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Keywords:	angina, myocardial infraction, multilevel analysis, MCMC, SES, Korea

Neighborhood- and Individual-level Socioeconomic Status and Self-reported Management of Ischemic Heart Disease: Results from the Health Examinees Study

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Neighborhood- and Individual-level Socioeconomic Status and Self-reported Management of Ischemic Heart Disease: Results from the Health Examinees Study

Abstract

Objective: Several studies identified neighborhood context as a predictor of ischemic heart disease (IHD) incidence and mortality. The present study investigates the relationships of individual- and neighborhood-level socioeconomic status (SES) with the odds of proper management of IHD, using baseline survey data from the Health Examinees-Gem study.

Design: In this cross-sectional study, we estimated the association of the odds of self-reported proper management with the neighborhood-level income quartile and percentage of college graduates after controlling for individual-level covariates in a cohort of participants in the Health Examinees-Gem study. Additionally, we fitted two-level multilevel logistic regression models using the Markov Chain Monte Carlo function to simultaneously estimate the contributions of individual-and neighborhood-level SES.

Setting: A survey conducted at 38 health examination centers and training hospitals in major Korean cities and metropolitan areas during 2004–2013.

Participants: 2,909 adult men and women.

Outcome measure: The self-reported current status of management after incident angina or myocardial infarction.

Results: At the neighborhood level, residence in a higher-income neighborhood was associated with the self-reported proper management of IHD, after controlling for individual-level covariates [odds ratio (OR): 1.25, 95% credible interval (CI): 1.03–1.47]. At the individual level, higher education was associated with the proper management of incident IHD (high school graduation, OR: 1.48, 95% CI: 1.23–1.50); college or higher, OR: 1.42, 95% CI: 1.06–1.50; reference, middle school graduation or below).

Conclusions: Our study suggests that policies or interventions aimed at improving the quality and availability of medical resources in low-income areas may also reduce inequalities in IHD management and mortality. Moreover, patient-centered education is essential for proper post-IHD management and reducing IHD mortality, especially when targeted to IHD patients with a low education level.

Keywords: angina, myocardial infraction, multilevel analysis, MCMC, SES, Korea

Strengths and Limitations of this Study

- This study is among the first to examine the association between individual- and neighborhood-level SES and management of ischemic heart disease in Asian countries.
- Our study benefitted from the use of population-based samples, which enabled a multi-level analysis based on the neighborhood-level socioeconomic status (SES).
- However, our findings were limited by the cross-sectional study design, use of survey data, and risk of selection bias.

INTRODUCTION

Ischemic heart disease (IHD), the current leading cause of death in Western countries, is rapidly becoming the leading cause of death in developing countries.[1] To reduce the mortality associated with IHD, researchers and clinicians have stressed the importance of patient management. Based on evidence demonstrating that medication adherence and behavioral lifestyle changes improved prognosis and retarded disease progression, clinical guidelines for incident IHD suggest that patient management should comprise pharmacologic treatments (e.g., antiplatelet therapy, beta-blocker therapy) or lifestyle modifications (e.g., weight control, smoking cessation, blood pressure management).[2 3]

Earlier research suggests that the management of incident IHD may differ by socioeconomic status (SES). Notably, the lower rates of mortality among IHD patients with a high SES[4] may be attributable to the availability of better care,[5] better adherence to therapy, better self-monitoring,[6] and more rapid implementation of behavioral lifestyle changes,[7] which are facilitated by economic, educational, and social resources. Additionally, the neighborhood context plays a critical role in various health outcomes, independent of the individual-level SES.[8 9] Several previous studies have shown that residence in a socioeconomically disadvantaged neighborhoods is associated with a greater risk of IHD[10 11] and shorter survival duration.[12 13] However, few studies have examined the association between the neighborhood SES and IHD management.

To our knowledge, no study has addressed this association in South Korea (hereafter Korea) or another Asian country. Although the IHD-related mortality rate in 2011 remained lower in Korea (42 per 100,000 individuals) than in Western countries, the incidence of IHD in Korea has increased by 60% during the past decade.[14] As this increase may be due to increases in body mass index (BMI) values and an increasingly westernized diet among middle-aged

adults,[15] IHD management may significantly reduce disparities in post-IHD survival, as well as IHD mortality. Therefore, this study aimed to evaluate the individual- and neighborhood-level SES as the main determinants of IHD management in Korea, using baseline data from a large population-based cohort study with a multi-level framework.

METHODS

Data source

We used baseline survey data from the Health Examinees-Gem (HEXA_G) study, which was constructed by dropping inconsistent data collected during pilot HEXA survey periods. The original HEXA, which is part of the Korean Genome Epidemiology Study (KoGES),[16] was a large-scale genomic cohort study for which 169,722 community-dwellers aged 40–69 years were recruited from 38 health examination centers and training hospitals (mainly general hospitals) in the major Korean cities and metropolitan areas during 2004–2013.[17] Eligible participants who visited the participating sites for biannual health check-ups covered in full by the National Health Insurance Program were asked to respond voluntarily to an interview-based survey conducted by well-trained interviewers using a structured questionnaire. The survey collected information about socio-demographic characteristics, medical history, medication usage, family history, and health/lifestyle behaviors. More detailed information about the HEXA cohort study can be found elsewhere.[16 17]

The HEXA-G dataset comprised 139,345 participants [men: 46,977 (33.7%); women: 92,368 (66.3%)]. Participants were excluded because of inconsistencies in data quality control, bio-specimen collection, a short duration of study participation at 21 centers that participated in a pilot study, or the withdrawal of provision of personal information for studies. All

participants completed a consent form before responding to the survey. The study was approved by the Institutional Review Board (IRB) of Seoul National University Hospital, Seoul, Korea (IRB No. 0608-018-179).

Study outcomes

The outcome of the current study was the self-reported current management status after incident angina or myocardial infarction. To identify patients with a history of IHD, the survey included the yes/no question of "Have you ever been diagnosed with angina or myocardial infarction by a medical doctor in a medical facility?" The sub-population with "yes" responses then answered a sub-question regarding the current status of the disease, using the following options: (a) "do not need treatment, as condition is cured"; (b) "currently receiving treatment"; (c) "was previously managed but is now neglected"; and (d) "have not received treatment." We dichotomized these responses as "proper management" and "poor management" (reference) by combining (a) with (b) and (c) with (d), respectively.

Main independent variable

The main neighborhood-level independent variables were (1) the income quartile and (2) percentage of college graduates. Seventeen neighborhoods were defined as the regions associated with 17 large general hospitals in 10 provinces and metropolitan areas. The total catchment area of these hospitals covered 89.3% of the total Korean population. We determined the neighborhood-level variables by averaging the individual-level income and education variables within each neighborhood.

Covariates

The individual-level covariates included sex, age, education, income, marital status, and occupation. Age was categorized into 40–50, 51–60, or 61+ years. Educational level was categorized into middle school or lower, high school graduation, or college graduation or higher. Income was measured by collapsing the data into four categories: <1, 1–2, 2–4, and ≥4 million Korean won (M KRW). Marital status was dichotomized into living with a spouse or not. Occupation was categorized as white collar, blue collar, housewife, or other.

After excluding participants with missing covariate data (n = 23, 0.8%) from those with a history of diagnosed angina or myocardial infarction (n = 2,932), we achieved a study sample of 2,909 adults. Table 1 presents the descriptive statistics of the respondents' information.

Statistical analysis

Two-level multilevel logistic regression models were fitted with individuals (level 1) nested within neighborhoods (level 2) to estimate the contributions of the individual- and neighborhood-level factors simultaneously. Random intercept models were fitted for the whole study samples to correct for cluster effects of the individual variables within the same neighborhood according to the region identifier in the model. We used the command *runmlwin* to run *MLwiN* within Stata software (Stata Corp. College Station, TX, USA).[18] This command enables researchers to fit multilevel models more quickly with *MLwiN* by taking advantage of the multi-level dataset analysis features included in Stata.[18] *MLwiN* was used to fit a binomial logit response model to an estimation using the Iterative Generalized Least Squares (IGLS) and second-order penalized quasi-likelihood (PQL2).

Estimates obtained using the above-described methods are known to exhibit bias for discrete responses;[19] therefore, we fitted our final model using the Markov chain Monte Carlo (MCMC) function. Additionally, we adopted the Bayesian estimation function to ensure the accuracy of the estimates and their standard errors, as a small sample size at level two can lead to biased estimates.[20 21] The MCMC was conducted to burn-in for 500 simulations, which yielded distribution starting values to discard, and subsequently to proceed for 5,000 additional simulations to obtain a precise estimate and distribution of interest. Once the convergence diagnostics were confirmed, the odds ratios (ORs) and 95% credible intervals (CIs) were presented in a Bayesian framework.

RESULTS

Table 1 presents characteristics of the study sample from the HEXA-Gem dataset, stratified by the self-reported management of IHD. A total of 2,412 (82.9%) participants reported proper management, and men comprised the majority of this group (54.2%). By contrast, the poorly managed group included a higher percentage of women (61.6%). Participants older than 65 years comprised more than half of the proper management group (52.9%).

Table 2 presents the results of the two-level multilevel logistic regression models for proper IHD management. In the Model 1, the odds of proper management were higher for those with IHD who resided in higher-income neighborhoods, with an OR of 1.74 (95% CI: 1.04–2.64) compared to those in low SES neighborhoods. In Model 2, a higher individual education level was associated with proper IHD management, with ORs of 1.48 (95% CI: 1.20–1.52) and 1.33 (95% CI: 1.09–1.52) for high school graduation and college graduation or higher, respectively, compared to those with a middle school or lower education. However, no

significant associations were observed between an individual's income group and the likelihood of self-reported proper management. In Model 3, the neighborhood-level income quartiles remained significantly associated with self-reported proper management even after adjusting for individual-level factors (OR: 1.25, 95% CI 1.03–1.47) (Figure 1). In this model, however, the association of residence in a neighborhood with a high percentage of college graduates with self-reported proper IHD management was not statistically significant. Finally, all models exhibited significant between-neighborhood variance.

DISCUSSION

According to our findings, residence in a neighborhood with a one-unit higher income quartile was associated with a 25% higher likelihood of self-reported proper IHD management compared to those living in an adjacent neighborhood with a lower quartile. By contrast, at the individual level, a higher income was not significantly associated with self-reported proper IHD management. However, a higher individual education level was associated with a higher likelihood of self-reported proper IHD management.

Previous studies have found that a lower neighborhood SES was associated with a higher risk of IHD[10 11] and a shorter survival duration after incident IHD.[12 13] Consistent with those reports, our study showed an association of the neighborhood SES with IHD management that was independent of individual-level factors. We attribute this association to several factors. First, residents of higher-income neighborhoods may have greater access to higher quality medical resources, such as physicians or primary care clinics, near their homes, regardless of individual income.[22] Second, residents in higher-income neighborhoods may enjoy a more favorable social environment for IHD management, which might include an

increased interest in health maintenance and a greater amount of social support from neighbors.[23] Third, residents of lower-income neighborhoods might have reduced access to health-oriented features such as recreation spaces and walkable environments[24] and stores that sell healthy foods,[25] concomitant with increased access to stores selling cigarettes and/or alcohol[26] and exposure to other environmental stressors. These factors may have important implications for self-care practices.

At the individual SES level, our study found that the education level was significantly associated with proper IHD management of IHD, whereas the income status was not. Similarly, previous studies also reported that IHD management may vary according to an individual's SES, and suggested that the survivors with lower income and education levels might fail to manage themselves appropriately because of (a) a lack of knowledge related to prevention and healthy habits,[27] (b) limited access to care or drugs due to economic constraints,[28] and (c) a lack of willingness or resources to change their lifestyles.[7] Patient education has been identified as an important factor in terms of the understanding of a specific disease process, medication management and adherence, and reported efficacies and side effects.[3] Previous studies demonstrated improved adherence to suggested management among IHD patients with higher education levels,[29] whereas patients with lower education levels may not adhere to guidelines because of a lack of knowledge or understanding about their disease. Alternatively, our study findings may reflect sub-optimal doctor–patient communication due to the exceptionally short consultation times with physicians in Korea, which are generally restricted to 2–3 minutes because of the lack of physicians and fee-for-service payment in the Korean healthcare system.[30] This restriction may stunt proper IHD management, especially among patients with lower education levels. Accordingly, our findings suggest that individualized education could maximize management outcomes.

