic influences and SES. Notably, this association was still robust when we also adjusted for district-level crime rate and individual-level perceived neighborhood safety.

Our findings are in line with previous research that showed associations between perceived regional safety and health outcomes. Past studies have also reported that residents who perceived that their neighborhood had more severe problems were more likely to experience greater anxiety, stress, and depression.[6,17] The studies sampled women, children, and the elderly also provided consistent evidence of a relationship between perceived crime risk and physical health.[7,14]

In this study, district-level crime rate was not associated with self-rated health in the fully adjusted model. Furthermore, our post-hoc analysis showed that there was no statistically significant relationship between district crime rate and residents' self-rated health regardless of covariate adjustment, although district-level crime rate could be a major influence on district-level safety. This finding is different from past studies that reported a significant relationship between district crime rate and residents' health such as coronary heart disease[18] and low birth weight.[19]

The differential association between perceived district-level perceived safety and crime rate in relation to self-rated health could be explained by three ways. First, mass media may increase individual-level perceived neighborhood insecurity regardless of their neighborhood crime rates, especially when they reported the crime in ways of exaggeration.[20,21] The mass media tend to

emphasize criminal stories which can draw attention from audience.[22] Previous studies called this phenomenon as "cultivation effect" meaning that exposure to the world of television cultivates exaggerated perceptions of viewers and magnifies viewers' fear about crime.[23] The residents who watched news on neighborhood crimes may perceive their neighborhood more vulnerable regions to crime. Moreover, mass media may also increase the perceived neighborhood safety of individuals regardless of their objective neighborhood crime rates.[21] Second, different types of crime have different effects on the perceived risk or fear of crime. For example, murder, rape, and personal theft may have higher effects on the fear of crime than larceny and auto-theft. Hence, total crime rate that was used in this research to indicate district-level crime rate would not be a proper measure when searching its association with the residents' health condition.[24] Finally, if social and physical resources of neighborhood are deteriorated or deprived, residents tend to perceive neighborhood safety more irrespective with the objective neighborhood crime rate.[25] The poor quality of social and physical environment, such as dilapidated houses or having no formal or informal neighborhood networks, may trigger to perceive neighborhood dangerous.[26,27]

There could be several pathways linking these perceived neighborhood safety to self-rated health irrespective to objective neighborhood crime rate. First, higher district-level perceived safety can cause less outdoor physical activities[7,28] leading to poor health. Second, elevated district-level perceived safety iteratively aggravate social supports or deteriorate physical environments, in turn, may harm mental and physical outcomes.[29] Last, elevated district-level perceived safety may be a latent stressor causing chronic stress status undermine residents' mental health.[30]

Our study has a limitation of potential reverse causation due to its cross-sectional study design, implying that people with poor-self rated health are more likely to perceive their neighborhood as unsafe. However, because the association was still significant after adjusting for individual-perceived safety, which is a critical pathway of this reverse causation, so we believe that the potential reverse causation cannot fully explain the observed association.

Despite this limitation, our study has the strength in that we used representative samples for each operationalized administrative district, which enabled multi-level analysis using an aggregate measure of perceived safety as an exposure variable. Furthermore, we found a significant association after adjusting for other relevant potential confounder such as district-crime rate that could influence both exposure and outcome variable in this study. To our knowledge, this is one of the first studies controlled for crime-rate to examine the association between perceived neighborhood safety and health outcome.

In sum, our study showed that district-level perceived safety was associated with residents' poor self-rated health even after controlling for demographic influences, SES, district-level crime rate, and individual-level perceived safety. Our study results evoke the importance of local authorities (or governments) to make efforts toward improving neighborhood safety to enhance resident health.

Table 1. Descriptive statistics for the independent variables and their associations with self-rated poor health (N=7761)

Variables	Total	Prevalence of poor self-rated health	
	N	N (%)	p-values
Individual level variables (N=7761)			
Sex			<0.0001
Male	3547	599 (16.9)	
Female	4214	1021 (24.2)	
Age (years)			<0.0001
15-19	536	17 (3.2)	
20-29	973	26 (2.7)	
30-39	1577	92 (5.8)	
40-49	1425	185 (13.0)	
50-59	1139	242 (21.2)	
60-69	1130	482 (42.7)	
70 or more	981	576 (58.7)	
Job Status			<0.0001
Employed	3199	293 (9.2)	
Unemployed	4562	1327 (29.1)	
Education Level			<0.0001
Elementary school or less	1143	664 (58.1)	
Middle school	703	271 (38.5)	
High school	2483	433 (17.4)	
College graduate	572	46 (8.0)	
University graduate	2516	185 (7.4)	
Graduate school or more	344	21 (6.1)	
Marital status			0.151
Married/cohabiting	5059	1031 (20.4)	
Others	2702	589 (21.8)	
Individual-level safety			<0.0001
Safe	6777	1361 (20.1)	
Unsafe	984	259 (26.3)	
Household level variables (N=3665)			
Household Income			
1,000,000 KRW or less	770		
1,010,000-2,000,000 KRW	772		
2,010,000-3,000,000 KRW	656		
3,010,000-4,000,000 KRW	510		
4,010,000-5,000,000 KRW	345		
Above 5,000,000 KRW	612		
District level variables (N=25)	Mean	S.D.	Range
District-level perceived safety (mean (SD)[a]	0.87	0.08	0.68-0.98

District-level crime rate (mean (SD)) [b]	4.63	2.94	2.25-16.31

[a] District-specific average of individual-level safety

[b] Expressed in number/year/1000persons

Table 2. Associations between district-level perceived safety and poor self-rated health

	Unadjusted		Adjusted[a]					
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
District-level perceived safety[b]	0.83***	(0.76, 0.91)	0.87*	(0.78, 0.97)	0.88*	(0.79, 0.98)	0.86**	(0.77, 0.96)
Individual-level perceived safety					0.83	(0.66, 1.04)	0.82	(0.65, 1.04)
District-level crime rate							0.97	(0.93, 1.01)

[a] Adjusted for sex, age, education level, job status, marital status, and household-level income

[b] Aggregated responses about neighborhood safety among residents in the same district. The variables was included in the data analysis after standardization

* p-value<0.05, ** p-value<0.01, *** p-value<0.001

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STROBE 2007 (v4) checklist of items to be included in reports of observational studies in epidemiology*

Checklist for cohort, case-control, and cross-sectional studies (combined)

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	3
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5-6
Objectives	3	State specific objectives, including any pre-specified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	6-7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6-7
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	6-7
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	6-7
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	
Bias	9	Describe any efforts to address potential sources of bias	7-9
Study size	10	Explain how the study size was arrived at	7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7-9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9
		(*b*) Describe any methods used to examine subgroups and interactions	9
		(*c*) Explain how missing data were addressed	9
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed	9

		Cross-sectional study—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	10
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	10
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10
		(*b*) Report category boundaries when continuous variables were categorized	10
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	11
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13
Generalisability	21	Discuss the generalisability (external validity) of the study results	
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	17

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.
Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Association between district-level safety and self-rated health: a multilevel study in an urban setting

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Abstract

Objectives: Several studies have reported the relationship between resident's perceived neighborhood safety and their health outcomes. However, those studies suffered from unreliability of neighborhood safety measure and potential residual confounding related to crime rates. In this study, using multilevel analysis to account for the hierarchical structure of the data, we examined associations between district-level safety and self-rated health after adjusting for potential confounders including individual-level perceived neighborhood safety and district-level crime rate.

Design: Cross-sectional study

Setting: We used the 1st wave of Seoul Welfare Panel Study, which has 7,761 individuals from 3,665 households in 25 administrative districts in Seoul, South Korea. District-level safety was obtained by aggregating responses from the residents that are representative samples for each administrative district in Seoul. To examine an association between district-level safety and residents' self-rated health, we used mixed effects logistic regression.

Results: Our results showed that higher district-level perceived safety, an aggregated measure of district residents' responses on neighborhood safety, was significantly associated with poor self-rated health after controlling for demographic influences and SES (OR: 0.87, 95% CI: 0.78-0.97). Notably, this association was still robust even when we additionally adjusted for district-level crime rate and individual-level perceived neighborhood safety (OR: 0.86, 95% CI: 0.77-0.96).

Conclusions: Our study highlights the importance of improving neighborhood safety to enhance resident health.

Keywords: perceived neighborhood safety, self-rated health, neighborhood crime rate, Seoul Welfare Panel Study, multilevel analysis

Strengths and limitations of this study

- Multilevel analytic frame was used to examine an association between district-level safety and residents' self-rated health using representative samples of metropolis, Seoul, South Korea.
- We succeed in adjusting for potential confounders such as individual-level perceived neighborhood safety and district-level crime rate in our analytic model, which past studies have failed.
- Causal relationships cannot be inferred from the cross-sectional data.

INTRODUCTION

Crime is one of the major problems in many metropolitan areas across countries. Although city crime rates have dropped globally since the mid-1990s,[1] there are still large variations and dramatic fluctuations across cities.[2] Past criminological studies revealed that variations in crime rates were explained by characteristics of metropolitan areas, such as population sizes, ethnic heterogeneity, geographic mobility, economic segregation, unemployment rate, poverty level and degree of social integration and control.[2-4] Thus, many governments have made great efforts to reduce the crime rates especially in metropolitan areas by intervening in those characteristics to ensure the safety of their residents.

Safety from crime is not only an essential human need in daily life, but also a prerequisite to human health.[5] A body of past studies has reported the relationship between residents' perceptions of neighborhood safety and their health outcomes.[6,7] For example, one UK survey with 407 adults reported that fear of crime was significantly associated with self-rated health and mental well-being.[8] Ziersch and Baum[9] showed that perceived neighborhood safety was related to physical and mental health among 2,400 residents in western suburbs of Adelaide, Australia.

However, these earlier studies suffer from the following limitations. First, most of previous studies used individual-level neighborhood perceived safety as exposure variable, which could be influenced by several factors such as prior individual experience of victimization or individual health conditions other than neighborhood-level safety.[10,11] This could be particularly a critical issue in previous cross-sectional studies because of the potential reverse causation, meaning that the sick are more likely to perceive their neighborhood as unsafe. [7,12] The second limitation is lack of representativeness of samples within the operationalized definition of neighborhood. Few

studies had enough sample size or the sample size within neighborhood to be representative for each neighborhood.[6,8,13] Unless the responses are obtained from a representative sample of participants within each neighborhood, aggregated perceived neighborhood measures can potentially be prone to measurement errors. The final limitation is that previous studies did not adjust for district-level crime rate as a potential confounder although crime-rate has been reported to influence perception of neighborhood safety as well as residents' health outcomes.

In this study, we assessed the district-level safety, which was obtained by aggregating responses from the residents that are representative samples for each administrative district in Seoul, the capital of South Korea. Then, using multilevel analysis to account for the hierarchical structure of the data, we examined associations between district-level safety and self-rated health after adjusting for potential confounders including individual-level perceived neighborhood safety and district-level crime rate.

METHODS

Study population

Data were obtained from the Seoul Welfare Panel Study (SWPS), which tracked a representative sample of households residing in 25 administrative districts in Seoul, South Korea. The SWPS was launched in 2008 by the Seoul Welfare Foundation. The 1st wave of the survey was conducted in 2008 and its supplementary survey targeting the low-income households was implemented in 2009. The SWPS was suspended after the 2nd wave of the survey was conducted in 2010 September. The survey employed a two-stage stratified cluster sampling approach where a representative sample of census tracts for each district was first drawn, and then households

were randomly selected within those sampled census tracts at baseline. A household representative answered household survey and all members of a household whose age is 15 or older were interviewed. A total of 7,761 individuals completed the interviews in Wave 1. The SWPS have been publicly released [http://panel.welfare.seoul.kr]. Because all respondents answered on questionnaire items we used in this study, we were able to conduct our analyses based on the entire sample participated in the first wave of SWPS without listwise deletion or missing value imputation for handling missing data. The final sample used in the data analysis of this research consists of 7,761 individuals from 3,665 households from 25 administrative districts in Seoul. The number of households in each district was 146.6 on average, ranging from 108 to 198. This research received IRB exemption from Division of Research Affairs at the San Diego State University.

Exposure: district-level perceived neighborhood safety

Perceived neighborhood safety was assessed through the household survey using a question about how much a household representative agrees with the following statement: 'My current residential environment is unsafe". Respondents answered in a five level ordinal scale from "strongly agree" (coded as 1) to "strongly disagree" (coded as 5). The answer was then dichotomized into "unsafe" (coded as 0) for the response, 1-2 and "safe" (coded as 1) for the response, 3-5. The binary responses from household representatives were aggregated to calculate an administrative district-level perceived neighborhood safety by taking a weighted average of household-specific perceived safety within each district with the household size used as weight. Such aggregation results in that the district-level perceived neighborhood safety is essentially sample proportion of individuals who answered "safe" within each district.

Outcome: self-rated health

Poor self-rated health was assessed through the individual interview using the question "How would you rate your overall health?" This question is on the ordinal level, ranging from "very good" (coded as 1) to "very poor" (coded as 5). The response was then dichotomized into "good health" (coded as 0) for response, 1-3 and "poor health" (coded as 1) for response, 4-5. Although self-rated health cannot assess multi-dimensional aspects of health conditions, it is known to be a reliable predictor of life-expectancy after adjusting for other health indicators.[14]

Covariates

We included several confounders in the data analysis. For individual-level confounders, we have sex, age group (15-19 yrs, 20-29 yrs, 30-39 yrs, 40-49 yrs, 50-59 yrs, 60-69 yrs, and 70 years or more), education level (elementary or less, junior high school, high school, college graduate, university graduate, and graduate school or more), marital status (married or cohabiting vs. others), and job status (employed vs. unemployed), household income with six categories (1,000,000 KRW or less, 1,010,000-2,000,000 KRW, 2,010,000-3,000,000 KRW, 3,010,000-4,000,000 KRW, 4,010,000-5,000,000 KRW, and Above 5,000,000 KRW), and individual-level neighborhood safety (unsafe vs. safe). Because neighborhood safety was assessed solely from the household survey, we assigned the value of perceived neighborhood safety measured from each household representative to all members of the household.

We considered district-level crime rate as a potential covariate at district-level because it can influence residents' health as well as perceived safety. District-level crime rates for each of 25 administrative district ('Gu') in Seoul were collected from the 'Analytical report on crimes

(2008)' that is annually published by supreme prosecutors' office in South Korea.[15] District-level crime rate was calculated by dividing the total number of crimes by the total number of residents in each district (Expressed in number/year/1000persons). Using an administrative district identifier in the SWPS, we linked the official crime rate of each administrative district to our final dataset of the SWPS.

Data analysis

Mixed effect logistic regression was used to investigate the association between district-level safety and self-rated health. Because of the hierarchical structure in our data (i.e., individuals are nested in households, which in turn are nested in districts), within-household and within-district correlations were incorporated using household-specific and district-specific random intercepts. We made stepwise adjustments of potential confounders in the data analysis. First, we adjusted for potential confounders including sex, age, education level, job status, marital status, and household-level income. Second, we added individual-level perceived neighborhood safety to the previously listed confounders for adjustment. Finally, we examined the association after adjusting for district-level crime rate in addition to all of the previously mentioned confounders. All of the confounders were included as categorical variables and the district-level safety was included after standardization for simple interpretation in the model. All computations were done using R statistical software.

RESULTS

Table 1 presents the distribution of the study population and the prevalence of poor self-rated health by each of the individual-level, household-level, and district-level characteristics. Overall, poor self-rated health was reported at 20.9% (1,620 out of 7,761 participants). The proportion was higher for women and showed an increasing pattern with age. Lower proportions were observed for participants in lower education levels. The unemployed and people living in an unsafe neighborhood exhibited higher prevalence of poor self-rated health compared to the employed and those living in a safe neighborhood. Household income were fairly equally distributed in the SWPS. As to the district-level safety and crime rate, given the overall mean of each variable, relative size of each standard deviation shows that there were considerable variations among the 25 districts.

District-level safety was significantly associated with poor self-rated health while different sets of confounders being step-wisely adjusted (Table 2). Living in a district where its safety level is 1 standard deviation (0.08) higher resulted in 13% lower odds of reporting self-rated poor health status (OR: 0.87, 95% CI: 0.78, 0.97) after adjusting for sex, age, education level, job status, marital status, and household-level income. When adjusted for individual-level safety, this association was slightly attenuated but still significant (OR: 0.88, 95% CI: 0.79, 0.98). When we controlled for district-level crime, the magnitude of this association was slightly increased and remained significant (OR: 0.86, 95% CI: 0.77, 0.96).

DISCUSSION

Evidence from our study indicated that district-level perceived safety, which was assessed by aggregating responses from residents in each district, was significantly associated with poor self-

rated health even after controlling for demographic information and SES. Notably, this association was still robust when we additionally adjusted for district-level crime rate and individual reporting of perceived neighborhood safety.

Our findings are in line with previous research that showed associations between perceived neighborhood safety and health outcomes. Past studies have also reported that residents who perceived that their neighborhood had more severe problems were more likely to experience greater anxiety, stress, and depression.[6,16] The studies sampled women, children, and the elderly also provided consistent evidence of a relationship between perceived crime risk and physical health.[7,13]

In this study, district-level crime rate was not associated with self-rated health in the fully adjusted model. Furthermore, our post-hoc analysis showed that there was no statistically significant relationship between district crime rate and residents' self-rated health regardless of covariate adjustment, although district-level crime rate could be a major influence on district-level safety. This finding is different from past studies that reported a significant relationship between district crime rate and residents' health such as coronary heart disease[17] and low birth weight.[18]

The differential association between district-level perceived safety and crime rate in relation to self-rated health could be explained by three ways. First, mass media may increase individual-level perceived neighborhood insecurity regardless of their neighborhood crime rates, especially when they reported the crime in ways of exaggeration.[19,20] The mass media tend to emphasize criminal stories which can draw attention from audience.[21] Previous studies called this

phenomenon as "cultivation effect" meaning that exposure to the world of television cultivates exaggerated perceptions of viewers and magnifies viewers' fear about crime.[22] The residents who watched news on neighborhood crimes may perceive their neighborhood more vulnerable regions to crime. Moreover, mass media may also increase the individual-level perceived neighborhood safety regardless of their objective neighborhood crime rates.[20] Second, different types of crime would have different effects on the perceived risk or fear of crime. For example, murder, rape, and personal theft may have higher effects on the fear of crime than larceny and auto-theft. Hence, total crime rate that was used in this research might not be sophisticated enough to clearly capture the association between the prevalence of crime in the district and the residents' health condition.[23] However, when we conducted a post-hoc analysis using a different measure, '5 index crime rate', which includes major five serious crimes (i.e. murder, robbery, rape, assault and theft) that has been adopted by Korean police to indicate violent crime rate, still we could not find any association with residents' self-rated health. Finally, if social and physical resources of neighborhood are deteriorated or deprived, residents tend to perceive neighborhood safety more irrespective of the objective neighborhood crime rate.[24] The poor quality of social and physical environment, such as dilapidated houses or having no formal or informal neighborhood networks, may work as a trigger to make residents perceive their neighborhood dangerous.[25,26]

There could be several pathways linking district-level perceived neighborhood safety to self-rated health irrespective of neighborhood crime rate and individual-level perceived neighborhood safety. First, higher district-level perceived safety can cause less outdoor physical activities[7,27] leading to poor health. Second, elevated district-level perceived safety iteratively aggravates

social supports or deteriorates physical environments, in turn, it may harm mental and physical outcomes.[28] Last, elevated district-level perceived safety may be a latent stressor causing chronic stress status that could undermine residents' mental health.[29]

Our study has several limitations. First, potential reverse causation is of concern due to its cross-sectional study design, implying that people with poor-self rated health are more likely to perceive their neighborhood as unsafe. However, because the association was still significant after adjusting for individual-perceived safety, which is a critical pathway of this reverse causation, so we believe that the potential reverse causation cannot fully explain the observed association. Second, this study assessed perceived neighborhood safety through a single-item measure. This item may not reflect multi-dimensional aspects of the neighborhood safety.