Our finding that the individual-level income status and proper IHD management were not associated may imply that economic barriers to care or drugs do not determine the proper management of this condition. However, previous studies have shown that economically disadvantaged patients might be more likely to decline follow-up procedures or prescribed medications because economic constraint.[5 28] Our favorable study finding of no significant income inequality might therefore be explained by the universal healthcare coverage benefits and medical subsidies provided to lower-income populations in Korea.[30]

Our study had several limitations of note. First, our cross-sectional study was unable to determine the causal relationship between our main exposures (e.g., individual- and neighborhood-level SES) and the self-reported management of IHD. Second, our study used self-reported survey data, which may have been biased by social desirability, and the patients' responses regarding IHD management may not have been confirmed by medical professionals. Third, selection bias may have been introduced by the deaths of disadvantaged individuals prior to the survey. However, this bias would have led to underestimation in our results. Fourth, the regions associated with the 17 participating general hospitals may not be the best proxy for the regions in which individual residents live, as we could not exclude the possibility that patients may have visited general hospitals in other communities to seek better-quality evaluations. Despite these limitations, however, one strength of our study was the use of population-based samples, which enabled a multi-level analysis based on the neighborhood-level SES. By contrast, most previous studies used hospital data, which frequently lack information about the individual's SES and neighborhood characteristics.[31] Moreover, to the best of our knowledge, this is among the first studies to examine the association between individual- and neighborhood-level SES and IHD management in an Asian country.

In conclusion, our study findings provide an opportunity to improve proper IHD management by identifying the individual- and neighborhood-level factors associated with SES-related and geographic inequalities in IHD mortality. Our results suggest that policies or interventions intended to improve the quality and availability of medical resources in low-income areas might also effectively reduce inequalities in management and, ultimately, mortality. Moreover, our data suggest that patient-centered education is required to ensure proper post-IHD management and reduce related mortality, particularly among patients with a low education level.

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Author Contributions

JH analyzed the data; drafted, reviewed, and edited the manuscript; and contributed to the discussion. JKL and DK conducted, designed, and supervised the study; reviewed and edited the manuscript; and contributed to the discussion. JO, HYL, JYC, SK, and SVS reviewed and edited the manuscript and contributed to the discussion.

Conflicts of Interest

The authors declare no conflicts of interest.

A data sharing statement

Data sharing of HEXA is available through the website of the Korea National Institute of Health (http://www.nih.go.kr/NIH/cms/content/eng/03/65203_view.html#menu4_1_2).

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Table 1. Characteristics of the study sample from the HEXA-Gem dataset (N = 2,909), stratified by self-reported management of post-ischemic heart disease

		Proper management (N = 2,412)		Poor management (N = 497)		
		N	(%)	N	(%)	
Sex	Men	1,306	87.2	191	12.8	*
	Women	1,106	78.3	306	21.7	
Age (years)	40–49	198	71.5	79	28.5	*
	50–59	869	82.0	191	18.0	
	60–69	1,345	85.6	227	14.4	
Education	≤Middle school	1,100	85.7	183	14.3	*
	High school	818	80.1	203	19.9	
	≥College	494	81.7	111	18.3	
Income (million Korean won)	<1	439	84.2	83	15.8	*
	1–2	677	87.2	99	12.8	
	2–4	879	80.3	215	19.7	
	≥4	417	80.7	100	19.3	
Marital status	Living with spouse	2,135	83.4	424	16.6	*
	Living without spouse	277	79.1	73	20.9	
Occupation	White collar	685	80.3	168	19.7	*
	Blue collar	425	84.5	78	15.5	
	Housewife	797	80.8	189	19.2	
	Other	505	89.1	62	10.9	

* Differences between two groups for the all variables were considered significant at a p value <0.05.

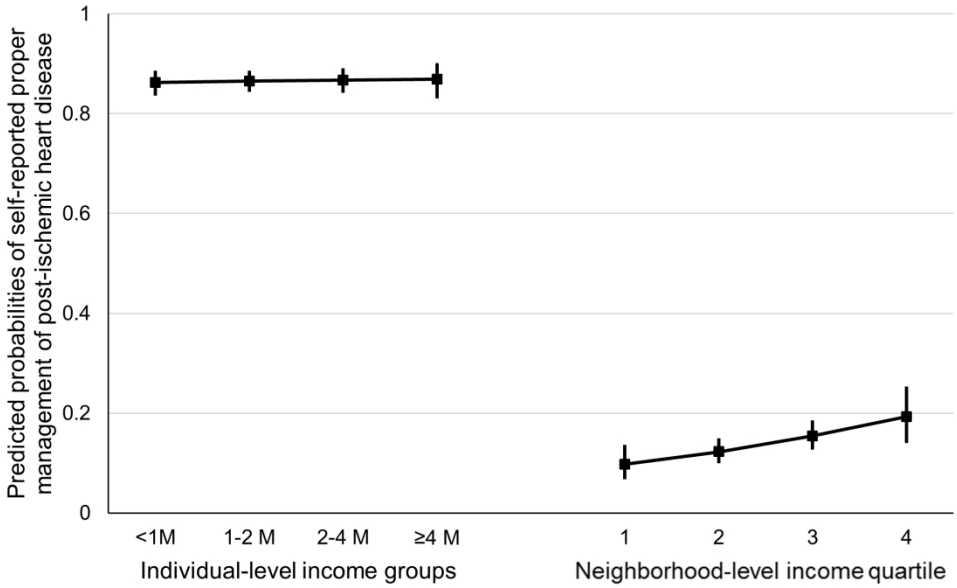
Table 2. Estimations from the two-level multilevel logistic regression models of self-reported proper management among ischemic heart disease survivors in the HEXA-Gem dataset

	Model 1			Model 2			Model 3		
	Odds Ratio	(95% Credible Interval)	p	Odds Ratio	(95% Credible Interval)	p	Odds Ratio	(95% Credible Interval)	p
Fixed Parameters									
Sex (ref: Female)									
Male				2.90	(2.12–3.93)	<0.001	2.43	(1.84–3.17)	<0.001
Age (years; ref: 40–49)									
50–59				1.83	(1.30–2.55)	<0.001	1.83	(1.33–2.52)	<0.001
61–69				2.65	(1.85–3.85)	<0.001	2.64	(1.87–3.74)	<0.001
Education (ref. ≤Middle school)									
High school				1.48	(1.20–1.52)	<0.001	1.48	(1.23–1.50)	<0.001
≥College				1.33	(1.09–1.52)	0.006	1.42	(1.06–1.50)	0.009
Income (ref: <1 million Korean won)									
1–2 million				1.28	(0.91–1.74)	0.081	1.27	(0.93–1.75)	0.134
2–4 million				1.03	(0.68–1.49)	0.475	1.02	(0.69–1.50)	0.931
≥4 million				1.00	(0.66–1.46)	0.455	0.96	(0.65–1.42)	0.840
Marital status (ref. Living with spouse)									
Living without spouse				0.94	(0.64–1.32)	0.342	0.94	(0.68–1.29)	0.300
Occupation (ref. White collar)									
Blue collar				1.01	(0.72–1.39)	0.487	0.87	(0.65–1.17)	0.167
Housewife				1.50	(1.08–2.02)	0.009	1.21	(0.94–1.55)	0.088
Other				1.12	(0.77–1.54)	0.294	1.16	(0.83–1.56)	0.204
Neighborhood-level income quartile	1.74	(1.04–2.64)	0.016				1.25	(1.03–1.47)	0.012
Neighborhood-level % of college graduates or higher	1.60	(1.05–2.44)	0.030				1.08	(0.87–1.33)	0.550
Random Parameters									
Between-neighborhood variance	0.39	(0.16–0.78)		0.37	(0.16–0.72)		0.27	(0.11–0.52)	
DIC	2597.31			2491.14			2489.83		

Note: Model 1 included the neighborhood-level SES only; model 2 included individual-level factors only; model 3 included all individual- and neighborhood-level factors.

Figure 1. Predicted probabilities of the self-reported proper management of ischemic heart disease across individual-level income groups and neighborhood-level income quartiles, using the HEXA-Gem dataset

Note: Individual income is shown in million (M) Korean won.



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Neighborhood- and Individual-level Socioeconomic Status and Self-reported Management of Ischemic Heart Disease: Cross-sectional Results from the Korea Health Examinees Study

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Abstract

Objective: Several studies identified neighborhood context as a predictor of prognosis in ischemic heart disease (IHD). The present study investigates the relationships of neighborhood- and individual-level socioeconomic status (SES) with the odds of ongoing management of IHD, using baseline survey data from the Korea Health Examinees-Gem study.

Design: In this cross-sectional study, we estimated the association of the odds of self-reported ongoing management with the neighborhood-level income status and percentage of college graduates after controlling for individual-level covariates using two-level multilevel logistic regression models based on the Markov Chain Monte Carlo function.

Setting: A survey conducted at 17 large general hospitals in major Korean cities and metropolitan areas during 2005–2013.

Participants: 2,931 adult men and women.

Outcome measure: The self-reported status of management after incident angina or myocardial infarction.

Results: At the neighborhood level, residence in a higher-income neighborhood was associated with the self-reported ongoing management of IHD, after controlling for individual-level covariates [odds ratio (OR): 1.24, 95% credible interval (CI): 1.03–1.46]. At the individual level, higher education was associated with the ongoing IHD management (high school graduation, OR: 1.46, 95% CI: 1.12–1.88); college or higher, OR: 2.05, 95% CI: 1.42–2.90; reference, middle school graduation or below).

Conclusions: Our study suggests that policies or interventions aimed at improving the quality and availability of medical resources in low-income areas may associate with ongoing IHD management. Moreover, patient-centered education is essential for ongoing IHD management, especially when targeted to IHD patients with a low education level.

Keywords: angina, myocardial infarction, multilevel analysis, MCMC, SES, Korea

Strengths and Limitations of this Study

- This study is among the first to examine the association between neighborhood- and individual-level SES and ongoing management of ischemic heart disease in Asian countries.
- Our study benefitted from the use of population-based samples, which enabled a multi-level analysis based on the neighborhood-level socioeconomic status.
- However, our findings were limited by the cross-sectional study design, use of survey data, and risk of selection bias.

INTRODUCTION

Ischemic heart disease (IHD), the current leading cause of death in Western countries, is rapidly becoming the leading cause of death in developing countries.[1] To reduce the mortality associated with IHD, researchers and clinicians have stressed the importance of patient management. Based on evidence demonstrating that medication adherence and behavioral lifestyle changes improved prognosis and retarded disease progression, guidelines for secondary IHD prevention suggest that patient management should comprise pharmacologic treatments (e.g., antiplatelet therapy, beta-blocker therapy) or lifestyle modifications (e.g., weight control, smoking cessation, blood pressure management).[2 3]

Earlier research suggests that the management of post-IHD may differ by socioeconomic status (SES). Notably, the lower rates of mortality among IHD patients with a high SES[4] may be attributable to the availability of better care,[5] better adherence to therapy, better self-monitoring,[6] and more rapid implementation of behavioral lifestyle changes,[7] which are facilitated by economic, educational, and social resources. Independent of the individual-level SES, neighborhood contexts also play critical roles in various health outcomes, including IHD-related outcomes.[8 9] Several previous studies have shown that residence in a socioeconomically disadvantaged neighborhoods was associated with a greater risk of IHD[10 11] and shorter survival duration.[12 13] However, few studies have examined the association between the neighborhood SES and IHD management.