Despite these limitations, our study has the strength in that we used representative samples for each operationalized administrative district, which enabled multi-level analysis using an district-level aggregate measure of perceived safety whereas most of previous studies used individual reporting of perceived safety as an exposure variable. Furthermore, to our knowledge, this is one of the first studies to examine the association between district-level perceived neighborhood safety and health outcome after adjusting for district-level crime rate.

In sum, our study showed that district-level perceived safety was associated with residents' poor self-rated health even after controlling for demographic influences, SES, district-level crime rate, and individual-level perceived safety. Our study results evoke the importance of local authorities (or governments) to make efforts toward improving neighborhood safety to enhance residents' health.

Table 1. Descriptive statistics for the independent variables and their associations with self-rated poor health (N=7761)

Variables	Total	Prevalence of poor self-rated health	
	N	N (%)	p-values
Individual level variables (N=7761)			
Sex			<0.0001
Male	3547	599 (16.9)	
Female	4214	1021 (24.2)	
Age (years)			<0.0001
15-19	536	17 (3.2)	
20-29	973	26 (2.7)	
30-39	1577	92 (5.8)	
40-49	1425	185 (13.0)	
50-59	1139	242 (21.2)	
60-69	1130	482 (42.7)	
70 or more	981	576 (58.7)	
Job Status			<0.0001
Employed	3199	293 (9.2)	
Unemployed	4562	1327 (29.1)	
Education Level			<0.0001
Elementary school or less	1143	664 (58.1)	
Middle school	703	271 (38.5)	
High school	2483	433 (17.4)	
College graduate	572	46 (8.0)	
University graduate	2516	185 (7.4)	
Graduate school or more	344	21 (6.1)	
Marital status			0.151
Married/cohabiting	5059	1031 (20.4)	
Others	2702	589 (21.8)	
Individual-level safety			<0.0001
Safe	6777	1361 (20.1)	
Unsafe	984	259 (26.3)	
Household level variables (N=3665)			
Household Income			
1,000,000 KRW or less	770		
1,010,000-2,000,000 KRW	772		
2,010,000-3,000,000 KRW	656		
3,010,000-4,000,000 KRW	510		
4,010,000-5,000,000 KRW	345		
Above 5,000,000 KRW	612		
District level variables (N=25)	Mean	S.D.	Range
District-level perceived safety (mean (SD)[a]	0.87	0.08	0.68-0.98

District-level crime rate (mean (SD)) [b]	4.63	2.94	2.25-16.31

[a] District-specific average of individual-level safety

[b] Expressed in number/year/1000persons

Table 2. Associations between district-level perceived safety and poor self-rated health

	Unadjusted		Adjusted[a]					
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
District-level perceived safety[b]	0.83***	(0.76, 0.91)	0.87*	(0.78, 0.97)	0.88*	(0.79, 0.98)	0.86**	(0.77, 0.96)
Individual-level perceived safety					0.83	(0.66, 1.04)	0.82	(0.65, 1.04)
District-level crime rate							0.97	(0.93, 1.01)

[a] Adjusted for sex, age, education level, job status, marital status, and household-level income

[b] Aggregated responses about neighborhood safety among residents in the same district. The variables was included in the data analysis after standardization

* p-value<0.05, ** p-value<0.01

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Data sharing: No additional data are available.

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Dear Editor-in-Chief in the BMJ open

This is the revision of our paper, "Association between district-level safety and self-rated health: a multilevel study in an urban setting". We really appreciate that the reviewer provided precious comments on how to improve the manuscript.

Sincerely yours,
Jongho Heo on behalf of co-authors

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Design: Cross-sectional study

Setting: We used the 1st wave of Seoul Welfare Panel Study, which has 7,761 individuals from 3,665 households in 25 administrative districts in Seoul, South Korea. District-level safety was obtained by aggregating responses from the residents that are representative samples for each administrative district in Seoul. ~~We controlled objective district-level crime rate, individual-level perceived neighborhood safety and socio-demographic factors as well.~~ To examine an association between district-level safety and residents' self-rated health, we used mixed effects logistic regression.

Results: Our results showed that higher district-level perceived safety, an aggregated measure of district residents' responses on neighborhood safety, was significantly associated with poor self-rated health after controlling for demographic influences and SES (OR: 0.87, 95% CI: 0.78-0.97). Notably, this association was still robust even when we additionally adjusted for district-level crime rate and individual-level perceived neighborhood safety (OR: 0.86, 95% CI: 0.77-0.96).

Conclusions: Our study highlights the importance of improving neighborhood safety to enhance resident health.

Keywords: perceived neighborhood safety, self-rated health, neighborhood crime rate, Seoul Welfare Panel Study, multilevel analysis

Strengths and limitations of this study

- Multilevel analytic frame was used to examine an association between district-level safety and residents' self-rated health using representative samples of metropolis, Seoul, South Korea.
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Crime is one of the major problems in many metropolitan areas across countries. Although city crime rates have dropped globally since the mid-1990s,[1] there are still large variations and dramatic fluctuations across cities.[2] Past criminological studies revealed that variations in crime rates were explained by characteristics of metropolitan areas, such as population sizes, ethnic heterogeneity, geographic mobility, economic segregation, unemployment rate, poverty level and degree of social integration and control.[2-4] Thus, many governments have made great efforts to reduce the crime rates especially in metropolitan areas by intervening in those characteristics to ensure the safety of their residents.

Safety from crime is not only an essential human need in daily life, but also a prerequisite to human health.[5] A body of past studies has reported the relationship between residents' perceptions of neighborhood safety and their health outcomes.[6,7] For example, one UK survey with 407 adults reported that fear of crime was significantly associated with self-rated health and mental well-being.[8] Ziersch and Baum[9] showed that perceived neighborhood safety was related to physical and mental health among 2,400 residents in western suburbs of Adelaide, Australia.

However, these earlier studies suffer from the following limitations. First, most of previous studies used individual-level neighborhood perceived safety as exposure variable, which could be influenced by several factors such as prior individual experience of victimization or individual health conditions other than neighborhood-level safety. ~~First is the potential measurement error of the perceived neighborhood safety. The individual perception can be influenced by several factors such as prior individual experience of victimization, or individual health conditions other than neighborhood-level safety.~~[10,11] This could be particularly a critical issue in previous cross-

sectional studies because of the potential reverse causation, meaning that the sick are more likely to perceive their neighborhood as unsafe. ~~This could be particularly a critical issue in previous cross-sectional studies which did not control for individuals' safety perception because of the potential reverse causation, meaning that the sick are more likely to perceive their neighborhood as unsafe.~~[7,12] The second limitation is lack of representativeness of samples within the operationalized definition of neighborhood. Few studies ~~The~~ had enough sample size or the sample size within neighborhood ~~of previous studies was too small~~ to be representative for each neighborhood.[6,8,13] Unless the responses are obtained from a representative sample of participants within each neighborhood, aggregated perceived neighborhood measures can potentially be prone to measurement errors. ~~Also, this unavailability in appropriate neighborhood measure may explain why there is scant hierarchical or multilevel study analysis which examined allows for estimating the influence of perceived neighborhood safetymeasures on residents' health outcomes.~~ The final limitation is that previous studies did not adjust for district-level crime rate as a potential confounder although crime-rate has been reported to influence perception of neighborhood safety as well as residents' health outcomes.

In this study, we assessed the district-level safety, which was obtained by aggregating responses from the residents that are representative samples for each administrative district in Seoul, the capital of South Korea. Then, using multilevel analysis to account for the hierarchical structure of the data, we examined associations between district-level safety and self-rated health after adjusting for potential confounders including individual-level perceived neighborhood safety and district-level crime rate.

METHODS

Study population

Data were obtained from the Seoul Welfare Panel Study (SWPS), which tracked a representative sample of households residing in 25 administrative districts in Seoul, South Korea. The SWPS was launched in 2008 by the Seoul Welfare Foundation. The 1st wave of the survey was conducted in 2008 and its supplementary survey targeting the low-income households was implemented in 2009. The SWPS was suspended after the 2nd wave of the survey was conducted in 2010 September. The survey employed a two-stage stratified cluster sampling approach where a representative sample of census tracts for each district was first drawn, and then households were randomly selected within those sampled census tracts at baseline. A household representative answered household survey and all members of a household whose age is 15 or older were interviewed. A total of 7,761 individuals completed the interviews in Wave 1. The SWPS have been publicly released [http://panel.welfare.seoul.kr]. Because a~~Because A~~all respondents answered on questionnaire items we used in this study, we were able to conduct our analyses based on the entire sample participated in the first wave of SWPS without listwise deletion or missing value imputation for handling missing data.~~there was no observation with missing variables,~~ The~~t~~he final sample used in the data analysis of this research consists of 7,761 individuals from 3,665 households from 25 administrative districts in Seoul. The number of households in each district was 146.6 on average, ranging from 108 to 198.~~.~~ This research received IRB exemption from Division of Research Affairs at the San Diego State University.

Exposure: district-level perceived neighborhood safety

Perceived neighborhood safety was assessed through the household survey using a question about how much a household representative agrees with the following statement: 'My current residential environment is unsafe". Respondents answered in a five level ordinal scale from "stronglyvery agree" (coded as 1) to "stronglyvery disagree" (coded as 5). The answer was then dichotomized into "unsafe" (coded as 0) for the response, 1-23 and "safe" (coded as 1) for the response, 3-5,4,54 5. The binary responses from household representatives were aggregated to calculate an administrative district-level perceived neighborhood safety by taking a weighted average of household-specific perceived safety within each district with the household size used as weight. Such aggregation implies results in that the district-level perceived neighborhood safety is essentially a sample proportion of individuals who answered "safe" within each district.

Outcome: self-rated health

Poor self-rated health was assessed through the individual interview using the question "How would you rate your overall health?" This question is on the Respondents answered within a five ordinal level,scale ranging from "vVery good" (coded as 1) to "very poor" (coded as 5). The response was then dichotomized into "good health" (coded as 0) for response, 1-3 and "poor health" (coded as 1) for response, 4-5. Although self-rated health cannot assess multi-dimensional aspects of health conditions, it is known to be a reliable predictor of life-expectancy after adjusting for other health indicators.[14]

Covariates

We included several confounders in the data analysis. For individual-level confounders, we have sex, age group (15-19 yrs, 20-29 yrs, 30-39 yrs, 40-49 yrs, 50-59 yrs, 60-69 yrs, and 70 years or

more), education level (elementary or less, junior high school, high school, college graduate, university graduate, and graduate school or more), marital status (married or cohabiting vs. others), and job status (employed vs. unemployed), household income with six categories (1,000,000 KRW or less, 1,010,000-2,000,000 KRW, 2,010,000-3,000,000 KRW, 3,010,000-4,000,000 KRW, 4,010,000-5,000,000 KRW, and Above 5,000,000 KRW), and individual-level neighborhood safety (unsafe vs. safe). Because neighborhood safety was assessed solely from the household survey, we assigned the value of perceived neighborhood safety measured from each household representative to all members of the household.

We considered district-level crime rate as a potential covariate at district-level because it can influence residents' health as well as perceived safety. District-level crime rates for each of 25 administrative district ('Gu') in Seoul were collected from the 'Analytical report on crimes (2008)' that is annually published by supreme prosecutors' office in South Korea.[15] District-level cCrime rate was calculated by dividing the total number of crimes by the total number of residents in each district (Expressed in number/year/1000persons). Using an administrative district identifier in the SWPS, we linked the official crime rate of each administrative district to our final dataset of the SWPS.

Data analysis

Mixed effects logistic regression was used to investigate the association between district-level safety and self-rated health. Because of the hierarchical structure in our data (i.e., individuals are nested in households, which in turn are nested in districts), within-household and within-district correlations were incorporated using household-specific and district-specific random intercepts. We made stepwise adjustments of potential confounders in the data analysis. First, we adjusted

for potential confounders including sex, age, education level, job status, marital status, and household-level income. Second, we added individual-level perceived neighborhood safety to the previously listed confounders for adjustment. Finally, we examined the association after adjusting for district-level crime rate in addition to all of the previously mentioned confounders. All of the confounders were included as categorical variables and the district-level safety was included after standardization for simple interpretation in the model. All computations were done using R statistical software.

RESULTS

Table 1 presents the distribution of the study population and the prevalence of poor self-rated health by each of the individual-level, household-level, and district-level characteristics. Overall, poor self-rated health was reported at 20.9% (1,620 out of 7,761 participants). The proportion was higher for women and showed an increasing pattern with age. Lower proportions were observed for participants in lower education levels. The unemployed and ~~the group of~~ people living in an unsafe neighborhood exhibited higher prevalence of poor self-rated health compared to the employed and those ~~the group~~ living in a safe neighborhood. Household income were fairly equally distributed in the SWPS. As to the district-level safety and crime rate, given the overall mean of each variable, relative size of each standard deviation shows that there were~~are~~ considerable variations among the 25 districts.

District-level safety was significantly associated with poor self-rated health while different sets of confounders being step-wisely adjusted (Table 2). Living in a district where its safety level is

1 standard deviation (0.08) higher resulted in 13% lower odds of reporting self-rated poor health status (OR: 0.87, 95% CI: 0.78, 0.97) after adjusting for sex, age, education level, job status, marital status, and household-level income. When adjusted for individual-level safety, this association was slightly attenuated but still significant (OR: 0.88, 95% CI: 0.79, 0.98). When we controlled for district-level crime, the magnitude of this association was slightly increased and remained significant (OR: 0.86, 95% CI: 0.77, 0.96).

DISCUSSION

Evidence from our study indicated that district-level perceived safety, ~~as~~ which was assessed by aggregating responses from ~~district~~ residents in each district, was significantly associated with poor self-rated health even after controlling for demographic information ~~graphic influences and~~and SES ~~SES~~. Notably, this association was still robust when we additionally~~lso~~ adjusted for district-level crime rate and individual reporting of ~~level~~ perceived neighborhood safety.

Our findings are in line with previous research that showed associations between- perceived ~~regional~~ neighborhood safety and health outcomes. Past studies have also reported that residents who perceived that their neighborhood had more severe problems were more likely to experience greater anxiety, stress, and depression.[6,16] The studies sampled women, children, and the elderly also provided consistent evidence of a relationship between perceived crime risk and physical health.[7,13]

In this study, district-level crime rate was not associated with self-rated health in the fully adjusted model. Furthermore, our post-hoc analysis showed that there was no statistically significant relationship between district crime rate and residents' self-rated health regardless of

covariate adjustment, although district-level crime rate could be a major influence on district-level safety. This finding is different from past studies that reported a significant relationship between district crime rate and residents' health such as coronary heart disease[17] and low birth weight.[18]

The differential association between ~~perceived~~ district-level perceived safety and crime rate in relation to self-rated health could be explained by three ways. First, mass media may increase individual-level perceived neighborhood insecurity regardless of their neighborhood crime rates, especially when they reported the crime in ways of exaggeration.[19,20] The mass media tend to emphasize criminal stories which can draw attention from audience.[21] Previous studies called this phenomenon as "cultivation effect" meaning that exposure to the world of television cultivates exaggerated perceptions of viewers and magnifies viewers' fear about crime.[22] The residents who watched news on neighborhood crimes may perceive their neighborhood more vulnerable regions to crime. Moreover, mass media may also increase the individual-level perceived neighborhood safety ~~of individuals~~ regardless of their objective neighborhood crime rates.[20] Second, different types of crime would have different effects on the perceived risk or fear of crime. For example, murder, rape, and personal theft may have higher effects on the fear of crime than larceny and auto-theft. Hence, total crime rate that was used in this research ~~to indicate district-level crime rate~~ might~~would~~ not be ~~a~~ sophisticated enough to clearly capture ~~proper measure when searching its~~ the association between the prevalence of crime in the district and ~~with~~ the residents' health condition.[23] However, when we conducted a post-hoc analysis using a different measure, ~~with~~ '5 index crime rate', which includes~~ing~~ major five serious ~~different~~ crimes (i.e. murder, robbery, rape, assault and theft) that~~, which~~ has been adopted by

Korean police to indicate violent crime rate, still we could not find any~~no~~ association ~~was observed~~with ~~in relation to~~residents' self-rated health. Finally, if social and physical resources of neighborhood are deteriorated or deprived, residents tend to perceive neighborhood safety more irrespective of~~with~~ the objective neighborhood crime rate.[24] The poor quality of social and physical environment, such as dilapidated houses or having no formal or informal neighborhood networks, may work as a trigger to make residents perceive their neighborhood dangerous.[25,26]

There could be several pathways linking ~~these perceived neighborhood safety~~district-level perceived neighborhood safety to self-rated health irrespective of~~to~~ ~~objective~~ neighborhood crime rate and individual-level perceived neighborhood safety. First, higher district-level perceived safety can cause less outdoor physical activities[7,27] leading to poor health. Second, elevated district-level perceived safety iteratively aggravates social supports- or deteriorates physical environments, in turn, it may harm mental and physical outcomes.[28] Last, elevated district-level perceived safety may be a latent stressor causing chronic stress status that could undermine residents' mental health.[29]

Our study has several ~~a~~ limitations. First, ~~of~~ potential reverse causation is of concern due to its cross-sectional study design, implying that people with poor-self rated health are more likely to perceive their neighborhood as unsafe. However, because the association was still significant after adjusting for individual-perceived safety, which is a critical pathway of this reverse causation, so we believe that the potential reverse causation cannot fully explain the observed association. Second, this study assessed perceived neighborhood safety through a single-item measure. This item may not reflect multi-dimensional aspects of the neighborhood safety-.

Despite theseis limitations, our study has the strength in that we used representative samples for each operationalized administrative district, which enabled multi-level analysis using an district-level aggregate measure of perceived safety as an exposure variablewhereas most of previous studies used individual reporting of perceived safety as an exposure variable. -Furthermore, t Furthermore, we found a significant association after adjusting for other relevant potential confounder such as district-crime rate that could influence both exposure and outcome variable in this study. To our knowledge, this is one of the first studies controlled for crime rate to examine the association between district-level perceived neighborhood safety and health outcome after adjusting for district-level crime rate. -

In sum, our study showed that district-level perceived safety was associated with residents' poor self-rated health even after controlling for demographic influences, SES, district-level crime rate, and individual-level perceived safety. Our study results evoke the importance of local authorities (or governments) to make efforts toward improving neighborhood safety to enhance residents' health.