To our knowledge, no study has addressed this association in South Korea (hereafter Korea) or another Asian country. Although the IHD-related mortality rate in 2011 remained lower in Korea (42 per 100,000 individuals) than in Western countries, the incidence of IHD in Korea has increased by 60% during the past decade[14] consequent to increases in body mass index values and an increasingly westernized diet among middle-aged adults.[15] Secondary IHD

mortality may be significantly reduced by ongoing IHD management involving both proper quality treatment and lifestyle modification, which may be shaped by neighborhood contexts as well as individual characteristics. Therefore, this study aimed to evaluate the individual- and neighborhood-level SES as the main determinants of ongoing IHD management in Korea, using baseline data from a large population-based cohort study with a multi-level framework.

METHODS

Data source

We used baseline survey data from the Health Examinees-Gem (HEXA_G) study, which was constructed by dropping inconsistent data collected during pilot HEXA survey periods. The original HEXA, which is part of the Korean Genome Epidemiology Study (KoGES),[16] was a large-scale genomic cohort study of 169,722 adults aged 40–69 years living in major Korean cities and metropolitan areas. Samples were recruited from 38 health examination centers and training hospitals (mainly general hospitals) during 2004–2013.[17] Eligible participants who visited the participating sites for biannual health check-ups, which were covered in full by the National Health Insurance Program were asked to respond voluntarily to an interview-based survey conducted by well-trained interviewers using a structured questionnaire. The survey collected information about socio-demographic characteristics, medical history, medication usage, family history, and health/lifestyle behaviors. More detailed information about the HEXA cohort study can be found elsewhere.[16 17]

The HEXA-G dataset comprised 139,345 participants [men: 46,977 (33.7%); women: 92,368 (66.3%)]. Participants were excluded because of inconsistencies in data quality control, bio-specimen collection, a short duration of study participation at 21 centers that participated in a

pilot study, or the withdrawal of provision of personal information for studies. All participants completed a consent form before responding to the survey. The study was approved by the Institutional Review Board (IRB) of Seoul National University Hospital, Seoul, Korea (IRB No. 0608-018-179).

Study outcome

The outcome of the study was the self-reported current management status after incident angina or myocardial infarction. To identify participants with a history of IHD, the survey included the yes/no question of "Have you ever been diagnosed with angina or myocardial infarction by a medical doctor in a medical facility?" The sub-population that responded "yes" then answered a sub-question regarding the current status of disease management for which the following options were available: (a) "condition has been good or improved due to management"; (b) "currently managed and treated"; (c) "was previously managed but is now neglected"; and (d) "neither managed nor treated." We dichotomized these responses as "ongoing management" by combining (a) with (b) versus "failure of ongoing management" (reference) by combining (c) with (d), respectively.

Neighborhood-level SES variables

The main neighborhood-level SES variables were (1) the regional median income status and (2) the regional mean percentage of college graduates. Seventeen neighborhoods were defined as 17 major cities and metropolitan areas (mean population: 201,210, range: 115,000-574,000) associated with 17 large general hospitals (Figure 1). The total catchment area of these hospitals covered 6.6% of the total Korean population. We obtained neighborhood-level

SES data from a nationally and regionally representative dataset, Korea Community Health Survey (https://chs.cdc.go.kr/chs/index.do), which has been conducted in 253 communities annually since 2008. This survey aims to estimate regional patterns of disease prevalence and morbidity, as well as to understand the personal lifestyle and health behavior.[18] An average of 800-900 adults (age: ≥19 years) who resided in each neighborhood were selected using the probability proportional to sampling and systematic sampling methods. The sampling strategies are described in more detail elsewhere.[18] We calculated exogenous neighborhood-level SES measures using regional mean centering of the percentage of college graduates and median centering of the income status of the survey years. We then linked the regional SES indicators to our main dataset using the neighborhood identifier and the year variable. A comparison of socio-demographic characteristics between neighborhoods included and not included in the study revealed that the former was comprised of younger (age: 49.2 vs. 52.9 years), more highly educated (college graduates: 43.9% vs. 33.0%), and wealthier (the top 25% of household incomes: 30.9% vs. 27.8%) population.

Individual-level SES variables

Educational level was categorized into middle school or lower, high school graduation, or college graduation or higher. Income was measured by collapsing the data into four categories: <1, 1–2, 2–4, and ≥4 million Korean won (M KRW).

Covariates

The individual-level covariates included sex, age, marital status occupation, and comorbidities. Age was categorized into 40–50, 51–60, or 61+ years. Marital status was dichotomized into living with a spouse or not. Occupation was categorized as white collar, blue collar, housewife, or other. Comorbidities were defined as the presence of hypertension, diabetes, or hyperlipidemia at the time of the survey.

Statistical analysis

Two-level multilevel logistic regression models were fitted with individuals (level 1) nested within neighborhoods (level 2) to estimate the contributions of the individual- and neighborhood-level factors simultaneously. Random intercept models were fitted for the whole study samples to correct for cluster effects of the individual variables within the same neighborhood according to the neighborhood identifier in the model. We used the command *runmlwin* to run *MLwiN* within Stata software (Stata Corp. College Station, TX, USA).[19] This command enables researchers to fit multilevel models more quickly with *MLwiN* by taking advantage of the multi-level dataset analysis features included in Stata.[19] *MLwiN* was used to fit a binomial logit response model to an estimation using the Iterative Generalized Least Squares (IGLS) and second-order penalized quasi-likelihood (PQL2).

Estimates obtained using the above-described methods are known to exhibit a bias for discrete responses;[20] therefore, we fitted our final model using the Markov chain Monte Carlo (MCMC) function. Additionally, we adopted the Bayesian estimation function to ensure the accuracy of the estimates and their standard errors, as a small sample size at level two can lead to biased estimates.[21 22] The MCMC was conducted to burn-in for 500 simulations, which yielded distribution starting values to discard, and subsequently to proceed for 5,000 additional simulations to obtain a precise estimate and distribution of interest. Once the

convergence diagnostics were confirmed, the odds ratios (ORs) and 95% credible intervals (CIs) were presented in a Bayesian framework. We created separate missing dummy categories to retain the missing cases in income (n=295), occupation (n=265), and other covariate data (n=35) in the regression analysis. Due to of little interpretive value, the results for the category were not reported. We did not stratify the analyses by gender because a Chow test [47] failed to detect significant differences in the slopes and intercepts of the gender-stratified regressions [F (1, 2,364) =0.95, P=0.3309].

RESULTS

Table 1 presents the characteristics of participants with IHD from the HEXA-Gem dataset (n = 2,932), stratified by self-reported IHD management. Men had higher proportions of self-reported ongoing management than women (89.0% vs. 79.7%). Participants of younger groups had higher proportions of failures of ongoing IHD management (40–49: 28.7% vs. 50–59: 16.5% vs. 60–69: 11.7%).

Table 2 presents the results of the two-level multilevel logistic regression models for ongoing IHD management. In Model 1, the odds of ongoing management were higher for those with IHD who resided in higher-income neighborhoods, with an OR of 1.24 (95% CI: 1.01–1.52). In Model 2, a higher individual education level was associated with ongoing IHD management, with ORs of 1.46 (95% CI: 1.11–1.87) and 2.33 (95% CI: 1.59–3.20) for high school graduation and college graduation or higher, respectively, compared to those with a middle school or lower education. However, no significant associations were observed between an individual's income group and the likelihood of self-reported ongoing management. In Model 3, the neighborhood-level income status remained significantly

associated with self-reported ongoing management even after adjusting for individual-level factors (OR: 1.24, 95% CI 1.03–1.46). In this model, however, the association of residence in a neighborhood with a high percentage of college graduates with self-reported ongoing IHD management was not statistically significant. Finally, all models exhibited significant between-neighborhood variance.

DISCUSSION

According to our findings, residence in a neighborhood with a one-unit higher income was associated with a 24% higher likelihood of self-reported ongoing IHD management, compared to residence in a neighborhood with a lower income status. By contrast, at the individual level, a higher income was not significantly associated with self-reported ongoing IHD management. However, a higher individual education level was associated with a higher likelihood of self-reported ongoing IHD management.

Previous studies have found that a lower neighborhood SES was associated with a higher risk of IHD[10 11] and a shorter survival duration after incident IHD.[12 13] Consistent with those reports, our study showed an association of the neighborhood SES with ongoing IHD management that was independent of individual-level factors. We attribute this association to several factors. First, residents of higher-income neighborhoods may have greater access to higher quality medical resources, such as physicians or primary care clinics near their homes, regardless of individual income.[23] Second, residents in higher-income neighborhoods may enjoy a more favorable social environment for IHD management, which might include an increased interest in health maintenance and a greater amount of social support from neighbors.[24] Third, residents of lower-income neighborhoods might have reduced access to

health-oriented features such as recreation spaces and walkable environments[25] and stores that sell healthy foods,[26] concomitant with increased access to stores selling cigarettes and/or alcohol[27] and exposure to other environmental stressors. These factors may have important implications for self-care practices.

At the individual SES level, our study found that the education level was significantly associated with ongoing IHD management, whereas the income status was not. Similarly, previous studies also reported that IHD management may vary according to an individual's SES, and suggested that the survivors with lower income and education levels might fail to manage themselves appropriately because of (a) a lack of knowledge related to prevention and healthy habits,[28] (b) limited access to care or drugs due to economic constraints,[29] and (c) a lack of willingness or resources to change their lifestyles.[7] Patient education has been identified as an important factor in terms of the understanding of a specific disease process, medication management and adherence, and reported efficacies and side effects.[3] Previous studies demonstrated improved adherence to suggested management among IHD patients with higher education levels,[30] whereas patients with lower education levels may not adhere to guidelines because of a lack of knowledge or understanding about their disease. Alternatively, our study findings may reflect sub-optimal doctor-patient communication due to the exceptionally short consultation times with physicians in Korea, which are generally restricted to 2–3 minutes because of the lack of physicians and fee-for-service payment in the Korean healthcare system.[31] This restriction may stunt ongoing IHD management, especially among patients with lower education levels. Accordingly, our findings suggest that individualized education could maximize IHD management outcomes.

Our finding that the individual-level income status and ongoing IHD management were not associated may imply that economic barriers to care or drugs do not determine the ongoing

management of this condition. However, previous studies have shown that economically disadvantaged patients might be more likely to decline follow-up procedures or prescribed medications because economic constraint.[5 29] Our favorable study finding of no significant income inequality might therefore be explained by the universal healthcare coverage benefits and medical subsidies provided to lower-income populations in Korea.[31]

Our study had several limitations of note. First, our cross-sectional study was unable to determine the causal relationship between our main exposures (e.g., individual- and neighborhood-level SES) and the self-reported management of IHD. Second, our study used self-reported survey data, which may have been biased by misclassification due to participants' misunderstanding or social desirability. Additionally, the participants' responses regarding ongoing IHD management may not have been confirmed by medical professionals whether the received treatment or participants' adherence to therapy was clinically appropriate. Third, we were not able to control for severity of IHD and time lapsed the acute event because of data limitations. Fourth, selection bias may have been introduced by non-random survey participation and attrition. Disadvantaged individuals were less likely to participate regular health examinations and were more likely to drop out in the survey, possibly due to a failure of ongoing management. This bias would have led to underestimating the likelihood of failure of ongoing management among disadvantaged individuals. Fifth, we assumed that most participants visited the general hospitals within the region they lived. This assumption is highly plausible, given the improved accessibility to the health examination service in Korea contexts, as the National Health Insurance Program provides free regular health examinations and medical facilities within and between regions exhibit minimal variations in examination quality.[32] However, we could not completely exclude the possibility that participants may have visited general hospitals in other

neighborhoods to seek better-quality evaluations. Despite these limitations, however, one strength of our study was the use of population-based samples, which enabled a multi-level analysis by linking neighborhood-level SES from the nationally and regionally representative dataset. By contrast, most previous studies used hospital data, which frequently lack information about the individual's SES and neighborhood characteristics.[33] Moreover, to the best of our knowledge, this is among the first studies to examine the association between individual- and neighborhood-level SES and IHD management in an Asian country.

In conclusion, our study findings provide an opportunity to improve ongoing IHD management by identifying the neighborhood- and individual-level factors, which are associated with SES-related and geographic inequalities in IHD mortality. Our results suggest that policies or interventions intended to improve the quality and availability of medical resources in low-income areas might also effectively reduce inequalities in management and, ultimately, mortality. Moreover, our data suggest that patient-centered education is required to ensure ongoing IHD management and reduce related mortality, particularly among patients with a low education level.

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Author Contributions

JH analyzed the data; drafted, reviewed, and edited the manuscript; and contributed to the discussion. JKL and DK conducted, designed, and supervised the study; reviewed and edited the manuscript; and contributed to the discussion. JO, HYL, JYC, SK, and SVS reviewed and edited the manuscript and contributed to the discussion.

Conflicts of Interest

The authors declare no conflicts of interest.

A data sharing statement

Data sharing of HEXA is available through the website of the Korea National Institute of Health (http://www.nih.go.kr/NIH/cms/content/eng/03/65203_view.html#menu4_1_2).

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Table 1. Characteristics of the study sample from the Korea HEXA-Gem dataset (N = 2,932), 2005-2013, stratified by self-reported ongoing management of post-ischemic heart disease

		Ongoing management				
		Yes (N = 2,474, 84.4%)		No (N = 458, 15.6%)		
		N	(%)	N	(%)	
Sex	Men	1,307	89.0	161	11.0	*
	Women	1,167	79.7	297	20.3	
Age (years)	40–49	251	71.3	101	28.7	*
	50–59	959	83.5	190	16.5	
	60–69	1,264	88.3	167	11.7	
Education	≤Middle school	1,095	86.4	172	13.6	*
	High school	868	82.0	191	18.0	
	≥College	487	84.3	91	15.7	
	Missing	24	85.7	4	14.3	
Income (million Korean won)	<1	419	84.3	78	15.7	*
	1–2	595	87.4	86	12.6	
	2–4	802	84.9	143	15.1	
	≥4	416	80.9	98	19.1	
	Missing	242	82.0	53	18.0	
Occupation	White collar	643	82.0	141	18.0	*
	Blue collar	377	85.9	62	14.1	
	Housewife	745	81.2	173	18.8	
	Other	479	91.1	47	8.9	
	Missing	230	86.8	35	13.2	
Marital status	Living with spouse	2,173	84.8	388	15.2	
	Living without spouse	293	80.7	70	19.3	
	Missing	8	100.0	0	0.0	
Comorbidities	Hypertension	1,296	80.5	315	19.5	*
	No hypertension	1,178	89.2	143	10.8	
	Diabetes	1,982	83.3	398	16.7	*
	No diabetes	492	89.1	60	10.9	
	Hyperlipidemia	1,945	84.4	360	15.6	
	No hyperlipidemia	529	84.4	98	15.6	

* Differences between two groups for the all variables were considered significant at a p value <0.05

Table 2. Estimations from the two-level multilevel logistic regression models of self-reported ongoing management among ischemic heart disease survivors in the Korea HEXA-Gem dataset, 2005-2013

	Model 1		Model 2		Model 3	
	Odds Ratio	(95% Credible Interval)	Odds Ratio	(95% Credible Interval)	Odds Ratio	(95% Credible Interval)
Fixed Parameters						
Sex (ref. Female)						
Male			2.99	(2.10–4.31)	2.90	(2.07–4.06)
Age (years; ref. 40–49)						
50–59			1.77	(1.25–2.38)	1.73	(1.25–2.39)
61–69			2.33	(1.59–3.20)	2.25	(1.58–3.22)
Education (ref. ≤Middle school)						
High school			1.46	(1.11–1.87)	1.46	(1.12–1.88)
≥College			2.04	(1.38–2.93)	2.05	(1.42–2.90)
Income (ref. <1 million Korean won)						
1–2 million			1.30	(0.95–1.72)	1.27	(0.92–1.74)
2–4 million			1.04	(0.72–1.53)	1.02	(0.69–1.51)
≥4 million			1.02	(0.68–1.47)	1.00	(0.68–1.48)
Marital status (ref. Living with spouse)						
Living without spouse			0.90	(0.61–1.26)	0.88	(0.61–1.27)
Occupation (ref. White collar)						
Blue collar			1.07	(0.72–1.56)	1.02	(0.70–1.50)
Housewife			1.42	(1.00–1.95)	1.38	(0.98–1.93)
Other			1.24	(0.81–1.83)	1.18	(0.78–1.80)
Hypertension (ref. No)						
Yes			1.67	(1.28–2.13)	1.64	(1.27–2.12)
Diabetes (ref. No)						
Yes			1.13	(0.80–1.53)	1.12	(0.81–1.57)
Hyperlipidemia (ref. No)						
Yes			0.88	(0.65–1.15)	0.88	(0.66–1.17)

Neighborhood-level income status	1.24	(1.01–1.52)			1.24	(1.03–1.46)
Neighborhood-level % of college graduates or higher	1.71	(1.16–2.56)			1.13	(0.93–1.45)
Random Parameters						
Between-neighborhood variance	0.12	(0.02–0.34)	0.13	(0.02–0.39)	0.14	(0.02–0.41)
DIC	2029.82		1926.20		1924.07	

Note: Model 1 included the neighborhood-level SES only; model 2 included individual-level factors only; model 3 included all individual. All models were controlled for year dummies.

Figure 1. Study areas of 17 major cities and counties in the Korea HEXA-Gem dataset, 2005-2013

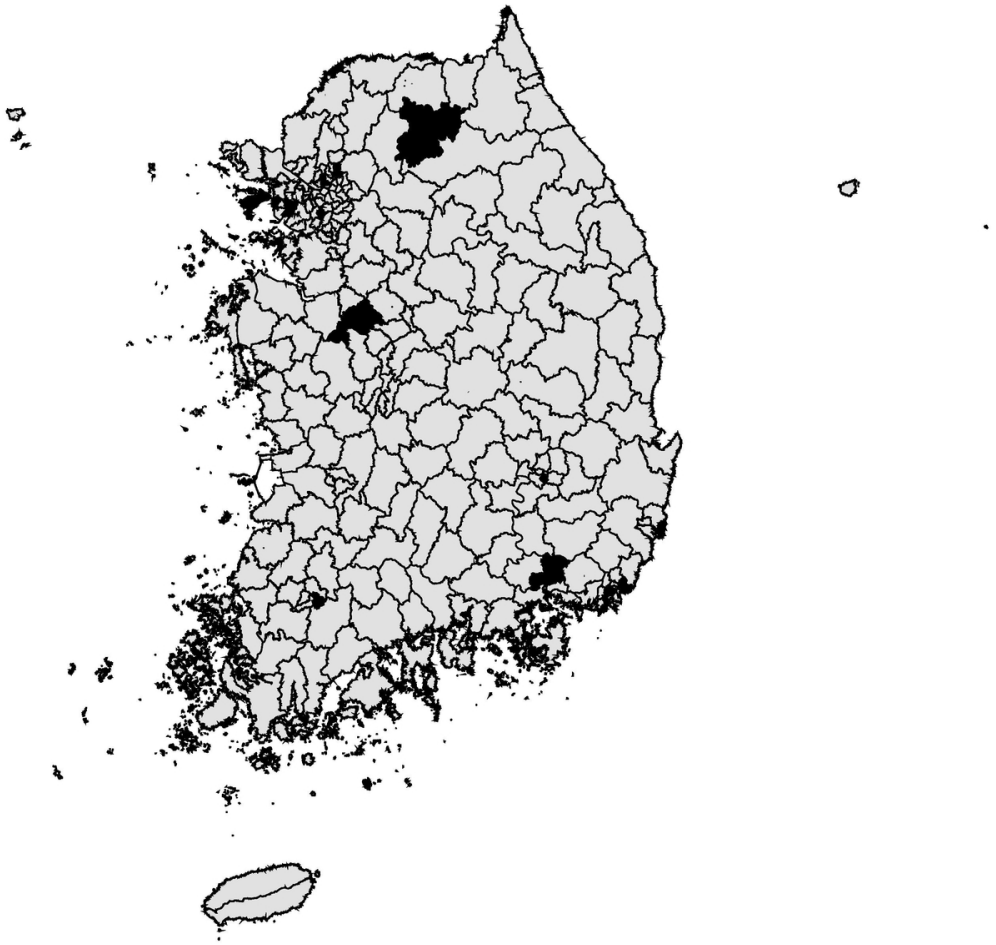

Figure 1. Study areas of 17 major cities and counties in the Korea HEXA-Gem dataset, 2005-2013

101x96mm (300 x 300 DPI)

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No.
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5, 7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6, 7
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	6, 7
Bias	9	Describe any efforts to address potential sources of bias	*6, 7*
Study size	10	Explain how the study size was arrived at	6, 7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7
		(*b*) Describe any methods used to examine subgroups and interactions	-
		(*c*) Explain how missing data were addressed	7
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	7
		(*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	8
		(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	17
		(b) Indicate number of participants with missing data for each variable of interest	7
Outcome data	15*	Report numbers of outcome events or summary measures	8, 17
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	8-9, 18

		(*b*) Report category boundaries when continuous variables were categorized	17
		(*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	9
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	11
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11
Generalisability	21	Discuss the generalisability (external validity) of the study results	11
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	13

*Give information separately for exposed and unexposed groups.

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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Neighborhood- and Individual-level Socioeconomic Status and Self-reported Management of Ischemic Heart Disease: Cross-sectional Results from the Korea Health Examinees Study

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Neighborhood- and Individual-level Socioeconomic Status and Self-reported Management of Ischemic Heart Disease: Cross-sectional Results from the Korea Health Examinees Study

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Neighborhood- and Individual-level Socioeconomic Status and Self-reported Management of Ischemic Heart Disease: Cross-sectional Results from the Korea Health Examinees Study

Abstract

Objective: Several studies identified neighborhood context as a predictor of prognosis in ischemic heart disease (IHD). The present study investigates the relationships of neighborhood- and individual-level socioeconomic status (SES) with the odds of ongoing management of IHD, using baseline survey data from the Korea Health Examinees-Gem study.

Design: In this cross-sectional study, we estimated the association of the odds of self-reported ongoing management with the neighborhood-level income status and percentage of college graduates after controlling for individual-level covariates using two-level multilevel logistic regression models based on the Markov Chain Monte Carlo function.

Setting: A survey conducted at 17 large general hospitals in major Korean cities and metropolitan areas during 2005–2013.

Participants: 2,932 adult men and women.

Outcome measure: The self-reported status of management after incident angina or myocardial infarction.

Results: At the neighborhood level, residence in a higher-income neighborhood was associated with the self-reported ongoing management of IHD, after controlling for individual-level covariates [odds ratio (OR): 1.22, 95% credible interval (CI): 1.01–1.61]. At the individual level, higher education was associated with the ongoing IHD management (high school graduation, OR: 1.33, 95% CI: 1.08–1.65); college or higher, OR: 1.63, 95% CI: 1.22–2.12; reference, middle school graduation or below).

Conclusions: Our study suggests that policies or interventions aimed at improving the quality and availability of medical resources in low-income areas may associate with ongoing IHD management. Moreover, patient-centered education is essential for ongoing IHD management, especially when targeted to IHD patients with a low education level.

Keywords: angina, myocardial infarction, multilevel analysis, MCMC, SES, Korea

Strengths and Limitations of this Study

- This study is among the first to examine the association between neighborhood- and individual-level SES and ongoing management of ischemic heart disease in Asian countries.
- Our study benefitted from the use of population-based samples, which enabled a multi-level analysis based on the neighborhood-level socioeconomic status.
- However, our findings were limited by the cross-sectional study design, use of survey data, and risk of selection bias.