Table 1. Descriptive statistics for the independent variables and their associations with self-rated poor health (N=7761)

Variables	Total	Prevalence of poor self-rated health	
	N	N (%)	p-values
Individual level variables (N=7761)			
Sex			<0.0001
Male	3547	599 (16.9)	
Female	4214	1021 (24.2)	
Age (years)			<0.0001
15-19	536	17 (3.2)	
20-29	973	26 (2.7)	
30-39	1577	92 (5.8)	
40-49	1425	185 (13.0)	
50-59	1139	242 (21.2)	
60-69	1130	482 (42.7)	
70 or more	981	576 (58.7)	
Job Status			<0.0001
Employed	3199	293 (9.2)	
Unemployed	4562	1327 (29.1)	
Education Level			<0.0001
Elementary school or less	1143	664 (58.1)	
Middle school	703	271 (38.5)	
High school	2483	433 (17.4)	
College graduate	572	46 (8.0)	
University graduate	2516	185 (7.4)	
Graduate school or more	344	21 (6.1)	
Marital status			0.151
Married/cohabiting	5059	1031 (20.4)	
Others	2702	589 (21.8)	
Individual-level safety			<0.0001
Safe	6777	1361 (20.1)	
Unsafe	984	259 (26.3)	
Household level variables (N=3665)			
Household Income			
1,000,000 KRW or less	770		
1,010,000-2,000,000 KRW	772		
2,010,000-3,000,000 KRW	656		
3,010,000-4,000,000 KRW	510		
4,010,000-5,000,000 KRW	345		
Above 5,000,000 KRW	612		
District level variables (N=25)	Mean	S.D.	Range
District-level perceived safety (mean (SD)[a]	0.87	0.08	0.68-0.98

District-level crime rate (mean (SD)) [b]	4.63	2.94	2.25-16.31

[a] District-specific average of individual-level safety

[b] Expressed in number/year/1000persons

Table 2. Associations between district-level perceived safety and poor self-rated health

	Unadjusted		Adjusted[a]					
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
District-level perceived safety[b]	0.83***	(0.76, 0.91)	0.87*	(0.78, 0.97)	0.88*	(0.79, 0.98)	0.86**	(0.77, 0.96)
Individual-level perceived safety					0.83	(0.66, 1.04)	0.82	(0.65, 1.04)
District-level crime rate							0.97	(0.93, 1.01)

[a] Adjusted for sex, age, education level, job status, marital status, and household-level income

[b] Aggregated responses about neighborhood safety among residents in the same district. The variables was included in the data analysis after standardization

* p-value<0.05, ** p-value<0.01~~, *** p-value<0.001~~

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STROBE 2007 (v4) checklist of items to be included in reports of observational studies in epidemiology*

Checklist for cohort, case-control, and cross-sectional studies (combined)

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	3
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5-6
Objectives	3	State specific objectives, including any pre-specified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	6-7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6-7
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	6-7
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	
Bias	9	Describe any efforts to address potential sources of bias	7-9
Study size	10	Explain how the study size was arrived at	7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7-9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9
		(*b*) Describe any methods used to examine subgroups and interactions	9
		(*c*) Explain how missing data were addressed	9
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed	9

		Cross-sectional study—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	10
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	10
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10
		(*b*) Report category boundaries when continuous variables were categorized	10
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	10-13
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13
Generalisability	21	Discuss the generalisability (external validity) of the study results	
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	17

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.
Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Association between district-level safety and self-rated health: a multilevel study in an urban setting

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Association between district-level safety and self-rated health: a multilevel study in an urban setting

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Association between district-level safety and self-rated health: a multilevel study in an urban setting

Abstract

Objectives: Several studies have reported the relationship between resident's perceived neighborhood safety and their health outcomes. However, those studies suffered from unreliability of neighborhood safety measure and potential residual confounding related to crime rates. In this study, using multilevel analysis to account for the hierarchical structure of the data, we examined associations between district-level safety and self-rated health after adjusting for potential confounders including district-level crime rate.

Design: Cross-sectional study

Setting: We used the 1st wave of Seoul Welfare Panel Study, which has 7,761 individuals from 3,665 households in 25 administrative districts in Seoul, South Korea. District-level safety was obtained by aggregating responses from the residents that are representative samples for each administrative district in Seoul. To examine an association between district-level safety and residents' self-rated health, we used mixed effects logistic regression.

Results: Our results showed that higher district-level perceived safety, an aggregated measure of district residents' responses on neighborhood safety, was significantly associated with poor self-rated health after controlling for sex, age, education level, job status, marital status, and household-level income (OR: 0.87, 95% CI: 0.78-0.97). Furthermore, this association was still robust when we additionally adjusted for district-level crime rate (OR: 0.86, 95% CI: 0.77-0.95).

Conclusions: Our study highlights the importance of improving neighborhood perceived safety to enhance residents' health.

Keywords: perceived neighborhood safety, self-rated health, neighborhood crime rate, Seoul Welfare Panel Study, multilevel analysis

Strengths and limitations of this study

- Multilevel analytic frame was used to examine an association between district-level safety and residents' self-rated health using representative samples of metropolis, Seoul, South Korea.
- We succeed in adjusting for potential confounders such as district-level crime rate in our analytic model, which past studies have failed.
- Causal relationships cannot be inferred from the cross-sectional data of this study.

INTRODUCTION

Crime is one of the major problems in many metropolitan areas across countries. Although city crime rates have dropped globally since the mid-1990s,[1] there are still large variations and dramatic fluctuations across cities.[2] Past criminological studies revealed that variations in crime rates were explained by characteristics of metropolitan areas, such as population sizes, ethnic heterogeneity, geographic mobility, economic segregation, unemployment rate, poverty level and degree of social integration and control.[2-4] Thus, many governments have made great efforts to reduce the crime rates especially in metropolitan areas by intervening in those characteristics to ensure the safety of their residents.

Safety from crime is not only an essential human need in daily life, but also a prerequisite to human health.[5] A body of past studies has reported the relationship between residents' perceptions of neighborhood safety and their health outcomes.[6,7] For example, one UK survey with 407 adults reported that fear of crime was significantly associated with self-rated health and mental well-being.[8] Ziersch and Baum[10] showed that perceived neighborhood safety was related to physical and mental health among 2,400 residents in western suburbs of Adelaide, Australia.

However, these earlier studies suffer from the following limitations. First, most of the previous studies used individual-level neighborhood perceived safety as an exposure variable, which could be influenced by several factors such as prior individual experience of victimization or individual health conditions other than neighborhood-level safety.[11,12] This could be particularly a critical issue in previous cross-sectional studies because of the potential reverse causation, meaning that the sick are more likely to perceive their neighborhood as unsafe.[7,13] The second limitation is lack of representativeness of samples within the operationalized definition of

neighborhood. Few studies had enough sample size or the sample size within neighborhood to be representative for each neighborhood.[6,8,14] Unless the responses are obtained from a representative sample of participants within each neighborhood, aggregated perceived neighborhood measures can potentially be prone to measurement errors. The final limitation is that previous studies did not adjust for district-level crime rate as a potential confounder although crime-rate has been reported to influence perception of neighborhood safety as well as residents' health outcomes.

In this study, we assessed the district-level safety, which was obtained by aggregating responses from the residents that are representative samples for each administrative district in Seoul, the capital of South Korea. Then, using multilevel analysis to account for the hierarchical structure of the data, we examined the association between district-level perceived safety and self-rated health after adjusting for potential confounders including district-level crime rate.

METHODS

Study population

Data were obtained from the Seoul Welfare Panel Study (SWPS), which tracked a representative sample of households residing in 25 administrative districts in Seoul, South Korea. The SWPS was launched in 2008 by the Seoul Welfare Foundation. The 1st wave of the survey was conducted in 2008 and its supplementary survey targeting the low-income households was implemented in 2009. The SWPS was suspended after the 2nd wave of the survey was conducted in 2010 September. The survey employed a two-stage stratified cluster sampling approach where a representative sample of census tracts for each district was first drawn, and then households

were randomly selected within those sampled census tracts at baseline. A household representative answered household survey and all members of a household whose age is 15 or older were interviewed. A total of 7,761 individuals completed the interviews in Wave 1. The SWPS have been publicly released [http://panel.welfare.seoul.kr]. Because all respondents answered on questionnaire items we used in this study, we were able to conduct our analyses based on the entire sample participated in the first wave of SWPS without listwise deletion or missing value imputation for handling missing data. The final sample used in the data analysis of this research consists of 7,761 individuals from 3,665 households from 25 administrative districts in Seoul. The number of households in each district was 146.6 on average, ranging from 108 to 198. This research received IRB exemption from Division of Research Affairs at the San Diego State University.

Exposure: district-level perceived safety

District-level perceived safety was assessed through the household survey using a question about how much a household representative agrees with the following statement: 'My current residential environment is unsafe". Respondents answered in a five level ordinal scale from "strongly agree" (coded as 1) to "strongly disagree" (coded as 5). The answer was then dichotomized into "unsafe" (coded as 0) for the response, 1-2 and "safe" (coded as 1) for the response, 3-5. The binary responses from household representatives were aggregated to calculate an administrative district-level perceived neighborhood safety by taking a weighted average of household-specific perceived safety within each district with the household size used as weight. Such aggregation results in that the district-level perceived neighborhood safety is essentially sample proportion of individuals who answered "safe" within each district.

Outcome: poor self-rated health

Poor self-rated health was assessed through the individual interview using the question "How would you rate your overall health?" This question is on the ordinal level, ranging from "very good" (coded as 1) to "very poor" (coded as 5). The response was then dichotomized into "good health" (coded as 0) for response, 1-3 and "poor health" (coded as 1) for response, 4-5. Although self-rated health cannot assess multi-dimensional aspects of health conditions, it is known to be a reliable predictor of life-expectancy after adjusting for other health indicators.[15]

Covariates

We included several confounders in the data analysis. For individual-level confounders, we have sex, age group (15-19, 20-29, 30-39, 40-49, 50-59, 60-69, and 70 or more), education level (elementary or less, junior high school, high school, college graduate, university graduate, and graduate school or more), marital status (married or cohabiting vs. others), and job status (employed vs. unemployed), household income with six categories (1,000,000 KRW or less; 1,010,000-2,000,000 KRW; 2,010,000-3,000,000 KRW; 3,010,000-4,000,000 KRW; 4,010,000-5,000,000 KRW; and Above 5,000,000 KRW), and individual-perception of district safety (unsafe vs. safe). Because neighborhood safety was assessed solely from the household survey, we assigned the value of perceived neighborhood safety measured from each household representative to all members of the household.

We considered district-level crime rate as a potential covariate at district-level because it can influence residents' health as well as perceived safety. District-level crime rates for each of 25 administrative district ('Gu') in Seoul were collected from the 'Analytical report on crimes,

2008' that is annually published by supreme prosecutors' office in South Korea.[16] District-level crime rate was calculated by dividing the total number of crimes by the total number of residents in each district (expressed in number/year/1,000 persons). Using an administrative district identifier in the SWPS, we linked the official crime rate of each administrative district to our final dataset of the SWPS.

Data analysis

Mixed effect logistic regression was used to investigate the association between district-level safety and self-rated health. Because of the hierarchical structure in our data (i.e., individuals are nested in households, which in turn are nested in districts), within-household and within-district correlations were incorporated using household-specific and district-specific random intercepts. We made stepwise adjustments of potential confounders in the data analysis. First, we adjusted for potential confounders including sex, age, education level, job status, marital status, and household-level income. Second, we additionally adjusted for district-level crime rate. Finally, we examined the association after adjusting for individual perception of district safety in addition to all of the previously mentioned confounders. All of the confounders were included as categorical variables, and the district-level perceived safety was included after standardization for simple interpretation in the model. All computations were done using R statistical software.

RESULTS

Table 1 presents the distribution of the study population and the prevalence of poor self-rated health by each of the individual-level, household-level, and district-level characteristics. Overall, poor self-rated health was reported at 20.9% (1,620 out of 7,761 participants). The proportion

was higher for women and showed an increasing pattern with age. Lower proportions were observed for participants in lower education levels. The unemployed and people living in an unsafe neighborhood exhibited higher prevalence of poor self-rated health compared to the employed and those living in a safe neighborhood. Household income were fairly equally distributed in the SWPS. As to the district-level perceived safety and crime rate, given the overall mean of each variable, relative size of each standard deviation shows that there were considerable variations among the 25 districts.

District-level perceived safety was significantly associated with poor self-rated health while different sets of confounders being step-wisely adjusted (Table 2). Living in a district where its safety level is 1 standard deviation (0.08) higher resulted in 13% lower odds of reporting self-rated poor health status (OR: 0.87, 95% CI: 0.78, 0.97) after adjusting for sex, age, education level, job status, marital status, and household-level income. When additionally adjusted for district-level crime rate, this association was slightly attenuated but still significant (OR: 0.86, 95% CI: 0.77, 0.95). When we adjusted for individual perception of district safety in addition to previously mentioned potential confounders, the magnitude of this association was remained significant (OR: 0.86, 95% CI: 0.77, 0.96).

DISCUSSION

Evidence from our study indicated that district-level perceived safety, which was assessed by aggregating responses from residents in each district, was significantly associated with poor self-rated health even after controlling for demographic information, SES, and district-level crime rate. Notably, this association was still robust when we additionally adjusted for individual perception of district safety.

Our findings are in line with previous research that showed associations between perceived neighborhood safety and health outcomes. Past studies have also reported that residents who perceived that their neighborhood had more severe problems were more likely to experience greater anxiety, stress, and depression.[6,17] The studies sampled women, children, and the elderly also provided consistent evidence of a relationship between perceived crime risk and physical health.[7,14]

In this study, district-level crime rate was not associated with self-rated health in the fully adjusted model. Furthermore, our post-hoc analysis showed that there was no statistically significant relationship between district crime rate and residents' self-rated health regardless of adjustment of confounders, although district-level crime rate could be a major influence on district-level safety. This finding is different from past studies that reported a significant relationship between district crime rate and residents' health such as coronary heart disease[18] and low birth weight.[19]

The differential association between district-level perceived safety and crime rate in relation to self-rated health could be explained in three ways. First, mass media may increase individual-level perceived neighborhood insecurity regardless of their neighborhood crime rates, especially when they reported the crime in ways of exaggeration.[20,21] The mass media tend to emphasize criminal stories which can draw attention from audience.[22] Previous studies called this phenomenon as "cultivation effect" meaning that exposure to the world of television cultivates exaggerated perceptions of viewers and magnifies viewers' fear about crime.[23] The residents who watched news about neighborhood crimes are more likely to perceive their neighborhood more vulnerable regions to crime regardless of regional crime rate.[21]

Second, different types of crime would have different effects on the perceived risk or fear of crime. For example, murder, rape, and personal theft may have higher effects on the fear of crime than larceny and auto-theft. Hence, total crime rate that was used in this research might not be sophisticated enough to capture the association between the prevalence of crime in the district and the residents' health condition.[24] However, when we conducted a post-hoc analysis using a different measure, '5 index crime rate', which includes major five serious crimes (i.e. murder, robbery, rape, assault and theft) that has been adopted by Korean police to indicate violent crime rate, still we could not find association with residents' self-rated health.

Finally, if social and physical resources of neighborhood are deteriorated or deprived, residents tend to perceive neighborhood safety more irrespective of the objective neighborhood crime rate.[25] The poor quality of social and physical environment, such as dilapidated houses or having no formal or informal neighborhood networks, may work as a trigger to make residents perceive their neighborhood dangerous.[26,27]

There could be several pathways linking district-level perceived neighborhood safety to resident's self-rated health. First, higher district-level perceived safety can cause less outdoor physical activities[7,28] leading to poor health. Second, elevated district-level perceived safety may aggravates social supports or deteriorates physical environments, in turn, it may harm mental and physical outcomes.[29] Last, elevated district-level perceived safety may be a latent stressor causing chronic stress status that could undermine residents' mental health.[30]

Our study has several limitations. First, potential reverse causation is of concern due to its cross-sectional study design, implying that people with poor-self rated health are more likely to perceive their neighborhood as unsafe. Future studies are required to examine the causal

association between district-level perceived safety and health outcomes. Second, this study assessed perceived neighborhood safety through a single-item measure. This item may not reflect multi-dimensional aspects of the neighborhood safety.

Despite these limitations, our study has the strength in that we used representative samples for each operationalized administrative district, which enabled multilevel analysis using a district-level aggregate measure of perceived safety whereas most of the previous studies used individual reporting of perceived safety as an exposure variable. Furthermore, to our knowledge, this is one of the first studies to examine the association between district-level perceived neighborhood safety and health outcome after adjusting for district-level crime rate.

In sum, our study showed that district-level perceived safety was associated with residents' poor self-rated health even after controlling for demographic influences, SES, and district-level crime rate. Our study results evoke the importance of local authorities (or governments) to make efforts toward improving neighborhood perceived safety to enhance residents' health.

Table 1. Descriptive statistics for the independent variables and their associations with self-rated poor health (N=7761)

Variables	Total	Prevalence of poor self-rated health	
	N	N (%)	p-values
Individual level variables (N=7,761)			
Sex			<0.0001
Male	3,547	599 (16.9)	
Female	4,214	1,021 (24.2)	
Age (years)			<0.0001
15-19	536	17 (3.2)	
20-29	973	26 (2.7)	
30-39	1,577	92 (5.8)	
40-49	1,425	185 (13.0)	
50-59	1,139	242 (21.2)	
60-69	1,130	482 (42.7)	
70 or more	981	576 (58.7)	
Job Status			<0.0001
Employed	3,199	293 (9.2)	
Unemployed	4,562	1,327 (29.1)	
Education Level			<0.0001
Elementary school or less	1,143	664 (58.1)	
Middle school	703	271 (38.5)	
High school	2,483	433 (17.4)	
College graduate	572	46 (8.0)	
University graduate	2,516	185 (7.4)	
Graduate school or more	344	21 (6.1)	
Marital status			0.151
Married/cohabiting	5,059	1,031 (20.4)	
Others	2,702	589 (21.8)	
Individual-level safety			<0.0001
Safe	6,777	1,361 (20.1)	
Unsafe	984	259 (26.3)	
Household level variables (N=3,665)			
Household Income			
1,000,000 KRW or less	770		
1,010,000-2,000,000 KRW	772		
2,010,000-3,000,000 KRW	656		
3,010,000-4,000,000 KRW	510		
4,010,000-5,000,000 KRW	345		
Above 5,000,000 KRW	612		
District level variables (N=25)	Mean	S.D.	Range
District-level perceived safety (mean (SD))[a]	0.87	0.08	0.68-0.98
District-level crime rate (mean (SD)) [b]	4.63	2.94	2.25-16.31

[a] District-specific average of individual-level safety

[b] Expressed in number/year/1,000 persons

Table 2. Associations between district-level perceived safety and poor self-rated health

	Unadjusted		Adjusted[a]					
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
District-level perceived safety[b]	0.83***	(0.76, 0.91)	0.87*	(0.78, 0.97)	0.86**	(0.77, 0.95)	0.86**	(0.77, 0.96)
District-level crime rate					0.97	(0.93, 1.01)	0.97	(0.93,1.01)
Individual perception of district safety							0.82	(0.65,1.04)

[a] Adjusted for sex, age, education level, job status, marital status, and household-level income

[b] Aggregated responses about neighborhood safety among residents in the same district. The variables was included in the data analysis after standardization

* p-value<0.05, ** p-value<0.01

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Competing interests: None

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Data Sharing Statement: No additional data available

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Editor-in-Chief
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Dear Editor-in-Chief in the BMJ open

This is the 2nd revision of our manuscript, "Association between district-level safety and self-rated health: a multilevel study in an urban setting". We really appreciate that the reviewer provided precious comments on how to improve the manuscript.