INTRODUCTION

Ischemic heart disease (IHD), the current leading cause of death in Western countries, is rapidly becoming the leading cause of death in developing countries.[1] To reduce the mortality associated with IHD, researchers and clinicians have stressed the importance of patient management. Based on evidence demonstrating that medication adherence and behavioral lifestyle changes improved prognosis and retarded disease progression, guidelines for secondary IHD prevention suggest that patient management should comprise pharmacologic treatments (e.g., antiplatelet therapy, beta-blocker therapy) or lifestyle modifications (e.g., weight control, smoking cessation, blood pressure management).[2 3]

Earlier research suggests that the management of post-IHD may differ by socioeconomic status (SES). Notably, the lower rates of mortality among IHD patients with a high SES[4] may be attributable to the availability of better care,[5] better adherence to therapy, better self-monitoring,[6] and more rapid implementation of behavioral lifestyle changes,[7] which are facilitated by economic, educational, and social resources. Independent of the individual-level SES, neighborhood contexts also play critical roles in various health outcomes, including IHD-related outcomes.[8 9] Several previous studies have shown that residence in a socioeconomically disadvantaged neighborhoods was associated with a greater risk of IHD[10 11] and shorter survival duration.[12 13] However, few studies have examined the association between the neighborhood SES and IHD management.

To our knowledge, no study has addressed this association in South Korea (hereafter Korea) or another Asian country. Although the IHD-related mortality rate in 2011 remained lower in Korea (42 per 100,000 individuals) than in Western countries, the incidence of IHD in Korea has increased by 60% during the past decade[14] consequent to increases in body mass index values and an increasingly westernized diet among middle-aged adults.[15] Secondary IHD

mortality may be significantly reduced by ongoing IHD management involving both proper quality treatment and lifestyle modification, which may be shaped by neighborhood contexts as well as individual characteristics. Therefore, this study aimed to evaluate the individual- and neighborhood-level SES as the main determinants of ongoing IHD management in Korea, using baseline data from a large population-based cohort study with a multi-level framework.

METHODS

Data source

We used baseline survey data from the Health Examinees-Gem (HEXA_G) study, which was constructed by dropping inconsistent data collected during pilot HEXA survey periods. The original HEXA, which is part of the Korean Genome Epidemiology Study (KoGES),[16] was a large-scale genomic cohort study of 169,722 adults aged 40–69 years living in major Korean cities and metropolitan areas. Samples were recruited from 38 health examination centers and training hospitals (mainly general hospitals) during 2004–2013.[17] Eligible participants who visited the participating sites for biannual health check-ups, which were covered in full by the National Health Insurance Program were asked to respond voluntarily to an interview-based survey conducted by well-trained interviewers using a structured questionnaire. The survey collected information about socio-demographic characteristics, medical history, medication usage, family history, and health/lifestyle behaviors. More detailed information about the HEXA cohort study can be found elsewhere.[16 17] The HEXA-G dataset comprised 139,345 participants [men: 46,977 (33.7%); women: 92,368 (66.3%)]. Participants were excluded because of inconsistencies in data quality control, bio-specimen collection, a short duration of

study participation at 21 centers that participated in a pilot study, or the withdrawal of provision of personal information for studies.

Patient and public involvement

All participants completed a consent form before responding to the survey. The original HEXA and HEXA-G were deidentified for research. The study was approved by the Institutional Review Board (IRB) of Seoul National University Hospital, Seoul, Korea (IRB No. 0608-018-179).

Study outcome

The outcome of the study was the self-reported current management status after incident angina or myocardial infarction. To identify participants with a history of IHD, the survey included the yes/no question of "Have you ever been diagnosed with angina or myocardial infarction by a medical doctor in a medical facility?" The sub-population that responded "yes" then answered a sub-question regarding the current status of disease management for which the following options were available: (a) "condition has been good or improved due to management"; (b) "currently managed and treated"; (c) "was previously managed but is now neglected"; and (d) "neither managed nor treated." We dichotomized these responses as "ongoing management" by combining (a) with (b) versus "failure of ongoing management" (reference) by combining (c) with (d), respectively.

Neighborhood-level SES variables

The main neighborhood-level SES variables were (1) the regional median income status and (2) the regional mean percentage of college graduates. Seventeen neighborhoods were defined as 17 major cities and metropolitan areas (mean population: 201,210, range: 115,000-574,000) associated with 17 large general hospitals (Figure 1). The total catchment area of these hospitals covered 6.6% of the total Korean population. We obtained neighborhood-level SES data from a nationally and regionally representative dataset, Korea Community Health Survey (https://chs.cdc.go.kr/chs/index.do), which has been conducted in 253 communities annually since 2008. This survey aims to estimate regional patterns of disease prevalence and morbidity, as well as to understand the personal lifestyle and health behavior.[18] An average of 800-900 adults (age: ≥19 years) who resided in each neighborhood were selected using the probability proportional to sampling and systematic sampling methods. The sampling strategies are described in more detail elsewhere.[18] We calculated exogenous neighborhood-level SES measures using regional mean centering of the percentage of college graduates and median centering of the income status of the survey years. We then linked the regional SES indicators to our main dataset using the neighborhood identifier and the year variable. A comparison of socio-demographic characteristics between neighborhoods included and not included in the study revealed that the former was comprised of younger (age: 49.2 vs. 52.9 years), more highly educated (college graduates: 43.9% vs. 33.0%), and wealthier (the top 25% of household incomes: 30.9% vs. 27.8%) population.

Individual-level SES variables

Educational level was categorized into middle school or lower, high school graduation, or college graduation or higher. Income was measured by collapsing the data into four categories: <1, 1–2, 2–4, and ≥4 million Korean won (M KRW).

Covariates

The individual-level covariates included sex, age, marital status occupation, and comorbidities. Age was categorized into 40–50, 51–60, or 61+ years. Marital status was dichotomized into living with a spouse or not. Occupation was categorized as white collar, blue collar, housewife, or other. Comorbidities were defined as the presence of hypertension, diabetes, or hyperlipidemia at the time of the survey.

Statistical analysis

Two-level multilevel logistic regression models were fitted with individuals (level 1) nested within neighborhoods (level 2) to estimate the contributions of the individual- and neighborhood-level factors simultaneously. Random intercept models were fitted for the whole study samples to correct for cluster effects of the individual variables within the same neighborhood according to the neighborhood identifier in the model. We used the command *runmlwin* to run *MLwiN* within Stata software (Stata Corp. College Station, TX, USA).[19] This command enables researchers to fit multilevel models more quickly with *MLwiN* by taking advantage of the multi-level dataset analysis features included in Stata.[19] *MLwiN* was used to fit a binomial logit response model to an estimation using the Iterative Generalized Least Squares (IGLS) and second-order penalized quasi-likelihood (PQL2).

Estimates obtained using the above-described methods are known to exhibit a bias for discrete responses;[20] therefore, we fitted our final model using the Markov chain Monte Carlo (MCMC) function. Additionally, we adopted the Bayesian estimation function to ensure the accuracy of the estimates and their standard errors, as a small sample size at level two can

lead to biased estimates.[21 22] The MCMC was conducted to burn-in for 500 simulations, which yielded distribution starting values to discard, and subsequently to proceed for 5,000 additional simulations to obtain a precise estimate and distribution of interest. Once the convergence diagnostics were confirmed, the odds ratios (ORs) and 95% credible intervals (CIs) were presented in a Bayesian framework. We created separate missing dummy categories to retain the missing cases in income (n=295), occupation (n=265), and other covariate data (n=35) in the regression analysis. Due to of little interpretive value, the results for the category were not reported. We did not stratify the analyses by gender because a Chow test [47] failed to detect significant differences in the slopes and intercepts of the gender-stratified regressions [F (1, 2,364) =0.95, P=0.3309].

RESULTS

Table 1 presents the characteristics of participants with IHD from the HEXA-Gem dataset (n = 2,932), stratified by self-reported IHD management. Men had higher proportions of self-reported ongoing management than women (85.9% vs. 75.5%). Participants of younger groups had higher proportions of failures of ongoing IHD management (40–49: 29.5% vs. 50–59: 21.3% vs. 60–69: 15.2%).

Table 2 presents the results of the two-level multilevel logistic regression models for ongoing IHD management. In Model 1, the odds of ongoing management were higher for those with IHD who resided in higher-income neighborhoods, with an OR of 1.39 (95% CI: 1.15–1.66). In Model 2, a higher individual education level was associated with ongoing IHD management, with ORs of 1.35 (95% CI: 1.06–1.66) and 1.52 (95% CI: 1.14–2.02) for high school graduation and college graduation or higher, respectively, compared to those with a

middle school or lower education. However, no significant associations were observed between an individual's income group and the likelihood of self-reported ongoing management. In Model 3, the neighborhood-level income status remained significantly associated with self-reported ongoing management even after adjusting for individual-level factors (OR: 1.22, 95% CI 1.01–1.61). In this model, however, the association of residence in a neighborhood with a high percentage of college graduates with self-reported ongoing IHD management was not statistically significant. Finally, all models exhibited significant between-neighborhood variance.

DISCUSSION

According to our findings, residence in a neighborhood with a one-unit higher income was associated with a 22% higher likelihood of self-reported ongoing IHD management, compared to residence in a neighborhood with a lower income status. By contrast, at the individual level, a higher income was not significantly associated with self-reported ongoing IHD management. However, a higher individual education level was associated with a higher likelihood of self-reported ongoing IHD management.

Previous studies have found that a lower neighborhood SES was associated with a higher risk of IHD[10 11] and a shorter survival duration after incident IHD.[12 13] Consistent with those reports, our study showed an association of the neighborhood SES with ongoing IHD management that was independent of individual-level factors. We attribute this association to several factors. First, residents of higher-income neighborhoods may have greater access to higher quality medical resources, such as physicians or primary care clinics near their homes, regardless of individual income.[23] Second, residents in higher-income neighborhoods may

enjoy a more favorable social environment for IHD management, which might include an increased interest in health maintenance and a greater amount of social support from neighbors.[24] Third, residents of lower-income neighborhoods might have reduced access to health-oriented features such as recreation spaces and walkable environments[25] and stores that sell healthy foods,[26] concomitant with increased access to stores selling cigarettes and/or alcohol[27] and exposure to other environmental stressors. These factors may have important implications for self-care practices.

At the individual SES level, our study found that the education level was significantly associated with ongoing IHD management, whereas the income status was not. Similarly, previous studies also reported that IHD management may vary according to an individual's SES, and suggested that the survivors with lower income and education levels might fail to manage themselves appropriately because of (a) a lack of knowledge related to prevention and healthy habits,[28] (b) limited access to care or drugs due to economic constraints,[29] and (c) a lack of willingness or resources to change their lifestyles.[7] Patient education has been identified as an important factor in terms of the understanding of a specific disease process, medication management and adherence, and reported efficacies and side effects.[3] Previous studies demonstrated improved adherence to suggested management among IHD patients with higher education levels,[30] whereas patients with lower education levels may not adhere to guidelines because of a lack of knowledge or understanding about their disease. Alternatively, our study findings may reflect sub-optimal doctor-patient communication due to the exceptionally short consultation times with physicians in Korea, which are generally restricted to 2–3 minutes because of the lack of physicians and fee-for-service payment in the Korean healthcare system.[31] This restriction may stunt ongoing IHD management, especially among patients with lower education levels. Accordingly, our findings suggest that

individualized education could maximize IHD management outcomes.