Sincerely yours,
Jongho Heo on behalf of co-authors

Association between district-level safety and self-rated health: a multilevel study in an urban setting

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Association between district-level safety and self-rated health: a multilevel study in an urban setting

Abstract

Objectives: Several studies have reported the relationship between resident's perceived neighborhood safety and their health outcomes. However, those studies suffered from unreliability of neighborhood safety measure and potential residual confounding related to crime rates. In this study, using multilevel analysis to account for the hierarchical structure of the data, we examined associations between district-level safety and self-rated health after adjusting for potential confounders including ~~individual-level perceived neighborhood safety and~~ district-level crime rate.

Design: Cross-sectional study

Setting: We used the 1st wave of Seoul Welfare Panel Study, which has 7,761 individuals from 3,665 households in 25 administrative districts in Seoul, South Korea. District-level safety was obtained by aggregating responses from the residents that are representative samples for each administrative district in Seoul. To examine an association between district-level safety and residents' self-rated health, we used mixed effects logistic regression.

Results: Our results showed that higher district-level perceived safety, an aggregated measure of district residents' responses on neighborhood safety, was significantly associated with poor self-rated health after controlling for sex, age, education level, job status, marital status, and household-level income ~~demographic influences and SES~~ (OR: 0.87, 95% CI: 0.78-0.97). ~~Notably~~Furthermore, this association was still robust ~~even~~ when we additionally adjusted for ~~district-level crime rate and individual-level perceived neighborhood safety~~district-level crime rate (OR: 0.86, 95% CI: 0.77-0.95). ~~(OR: 0.86, 95% CI: 0.77-0.96).~~

Conclusions: Our study highlights the importance of improving neighborhood perceived safety to enhance residents' health.

Keywords: perceived neighborhood safety, self-rated health, neighborhood crime rate, Seoul Welfare Panel Study, multilevel analysis

Strengths and limitations of this study

- Multilevel analytic frame was used to examine an association between district-level safety and residents' self-rated health using representative samples of metropolis, Seoul, South Korea.
- We succeed in adjusting for potential confounders such as district-level crime rate ~~individual-level perceived neighborhood safety and district-level crime rate~~ in our analytic model, which past studies have failed.
- Causal relationships cannot be inferred from the cross-sectional data of this study. ~~-~~

INTRODUCTION

Crime is one of the major problems in many metropolitan areas across countries. Although city crime rates have dropped globally since the mid-1990s,[1] there are still large variations and dramatic fluctuations across cities.[2] Past criminological studies revealed that variations in crime rates were explained by characteristics of metropolitan areas, such as population sizes, ethnic heterogeneity, geographic mobility, economic segregation, unemployment rate, poverty level and degree of social integration and control.[2-4] Thus, many governments have made great efforts to reduce the crime rates especially in metropolitan areas by intervening in those characteristics to ensure the safety of their residents.

Safety from crime is not only an essential human need in daily life, but also a prerequisite to human health.[5] A body of past studies has reported the relationship between residents' perceptions of neighborhood safety and their health outcomes.[6,7] For example, one UK survey with 407 adults reported that fear of crime was significantly associated with self-rated health and mental well-being.[8] Ziersch and Baum[10] showed that perceived neighborhood safety was related to physical and mental health among 2,400 residents in western suburbs of Adelaide, Australia.

However, these earlier studies suffer from the following limitations. First, most of the previous studies used individual-level neighborhood perceived safety as an exposure variable, which could be influenced by several factors such as prior individual experience of victimization or individual health conditions other than neighborhood-level safety.[11,12] This could be particularly a critical issue in previous cross-sectional studies because of the potential reverse causation, meaning that the sick are more likely to perceive their neighborhood as unsafe.[7,13] The second limitation is lack of representativeness of samples within the operationalized definition of

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METHODS

Study population

Data were obtained from the Seoul Welfare Panel Study (SWPS), which tracked a representative sample of households residing in 25 administrative districts in Seoul, South Korea. The SWPS was launched in 2008 by the Seoul Welfare Foundation. The 1st wave of the survey was conducted in 2008 and its supplementary survey targeting the low-income households was implemented in 2009. The SWPS was suspended after the 2nd wave of the survey was conducted in 2010 September. The survey employed a two-stage stratified cluster sampling approach where

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Exposure: district-level perceived ~~neighborhood~~ safety

District-level perceived ~~Perceived neighborhood~~ safety was assessed through the household survey using a question about how much a household representative agrees with the following statement: 'My current residential environment is unsafe". Respondents answered in a five level ordinal scale from "strongly agree" (coded as 1) to "strongly disagree" (coded as 5). The answer was then dichotomized into "unsafe" (coded as 0) for the response, 1-2 and "safe" (coded as 1) for the response, 3-5. The binary responses from household representatives were aggregated to calculate an administrative district-level perceived neighborhood safety by taking a weighted average of household-specific perceived safety within each district with the household size used

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Poor self-rated health was assessed through the individual interview using the question "How would you rate your overall health?" This question is on the ordinal level, ranging from "very good" (coded as 1) to "very poor" (coded as 5). The response was then dichotomized into "good health" (coded as 0) for response, 1-3 and "poor health" (coded as 1) for response, 4-5. Although self-rated health cannot assess multi-dimensional aspects of health conditions, it is known to be a reliable predictor of life-expectancy after adjusting for other health indicators.[15]

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We included several confounders in the data analysis. For individual-level confounders, we have sex, age group (15-19 yrs, 20-29 yrs, 30-39 yrs, 40-49 yrs, 50-59 yrs, 60-69 yrs, and 70 years or more), education level (elementary or less, junior high school, high school, college graduate, university graduate, and graduate school or more), marital status (married or cohabiting vs. others), and job status (employed vs. unemployed), household income with six categories (1,000,000 KRW or less; 1,010,000-2,000,000 KRW; 2,010,000-3,000,000 KRW; 3,010,000-4,000,000 KRW; 4,010,000-5,000,000 KRW; and Above 5,000,000 KRW), and individual-level perception of district neighborhood safety (unsafe vs. safe). Because neighborhood safety was assessed solely from the household survey, we assigned the value of perceived neighborhood safety measured from each household representative to all members of the household.

We considered district-level crime rate as a potential covariate at district-level because it can influence residents' health as well as perceived safety. District-level crime rates for each of 25 administrative district ('Gu') in Seoul were collected from the 'Analytical report on crimes, (2008)' that is annually published by supreme prosecutors' office in South Korea.[16] District-level crime rate was calculated by dividing the total number of crimes by the total number of residents in each district (Expressed in number/year/1,000 persons). Using an administrative district identifier in the SWPS, we linked the official crime rate of each administrative district to our final dataset of the SWPS.

Data analysis

Mixed effect logistic regression was used to investigate the association between district-level safety and self-rated health. Because of the hierarchical structure in our data (i.e., individuals are nested in households, which in turn are nested in districts), within-household and within-district correlations were incorporated using household-specific and district-specific random intercepts. We made stepwise adjustments of potential confounders in the data analysis. First, we adjusted for potential confounders including sex, age, education level, job status, marital status, and household-level income. Second, we additionally adjusteda for dded district-level crime rate. individual-level perceived neighborhood safety to the previously listed confounders for adjustment. Finally, we examined the association after adjusting for individual perception of district safetyindividual-level perceived neighborhood safety district-level crime rate in addition to all of the previously mentioned confounders. All of the confounders were included as categorical variables, and the district-level perceived safety was included after standardization for simple interpretation in the model. All computations were done using R statistical software.

RESULTS

Table 1 presents the distribution of the study population and the prevalence of poor self-rated health by each of the individual-level, household-level, and district-level characteristics. Overall, poor self-rated health was reported at 20.9% (1,620 out of 7,761 participants). The proportion was higher for women and showed an increasing pattern with age. Lower proportions were observed for participants in lower education levels. The unemployed and people living in an unsafe neighborhood exhibited higher prevalence of poor self-rated health compared to the employed and those living in a safe neighborhood. Household income were fairly equally distributed in the SWPS. As to the district-level perceived safety and crime rate, given the overall mean of each variable, relative size of each standard deviation shows that there were considerable variations among the 25 districts.

District-level perceived safety was significantly associated with poor self-rated health while different sets of confounders being step-wisely adjusted (Table 2). Living in a district where its safety level is 1 standard deviation (0.08) higher resulted in 13% lower odds of reporting self-rated poor health status (OR: 0.87, 95% CI: 0.78, 0.97) after adjusting for sex, age, education level, job status, marital status, and household-level income. When additionally adjusted for district-level crime rate, this association was slightly attenuated but still significant (OR: 0.86, 95% CI: 0.77, 0.95). ~~individual-level safety, this association was slightly attenuated but still significant (OR: 0.88, 95% CI: 0.79, 0.98).~~ When we ~~controlled~~ adjusted for ~~for~~ individual perception of district safety ~~district-level crime~~in addition to previously mentioned potential

confounders, the magnitude of this association was ~~slightly increased and r~~remained significant (OR: 0.86, 95% CI: 0.77, 0.96).