Our finding that the individual-level income status and ongoing IHD management were not associated may imply that economic barriers to care or drugs do not determine the ongoing management of this condition. However, previous studies have shown that economically disadvantaged patients might be more likely to decline follow-up procedures or prescribed medications because economic constraint.[5 29] Our favorable study finding of no significant income inequality might therefore be explained by the universal healthcare coverage benefits and medical subsidies provided to lower-income populations in Korea.[31]

Our study had several limitations of note. First, our cross-sectional study was unable to determine the causal relationship between our main exposures (e.g., individual- and neighborhood-level SES) and the self-reported management of IHD. Second, our study used self-reported survey data, which may have been biased by misclassification due to participants' misunderstanding or social desirability. Additionally, the participants' responses regarding ongoing IHD management may not have been confirmed by medical professionals whether the received treatment or participants' adherence to therapy was clinically appropriate. Third, we were not able to control for severity of IHD and time lapsed the acute event because of data limitations. Fourth, selection bias may have been introduced by non-random survey participation and attrition. Disadvantaged individuals were less likely to participate regular health examinations and were more likely to drop out in the survey, possibly due to a failure of ongoing management. This bias would have led to underestimating the likelihood of failure of ongoing management among disadvantaged individuals. Fifth, we assumed that most participants visited the general hospitals within the region they lived. This assumption is highly plausible, given the improved accessibility to the health examination service in Korea contexts, as the National Health Insurance Program

provides free regular health examinations and medical facilities within and between regions exhibit minimal variations in examination quality.[32] However, we could not completely exclude the possibility that participants may have visited general hospitals in other neighborhoods to seek better-quality evaluations. Despite these limitations, however, one strength of our study was the use of population-based samples, which enabled a multi-level analysis by linking neighborhood-level SES from the nationally and regionally representative dataset. By contrast, most previous studies used hospital data, which frequently lack information about the individual's SES and neighborhood characteristics.[33] Moreover, to the best of our knowledge, this is among the first studies to examine the association between individual- and neighborhood-level SES and IHD management in an Asian country.

In conclusion, our study findings provide an opportunity to improve ongoing IHD management by identifying the neighborhood- and individual-level factors, which are associated with SES-related and geographic inequalities in IHD mortality. Our results suggest that policies or interventions intended to improve the quality and availability of medical resources in low-income areas might also effectively reduce inequalities in management and, ultimately, mortality. Moreover, our data suggest that patient-centered education is required to ensure ongoing IHD management and reduce related mortality, particularly among patients with a low education level.

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Author Contributions

JH analyzed the data; drafted, reviewed, and edited the manuscript; and contributed to the discussion. JKL and DK conducted, designed, and supervised the study; reviewed and edited the manuscript; and contributed to the discussion. JO, HYL, JYC, SK, and SVS reviewed and edited the manuscript and contributed to the discussion.

Conflicts of Interest

The authors declare no conflicts of interest.

A data sharing statement

Data sharing of HEXA is available through the website of the Korea National Institute of Health (http://www.nih.go.kr/NIH/cms/content/eng/03/65203_view.html#menu4_1_2).

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Table 1. Characteristics of the study sample from the Korea HEXA-Gem dataset (N = 2,932), 2005-2013, stratified by self-reported ongoing management of post-ischemic heart disease

		Ongoing management				
		Yes (N = 2,366, 80.7%)		No (N = 566, 19.3%)		
		N	(%)	N	(%)	
Sex	Men	1,261	85.9	207	14.1	*
	Women	1,105	75.5	359	24.5	
Age (years)	40–49	248	70.5	104	29.5	*
	50–59	904	78.7	245	21.3	
	60–69	1,214	84.8	217	15.2	
Education	≤Middle school	987	77.8	281	22.2	*
	High school	868	82.0	191	18.0	
	≥College	487	84.3	91	15.7	
	Missing	24	85.7	3	11.1	
Income (million Korean won)	<1	779	83.1	159	16.9	*
	1–2	588	80.8	140	19.2	
	2–4	418	78.3	116	21.7	
	≥4	581	79.4	151	19.3	
	Missing	204	69.2	91	30.9	
Occupation	White collar	618	78.8	166	21.2	*
	Blue collar	359	81.8	80	18.2	
	Housewife	702	76.5	216	23.5	
	Other	466	88.6	60	11.4	
	Missing	221	83.4	44	16.6	
Marital status	Living with spouse	2,073	80.9	488	19.1	
	Living without spouse	293	79	78	21.0	
Comorbidities	Hypertension	1,104	84.5	202	15.5	*
	No hypertension	1,262	77.6	364	22.4	
	Diabetes	465	85.3	80	14.6	*
	No diabetes	1,901	79.6	486	20.4	
	Hyperlipidemia	476	79.7	121	20.3	
	No hyperlipidemia	1,890	80.9	445	19.1	

* Differences between two groups for the all variables were considered significant at a p value <0.05

Table 2. Estimations from the two-level multilevel logistic regression models of self-reported ongoing management among ischemic heart disease survivors in the Korea HEXA-Gem dataset, 2005-2013

	Model 1		Model 2		Model 3	
	Odds Ratio	(95% Credible Interval)	Odds Ratio	(95% Credible Interval)	Odds Ratio	(95% Credible Interval)
Fixed Parameters						
Sex (ref. Female)						
Male			1.83	(1.38–2.39)	1.81	(1.37–2.32)
Age (years; ref. 40–49)						
50–59			1.57	(1.16–2.07)	1.57	(1.14-2.07)
61–69			2.19	(1.60–2.94)	2.19	(1.56-2.93)
Education (ref. ≤Middle school)						
High school			1.35	(1.06-1.66)	1.33	(1.08-1.65)
≥College			1.52	(1.14-2.02)	1.63	(1.22-2.12)
Income (ref. <1 million Korean won)						
1–2 million			0.89	(0.50-1.49)	0.88	(0.37-1.48)
2–4 million			1.09	(0.63-1.76)	1.14	(0.66-1.87)
≥4 million			1.26	(0.85-1.81)	1.07	(0.70-1.65)
Marital status (ref. Living with spouse)						
Living without spouse			1.08	(0.82–1.42)	1.09	(0.80-1.44)
Occupation (ref. White collar)						
Blue collar			1.11	(0.79–1.53)	1.11	(0.81-1.50)
Housewife			1.13	(0.84–1.48)	1.12	(0.85-1.46)
Other			1.42	(1.00–1.97)	1.42	(0.99-1.97)
Hypertension (ref. No)						
Yes			1.49	(1.20–1.84)	1.49	(1.21-1.80)
Diabetes (ref. No)						
Yes			1.21	(0.91–1.58)	1.20	(0.91-1.57)
Hyperlipidemia (ref. No)						
Yes			0.91	(0.67–1.23)	0.91	(0.68-1.19)

Neighborhood-level income status	1.39	(1.15–1.66)			1.22	(1.01–1.61)
Neighborhood-level % of college graduates or higher	1.06	(0.86–1.30)			1.12	(0.89–1.41)
Random Parameters						
Between-neighborhood variance	0.11	(0.02–0.32)	0.14	(0.03–0.37)	0.16	(0.03–0.46)
DIC	2853.90		2756.97		2754.86	

Note: Model 1 included the neighborhood-level SES only; model 2 included individual-level factors only; model 3 included all individual. All models were controlled for year dummies.

Figure 1. Study areas of 17 major cities and counties in the Korea HEXA-Gem dataset, 2005-2013

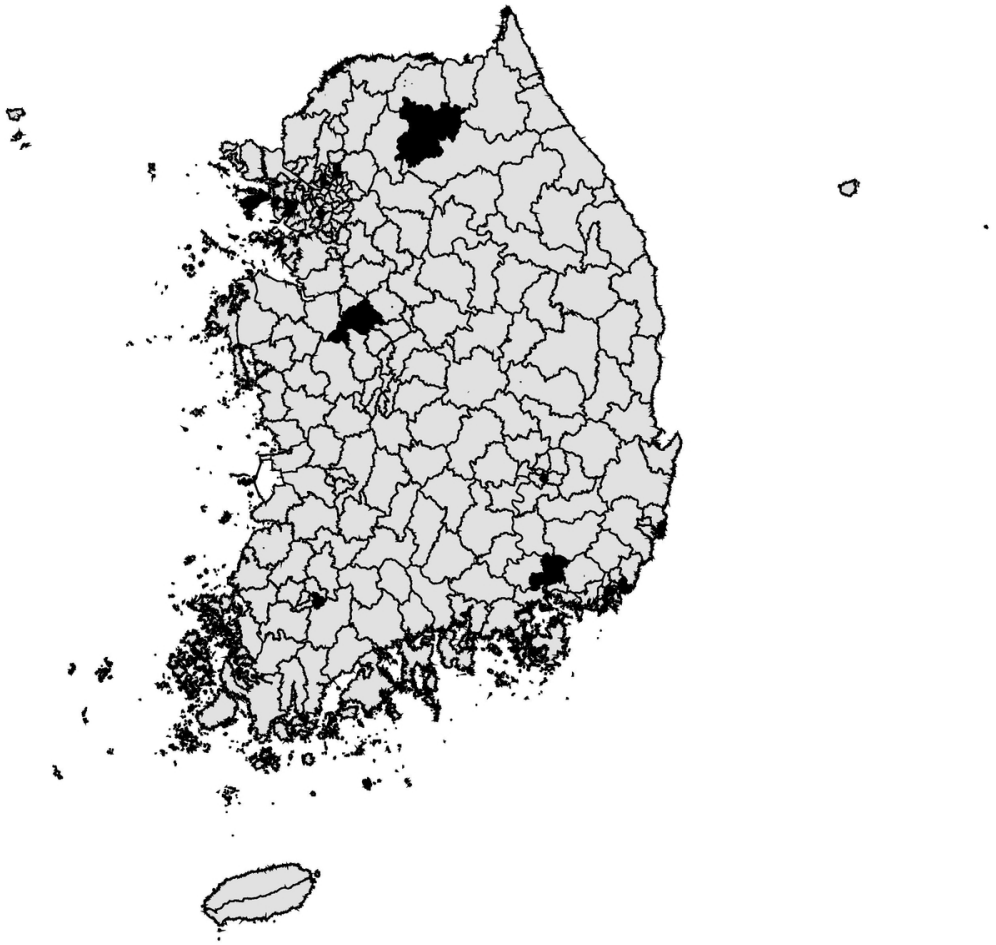

Figure 1. Study areas of 17 major cities and counties in the Korea HEXA-Gem dataset, 2005-2013

101x96mm (300 x 300 DPI)

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No.
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5, 7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6, 7
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	6, 7
Bias	9	Describe any efforts to address potential sources of bias	*6, 7*
Study size	10	Explain how the study size was arrived at	6, 7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7
		(*b*) Describe any methods used to examine subgroups and interactions	-
		(*c*) Explain how missing data were addressed	7
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	7
		(*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	8
		(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	17
		(b) Indicate number of participants with missing data for each variable of interest	7
Outcome data	15*	Report numbers of outcome events or summary measures	8, 17
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	8-9, 18

		(*b*) Report category boundaries when continuous variables were categorized	17
		(*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	9
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	11
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11
Generalisability	21	Discuss the generalisability (external validity) of the study results	11
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	13

*Give information separately for exposed and unexposed groups.

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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Neighborhood- and Individual-level Socioeconomic Status and Self-reported Management of Ischemic Heart Disease: Cross-sectional Results from the Korea Health Examinees Study

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Neighborhood- and Individual-level Socioeconomic Status and Self-reported Management of Ischemic Heart Disease: Cross-sectional Results from the Korea Health Examinees Study

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Neighborhood- and Individual-level Socioeconomic Status and Self-reported Management of Ischemic Heart Disease: Cross-sectional Results from the Korea Health Examinees Study

Abstract

Objective: Several studies identified neighborhood context as a predictor of prognosis in ischemic heart disease (IHD). The present study investigates the relationships of neighborhood- and individual-level socioeconomic status (SES) with the odds of ongoing management of IHD, using baseline survey data from the Korea Health Examinees-Gem study.

Design: In this cross-sectional study, we estimated the association of the odds of self-reported ongoing management with the neighborhood-level income status and percentage of college graduates after controlling for individual-level covariates using two-level multilevel logistic regression models based on the Markov Chain Monte Carlo function.

Setting: A survey conducted at 17 large general hospitals in major Korean cities and metropolitan areas during 2005–2013.

Participants: 2,932 adult men and women.

Outcome measure: The self-reported status of management after incident angina or myocardial infarction.

Results: At the neighborhood level, residence in a higher-income neighborhood was associated with the self-reported ongoing management of IHD, after controlling for individual-level covariates [odds ratio (OR): 1.22, 95% credible interval (CI): 1.01–1.61]. At the individual level, higher education was associated with the ongoing IHD management (high school graduation, OR: 1.33, 95% CI: 1.08–1.65); college or higher, OR: 1.63, 95% CI: 1.22–2.12; reference, middle school graduation or below).

Conclusions: Our study suggests that policies or interventions aimed at improving the quality and availability of medical resources in low-income areas may associate with ongoing IHD management. Moreover, patient-centered education is essential for ongoing IHD management, especially when targeted to IHD patients with a low education level.

Keywords: angina, myocardial infarction, multilevel analysis, MCMC, SES, Korea

Strengths and Limitations of this Study

- This study is among the first to examine the association between neighborhood- and individual-level SES and ongoing management of ischemic heart disease in Asian countries.
- Our study benefitted from the use of population-based samples, which enabled a multi-level analysis based on the neighborhood-level socioeconomic status.
- However, our findings were limited by the cross-sectional study design, use of survey data, and risk of selection bias.

INTRODUCTION

Ischemic heart disease (IHD), the current leading cause of death in Western countries, is rapidly becoming the leading cause of death in developing countries.[1] To reduce the mortality associated with IHD, researchers and clinicians have stressed the importance of patient management. Based on evidence demonstrating that medication adherence and behavioral lifestyle changes improved prognosis and retarded disease progression, guidelines for secondary IHD prevention suggest that patient management should comprise pharmacologic treatments (e.g., antiplatelet therapy, beta-blocker therapy) or lifestyle modifications (e.g., weight control, smoking cessation, blood pressure management).[2 3]

Earlier research suggests that the management of post-IHD may differ by socioeconomic status (SES). Notably, the lower rates of mortality among IHD patients with a high SES[4] may be attributable to the availability of better care,[5] better adherence to therapy, better self-monitoring,[6] and more rapid implementation of behavioral lifestyle changes,[7] which are facilitated by economic, educational, and social resources. Independent of the individual-level SES, neighborhood contexts also play critical roles in various health outcomes, including IHD-related outcomes.[8 9] Several previous studies have shown that residence in a socioeconomically disadvantaged neighborhoods was associated with a greater risk of IHD[10 11] and shorter survival duration.[12 13] However, few studies have examined the association between the neighborhood SES and IHD management.

To our knowledge, no study has addressed this association in South Korea (hereafter Korea) or another Asian country. Although the IHD-related mortality rate in 2011 remained lower in Korea (42 per 100,000 individuals) than in Western countries, the incidence of IHD in Korea has increased by 60% during the past decade[14] consequent to increases in body mass index values and an increasingly westernized diet among middle-aged adults.[15] Secondary IHD

mortality may be significantly reduced by ongoing IHD management involving both proper quality treatment and lifestyle modification, which may be shaped by neighborhood contexts as well as individual characteristics. Therefore, this study aimed to evaluate the individual- and neighborhood-level SES as the main determinants of ongoing IHD management in Korea, using baseline data from a large population-based cohort study with a multi-level framework.

METHODS

Data source

We used baseline survey data from the Health Examinees-Gem (HEXA_G) study, which was constructed by dropping inconsistent data collected during pilot HEXA survey periods. The original HEXA, which is part of the Korean Genome Epidemiology Study (KoGES),[16] was a large-scale genomic cohort study of 169,722 adults aged 40–69 years living in major Korean cities and metropolitan areas. Samples were recruited from 38 health examination centers and training hospitals (mainly general hospitals) during 2004–2013.[17] Eligible participants who visited the participating sites for biannual health check-ups, which were covered in full by the National Health Insurance Program were asked to respond voluntarily to an interview-based survey conducted by well-trained interviewers using a structured questionnaire. The survey collected information about socio-demographic characteristics, medical history, medication usage, family history, and health/lifestyle behaviors. More detailed information about the HEXA cohort study can be found elsewhere.[16 17] The HEXA-G dataset comprised 139,345 participants [men: 46,977 (33.7%); women: 92,368 (66.3%)]. Participants were excluded because of inconsistencies in data quality control, bio-specimen collection, a short duration of

study participation at 21 centers that participated in a pilot study, or the withdrawal of provision of personal information for studies. All participants completed a consent form before responding to the survey. The original HEXA and HEXA-G were deidentified for research. The study was approved by the Institutional Review Board (IRB) of Seoul National University Hospital, Seoul, Korea (IRB No. 0608-018-179).

Patient and public involvement

Patients and public were not involved in the design and conduct of this study. The results will not be disseminated to study participants.

Study outcome

The outcome of the study was the self-reported current management status after incident angina or myocardial infarction. To identify participants with a history of IHD, the survey included the yes/no question of "Have you ever been diagnosed with angina or myocardial infarction by a medical doctor in a medical facility?" The sub-population that responded "yes" then answered a sub-question regarding the current status of disease management for which the following options were available: (a) "condition has been good or improved due to management"; (b) "currently managed and treated"; (c) "was previously managed but is now neglected"; and (d) "neither managed nor treated." We dichotomized these responses as "ongoing management" by combining (a) with (b) versus "failure of ongoing management" (reference) by combining (c) with (d), respectively.

Neighborhood-level SES variables

The main neighborhood-level SES variables were (1) the regional median income status and (2) the regional mean percentage of college graduates. Seventeen neighborhoods were defined as 17 major cities and metropolitan areas (mean population: 201,210, range: 115,000-574,000) associated with 17 large general hospitals (Figure 1). The total catchment area of these hospitals covered 6.6% of the total Korean population. We obtained neighborhood-level SES data from a nationally and regionally representative dataset, Korea Community Health Survey (https://chs.cdc.go.kr/chs/index.do), which has been conducted in 253 communities annually since 2008. This survey aims to estimate regional patterns of disease prevalence and morbidity, as well as to understand the personal lifestyle and health behavior.[18] An average of 800-900 adults (age: ≥19 years) who resided in each neighborhood were selected using the probability proportional to sampling and systematic sampling methods. The sampling strategies are described in more detail elsewhere.[18] We calculated exogenous neighborhood-level SES measures using regional mean centering of the percentage of college graduates and median centering of the income status of the survey years. We then linked the regional SES indicators to our main dataset using the neighborhood identifier and the year variable. A comparison of socio-demographic characteristics between neighborhoods included and not included in the study revealed that the former was comprised of younger (age: 49.2 vs. 52.9 years), more highly educated (college graduates: 43.9% vs. 33.0%), and wealthier (the top 25% of household incomes: 30.9% vs. 27.8%) population.

Individual-level SES variables

Educational level was categorized into middle school or lower, high school graduation, or college graduation or higher. Income was measured by collapsing the data into four categories: <1, 1–2, 2–4, and ≥4 million Korean won (M KRW).

Covariates

The individual-level covariates included sex, age, marital status occupation, and comorbidities. Age was categorized into 40–50, 51–60, or 61+ years. Marital status was dichotomized into living with a spouse or not. Occupation was categorized as white collar, blue collar, housewife, or other. Comorbidities were defined as the presence of hypertension, diabetes, or hyperlipidemia at the time of the survey.

Statistical analysis

Two-level multilevel logistic regression models were fitted with individuals (level 1) nested within neighborhoods (level 2) to estimate the contributions of the individual- and neighborhood-level factors simultaneously. Random intercept models were fitted for the whole study samples to correct for cluster effects of the individual variables within the same neighborhood according to the neighborhood identifier in the model. We used the command *runmlwin* to run *MLwiN* within Stata software (Stata Corp. College Station, TX, USA).[19] This command enables researchers to fit multilevel models more quickly with *MLwiN* by taking advantage of the multi-level dataset analysis features included in Stata.[19] *MLwiN* was used to fit a binomial logit response model to an estimation using the Iterative Generalized Least Squares (IGLS) and second-order penalized quasi-likelihood (PQL2).

Estimates obtained using the above-described methods are known to exhibit a bias for discrete responses;[20] therefore, we fitted our final model using the Markov chain Monte Carlo (MCMC) function. Additionally, we adopted the Bayesian estimation function to ensure the accuracy of the estimates and their standard errors, as a small sample size at level two can lead to biased estimates.[21 22] The MCMC was conducted to burn-in for 500 simulations, which yielded distribution starting values to discard, and subsequently to proceed for 5,000 additional simulations to obtain a precise estimate and distribution of interest. Once the convergence diagnostics were confirmed, the odds ratios (ORs) and 95% credible intervals (CIs) were presented in a Bayesian framework. We created separate missing dummy categories to retain the missing cases in income (n=295), occupation (n=265), and other covariate data (n=35) in the regression analysis. Due to of little interpretive value, the results for the category were not reported. We did not stratify the analyses by gender because a Chow test [47] failed to detect significant differences in the slopes and intercepts of the gender-stratified regressions [F (1, 2,364) =0.95, P=0.3309].

RESULTS

Table 1 presents the characteristics of participants with IHD from the HEXA-Gem dataset (n = 2,932), stratified by self-reported IHD management. Men had higher proportions of self-reported ongoing management than women (85.9% vs. 75.5%). Participants of younger groups had higher proportions of failures of ongoing IHD management (40–49: 29.5% vs. 50–59: 21.3% vs. 60–69: 15.2%).

Table 2 presents the results of the two-level multilevel logistic regression models for ongoing IHD management. In Model 1, the odds of ongoing management were higher for those with

IHD who resided in higher-income neighborhoods, with an OR of 1.39 (95% CI: 1.15–1.66). In Model 2, a higher individual education level was associated with ongoing IHD management, with ORs of 1.35 (95% CI: 1.06–1.66) and 1.52 (95% CI: 1.14–2.02) for high school graduation and college graduation or higher, respectively, compared to those with a middle school or lower education. However, no significant associations were observed between an individual's income group and the likelihood of self-reported ongoing management. In Model 3, the neighborhood-level income status remained significantly associated with self-reported ongoing management even after adjusting for individual-level factors (OR: 1.22, 95% CI 1.01–1.61). In this model, however, the association of residence in a neighborhood with a high percentage of college graduates with self-reported ongoing IHD management was not statistically significant. Finally, all models exhibited significant between-neighborhood variance.

DISCUSSION

According to our findings, residence in a neighborhood with a one-unit higher income was associated with a 22% higher likelihood of self-reported ongoing IHD management, compared to residence in a neighborhood with a lower income status. By contrast, at the individual level, a higher income was not significantly associated with self-reported ongoing IHD management. However, a higher individual education level was associated with a higher likelihood of self-reported ongoing IHD management.

Previous studies have found that a lower neighborhood SES was associated with a higher risk of IHD[10 11] and a shorter survival duration after incident IHD.[12 13] Consistent with those reports, our study showed an association of the neighborhood SES with ongoing IHD

management that was independent of individual-level factors. We attribute this association to several factors. First, residents of higher-income neighborhoods may have greater access to higher quality medical resources, such as physicians or primary care clinics near their homes, regardless of individual income.[23] Second, residents in higher-income neighborhoods may enjoy a more favorable social environment for IHD management, which might include an increased interest in health maintenance and a greater amount of social support from neighbors.[24] Third, residents of lower-income neighborhoods might have reduced access to health-oriented features such as recreation spaces and walkable environments[25] and stores that sell healthy foods,[26] concomitant with increased access to stores selling cigarettes and/or alcohol[27] and exposure to other environmental stressors. These factors may have important implications for self-care practices.