DISCUSSION

Evidence from our study indicated that district-level perceived safety, which was assessed by aggregating responses from residents in each district, was significantly associated with poor self-rated health even after controlling for demographic information, ~~and~~ SES, and district-level crime rate. Notably, this association was still robust when we additionally adjusted for ~~district-level crime rate and~~ individual ~~reporting~~ perception of ~~perceived neighborhood~~district safety.

Our findings are in line with previous research that showed associations between perceived neighborhood safety and health outcomes. Past studies have also reported that residents who perceived that their neighborhood had more severe problems were more likely to experience greater anxiety, stress, and depression.[6,17] The studies sampled women, children, and the elderly also provided consistent evidence of a relationship between perceived crime risk and physical health.[7,14]

In this study, district-level crime rate was not associated with self-rated health in the fully adjusted model. Furthermore, our post-hoc analysis showed that there was no statistically significant relationship between district crime rate and residents' self-rated health regardless of adjustment of confounders~~covariate adjustment~~, although district-level crime rate could be a major influence on district-level safety. This finding is different from past studies that reported a significant relationship between district crime rate and residents' health such as coronary heart disease[18] and low birth weight.[19]

The differential association between district-level perceived safety and crime rate in relation to self-rated health could be explained ~~by~~ in three ways. First, mass media may increase individual-level perceived neighborhood insecurity regardless of their neighborhood crime rates, especially when they reported the crime in ways of exaggeration.[20,21] The mass media tend to emphasize criminal stories which can draw attention from audience.[22] Previous studies called this phenomenon as "cultivation effect" meaning that exposure to the world of television cultivates exaggerated perceptions of viewers and magnifies viewers' fear about crime.[23] The residents who watched news ~~on~~ about neighborhood crimes are more likely to ~~may~~ perceive their neighborhood more vulnerable regions to crime regardless of regional crime rate~~. Moreover, mass media may also increase the individual-level perceived neighborhood safety regardless of their objective neighborhood crime rates~~.[21]

Second, different types of crime would have different effects on the perceived risk or fear of crime. For example, murder, rape, and personal theft may have higher effects on the fear of crime than larceny and auto-theft. Hence, total crime rate that was used in this research might not be sophisticated enough to ~~clearly~~ capture the association between the prevalence of crime in the district and the residents' health condition.[24] However, when we conducted a post-hoc analysis using a different measure, '5 index crime rate', which includes major five serious crimes (i.e. murder, robbery, rape, assault and theft) that has been adopted by Korean police to indicate violent crime rate, still we could not find ~~any~~ association with residents' self-rated health.

Finally, if social and physical resources of neighborhood are deteriorated or deprived, residents tend to perceive neighborhood safety more irrespective of the objective neighborhood crime rate.[25] The poor quality of social and physical environment, such as dilapidated houses or having

no formal or informal neighborhood networks, may work as a trigger to make residents perceive their neighborhood dangerous.[26,27]

There could be several pathways linking district-level perceived neighborhood safety to resident's self-rated health ~~irrespective of neighborhood crime rate and individual-level perceived neighborhood safety~~. First, higher district-level perceived safety can cause less outdoor physical activities[7,28] leading to poor health. Second, elevated district-level perceived safety may ~~iteratively~~ aggravates social supports or deteriorates physical environments, in turn, it may harm mental and physical outcomes.[29] Last, elevated district-level perceived safety may be a latent stressor causing chronic stress status that could undermine residents' mental health.[30]

Our study has several limitations. First, potential reverse causation is of concern due to its cross-sectional study design, implying that people with poor-self rated health are more likely to perceive their neighborhood as unsafe. Future studies are required to examine the causal association between district-level perceived safety and health outcomes. ~~However, because the association was still significant after adjusting for individual-perceived safety, which is a critical pathway of this reverse causation, so we believe that the potential reverse causation cannot fully explain the observed association.~~ Second, this study assessed perceived neighborhood safety through a single-item measure. This item may not reflect multi-dimensional aspects of the neighborhood safety.

Despite these limitations, our study has the strength in that we used representative samples for each operationalized administrative district, which enabled multi-level analysis using a~~n~~ district-level aggregate measure of perceived safety whereas most of the previous studies used individual reporting of perceived safety as an exposure variable. Furthermore, to our knowledge, this is one

of the first studies to examine the association between district-level perceived neighborhood safety and health outcome after adjusting for district-level crime rate.

In sum, our study showed that district-level perceived safety was associated with residents' poor self-rated health even after controlling for demographic influences, SES, and district-level crime rate~~, and individual-level perceived safety~~. Our study results evoke the importance of local authorities (or governments) to make efforts toward improving neighborhood perceived safety to enhance residents' health.

Table 1. Descriptive statistics for the independent variables and their associations with self-rated poor health (N=7761)

Variables	Total	Prevalence of poor self-rated health	
	N	N (%)	p-values
Individual level variables (N=7,761)			
Sex			<0.0001
Male	3,547	599 (16.9)	
Female	4,214	1,021 (24.2)	
Age (years)			<0.0001
15-19	536	17 (3.2)	
20-29	973	26 (2.7)	
30-39	1,577	92 (5.8)	
40-49	1,425	185 (13.0)	
50-59	1,139	242 (21.2)	
60-69	1,130	482 (42.7)	
70 or more	981	576 (58.7)	
Job Status			<0.0001
Employed	3,199	293 (9.2)	
Unemployed	4,562	1,327 (29.1)	
Education Level			<0.0001
Elementary school or less	1,143	664 (58.1)	
Middle school	703	271 (38.5)	
High school	2,483	433 (17.4)	
College graduate	572	46 (8.0)	
University graduate	2,516	185 (7.4)	
Graduate school or more	344	21 (6.1)	
Marital status			0.151
Married/cohabiting	5,059	1,031 (20.4)	
Others	2,702	589 (21.8)	
Individual-level safety			<0.0001
Safe	6,777	1,361 (20.1)	
Unsafe	984	259 (26.3)	
Household level variables (N=3,665)			
Household Income			
1,000,000 KRW or less	770		
1,010,000-2,000,000 KRW	772		
2,010,000-3,000,000 KRW	656		
3,010,000-4,000,000 KRW	510		
4,010,000-5,000,000 KRW	345		
Above 5,000,000 KRW	612		
District level variables (N=25)	Mean	S.D.	Range
District-level perceived safety (mean (SD))[a]	0.87	0.08	0.68-0.98
District-level crime rate (mean (SD)) [b]	4.63	2.94	2.25-16.31

[a] District-specific average of individual-level safety

[b] Expressed in number/year/1,000 persons

Table 2. Associations between district-level perceived safety and poor self-rated health

	Unadjusted		Adjusted[a]					
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
District-level perceived safety[b]	0.83***	(0.76, 0.91)	0.87*	(0.78, 0.97)	0.86**	(0.77, 0.95)	0.86**	(0.77, 0.96)
District-level crime rate					0.97	(0.93, 1.01)	0.97	(0.93,1.01)
Individual perception of district safety							0.82	(0.65,1.04)

[a] Adjusted for sex, age, education level, job status, marital status, and household-level income

[b] Aggregated responses about neighborhood safety among residents in the same district. The variables was included in the data analysis after standardization

* p-value<0.05, ** p-value<0.01

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STROBE 2007 (v4) checklist of items to be included in reports of observational studies in epidemiology*

Checklist for cohort, case-control, and cross-sectional studies (combined)

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	3
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	3
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	5-6
Objectives	3	State specific objectives, including any pre-specified hypotheses	6
Methods			
Study design	4	Present key elements of study design early in the paper	6-7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	6-7
Participants	6	(*a*) *Cohort study*—Give the eligibility criteria, and the sources and methods of selection of participants. Describe methods of follow-up *Case-control study*—Give the eligibility criteria, and the sources and methods of case ascertainment and control selection. Give the rationale for the choice of cases and controls *Cross-sectional study*—Give the eligibility criteria, and the sources and methods of selection of participants	6-7
		(*b*) *Cohort study*—For matched studies, give matching criteria and number of exposed and unexposed *Case-control study*—For matched studies, give matching criteria and the number of controls per case	
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	7-9
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	
Bias	9	Describe any efforts to address potential sources of bias	7-9
Study size	10	Explain how the study size was arrived at	7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7-9
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	9
		(*b*) Describe any methods used to examine subgroups and interactions	9
		(*c*) Explain how missing data were addressed	9
		(*d*) *Cohort study*—If applicable, explain how loss to follow-up was addressed *Case-control study*—If applicable, explain how matching of cases and controls was addressed	9

		Cross-sectional study—If applicable, describe analytical methods taking account of sampling strategy	
		(*e*) Describe any sensitivity analyses	
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	10
		(b) Give reasons for non-participation at each stage	
		(c) Consider use of a flow diagram	
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	10
		(b) Indicate number of participants with missing data for each variable of interest	
		(c) *Cohort study*—Summarise follow-up time (eg, average and total amount)	
Outcome data	15*	*Cohort study*—Report numbers of outcome events or summary measures over time	
		Case-control study—Report numbers in each exposure category, or summary measures of exposure	
		Cross-sectional study—Report numbers of outcome events or summary measures	10
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	10
		(*b*) Report category boundaries when continuous variables were categorized	10
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	
Discussion			
Key results	18	Summarise key results with reference to study objectives	10-13
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	13
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	13
Generalisability	21	Discuss the generalisability (external validity) of the study results	
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	17

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.
Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.