At the individual SES level, our study found that the education level was significantly associated with ongoing IHD management, whereas the income status was not. Similarly, previous studies also reported that IHD management may vary according to an individual's SES, and suggested that the survivors with lower income and education levels might fail to manage themselves appropriately because of (a) a lack of knowledge related to prevention and healthy habits,[28] (b) limited access to care or drugs due to economic constraints,[29] and (c) a lack of willingness or resources to change their lifestyles.[7] Patient education has been identified as an important factor in terms of the understanding of a specific disease process, medication management and adherence, and reported efficacies and side effects.[3] Previous studies demonstrated improved adherence to suggested management among IHD patients with higher education levels,[30] whereas patients with lower education levels may not adhere to guidelines because of a lack of knowledge or understanding about their disease. Alternatively, our study findings may reflect sub-optimal doctor-patient communication due

to the exceptionally short consultation times with physicians in Korea, which are generally restricted to 2–3 minutes because of the lack of physicians and fee-for-service payment in the Korean healthcare system.[31] This restriction may stunt ongoing IHD management, especially among patients with lower education levels. Accordingly, our findings suggest that individualized education could maximize IHD management outcomes.

Our finding that the individual-level income status and ongoing IHD management were not associated may imply that economic barriers to care or drugs do not determine the ongoing management of this condition. However, previous studies have shown that economically disadvantaged patients might be more likely to decline follow-up procedures or prescribed medications because economic constraint.[5 29] Our favorable study finding of no significant income inequality might therefore be explained by the universal healthcare coverage benefits and medical subsidies provided to lower-income populations in Korea.[31]

Our study had several limitations of note. First, our cross-sectional study was unable to determine the causal relationship between our main exposures (e.g., individual- and neighborhood-level SES) and the self-reported management of IHD. Second, our study used self-reported survey data, which may have been biased by misclassification due to participants' misunderstanding or social desirability. Additionally, the participants' responses regarding ongoing IHD management may not have been confirmed by medical professionals whether the received treatment or participants' adherence to therapy was clinically appropriate. Third, we were not able to control for severity of IHD and time lapsed the acute event because of data limitations. Fourth, selection bias may have been introduced by non-random survey participation and attrition. Disadvantaged individuals were less likely to participate regular health examinations and were more likely to drop out in the survey, possibly due to a failure of ongoing management. This bias would have led to

underestimating the likelihood of failure of ongoing management among disadvantaged individuals. Fifth, we assumed that most participants visited the general hospitals within the region they lived. This assumption is highly plausible, given the improved accessibility to the health examination service in Korea contexts, as the National Health Insurance Program provides free regular health examinations and medical facilities within and between regions exhibit minimal variations in examination quality.[32] However, we could not completely exclude the possibility that participants may have visited general hospitals in other neighborhoods to seek better-quality evaluations. Despite these limitations, however, one strength of our study was the use of population-based samples, which enabled a multi-level analysis by linking neighborhood-level SES from the nationally and regionally representative dataset. By contrast, most previous studies used hospital data, which frequently lack information about the individual's SES and neighborhood characteristics.[33] Moreover, to the best of our knowledge, this is among the first studies to examine the association between individual- and neighborhood-level SES and IHD management in an Asian country.

In conclusion, our study findings provide an opportunity to improve ongoing IHD management by identifying the neighborhood- and individual-level factors, which are associated with SES-related and geographic inequalities in IHD mortality. Our results suggest that policies or interventions intended to improve the quality and availability of medical resources in low-income areas might also effectively reduce inequalities in management and, ultimately, mortality. Moreover, our data suggest that patient-centered education is required to ensure ongoing IHD management and reduce related mortality, particularly among patients with a low education level.

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Author Contributions

JH analyzed the data; drafted, reviewed, and edited the manuscript; and contributed to the discussion. JKL and DK conducted, designed, and supervised the study; reviewed and edited the manuscript; and contributed to the discussion. JO, HYL, JYC, SK, and SVS reviewed and edited the manuscript and contributed to the discussion.

Conflicts of Interest

The authors declare no conflicts of interest.

A data sharing statement

Data sharing of HEXA is available through the website of the Korea National Institute of Health (http://www.nih.go.kr/NIH/cms/content/eng/03/65203_view.html#menu4_1_2).

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Table 1. Characteristics of the study sample from the Korea HEXA-Gem dataset (N = 2,932), 2005-2013, stratified by self-reported ongoing management of post-ischemic heart disease

		Ongoing management				
		Yes (N = 2,366, 80.7%)		No (N = 566, 19.3%)		
Individuals		N	%	N	%	
Sex	Men	1,261	85.9	207	14.1	*
	Women	1,105	75.5	359	24.5	
Age (years)	40–49	248	70.5	104	29.5	*
	50–59	904	78.7	245	21.3	
	60–69	1,214	84.8	217	15.2	
Education	≤Middle school	987	77.8	281	22.2	*
	High school	868	82.0	191	18.0	
	≥College	487	84.3	91	15.7	
	Missing	24	85.7	3	11.1	
Income (million Korean won)	<1	779	83.1	159	16.9	*
	1–2	588	80.8	140	19.2	
	2–4	418	78.3	116	21.7	
	≥4	581	79.4	151	19.3	
	Missing	204	69.2	91	30.9	
Occupation	White collar	618	78.8	166	21.2	*
	Blue collar	359	81.8	80	18.2	
	Housewife	702	76.5	216	23.5	
	Other	466	88.6	60	11.4	
	Missing	221	83.4	44	16.6	
Marital status	Living with spouse	2,073	80.9	488	19.1	
	Living without spouse	293	79	78	21.0	
Comorbidities	Hypertension	1,104	84.5	202	15.5	*
	No hypertension	1,262	77.6	364	22.4	
	Diabetes	465	85.3	80	14.6	*
	No diabetes	1,901	79.6	486	20.4	
	Hyperlipidemia	476	79.7	121	20.3	
	No hyperlipidemia	1,890	80.9	445	19.1	
Neighborhoods		Mean		SD		
Neighborhood-level income status		0.46		0.98		
Neighborhood-level % of college graduates or higher		0.10		0.07		

* Differences between two groups for the all variables were considered significant at a p value <0.05

Table 2. Estimations from the two-level multilevel logistic regression models of self-reported ongoing management among ischemic heart disease survivors in the Korea HEXA-Gem dataset, 2005-2013

	Model 1		Model 2		Model 3	
	Odds Ratio	(95% Credible Interval)	Odds Ratio	(95% Credible Interval)	Odds Ratio	(95% Credible Interval)
Fixed Parameters						
Sex (ref. Female)						
Male			1.83	(1.38–2.39)	1.81	(1.37–2.32)
Age (years; ref. 40–49)						
50–59			1.57	(1.16–2.07)	1.57	(1.14-2.07)
61–69			2.19	(1.60–2.94)	2.19	(1.56-2.93)
Education (ref. ≤Middle school)						
High school			1.35	(1.06-1.66)	1.33	(1.08-1.65)
≥College			1.52	(1.14-2.02)	1.63	(1.22-2.12)
Income (ref. <1 million Korean won)						
1–2 million			0.89	(0.50-1.49)	0.88	(0.37-1.48)
2–4 million			1.09	(0.63-1.76)	1.14	(0.66-1.87)
≥4 million			1.26	(0.85-1.81)	1.07	(0.70-1.65)
Marital status (ref. Living with spouse)						
Living without spouse			1.08	(0.82–1.42)	1.09	(0.80-1.44)
Occupation (ref. White collar)						
Blue collar			1.11	(0.79–1.53)	1.11	(0.81-1.50)
Housewife			1.13	(0.84–1.48)	1.12	(0.85-1.46)
Other			1.42	(1.00–1.97)	1.42	(0.99-1.97)
Hypertension (ref. No)						
Yes			1.49	(1.20–1.84)	1.49	(1.21-1.80)
Diabetes (ref. No)						
Yes			1.21	(0.91–1.58)	1.20	(0.91-1.57)
Hyperlipidemia (ref. No)						
Yes			0.91	(0.67–1.23)	0.91	(0.68-1.19)

Neighborhood-level income status	1.39	(1.15–1.66)			1.22	(1.01–1.61)
Neighborhood-level % of college graduates or higher	1.06	(0.86–1.30)			1.12	(0.89–1.41)
Random Parameters						
Between-neighborhood variance	0.11	(0.02–0.32)	0.14	(0.03–0.37)	0.16	(0.03–0.46)
DIC	2853.90		2756.97		2754.86	

Note: Model 1 included the neighborhood-level SES only; model 2 included individual-level factors only; model 3 included all individual. All models were controlled for year dummies.

Figure 1. Study areas of 17 major cities and counties in the Korea HEXA-Gem dataset, 2005-2013

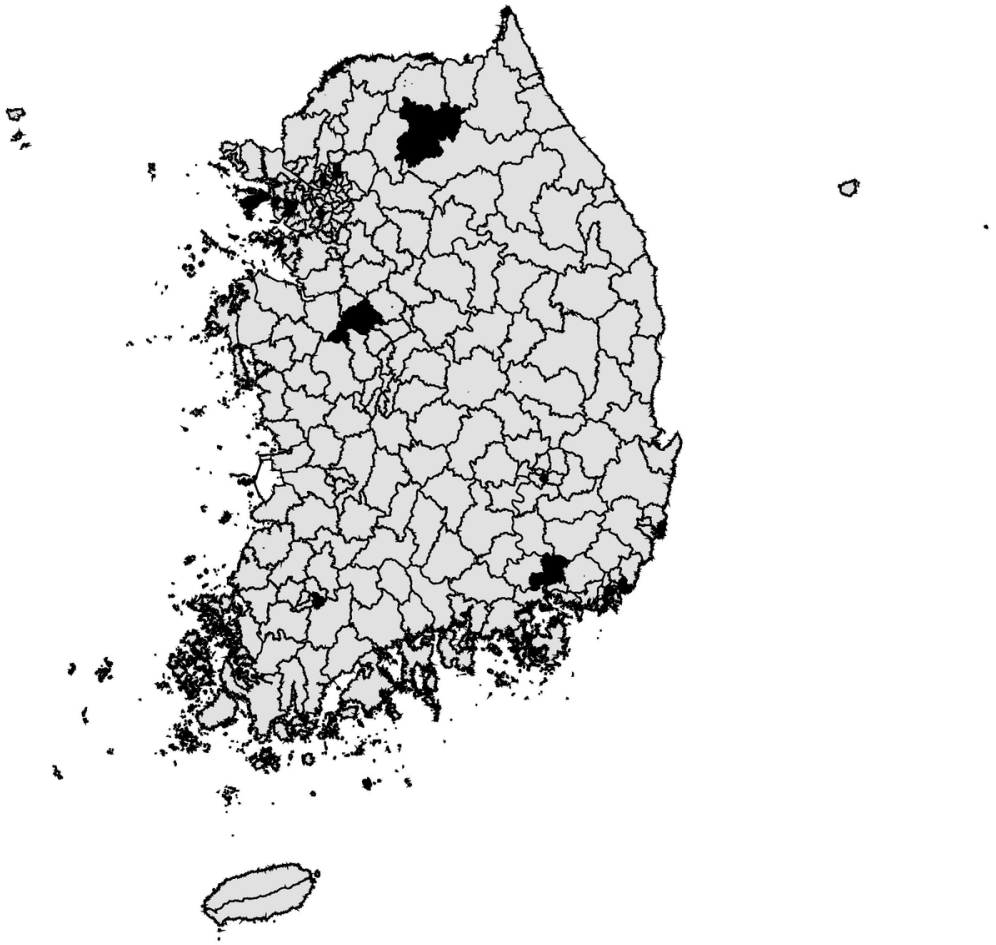

Figure 1. Study areas of 17 major cities and counties in the Korea HEXA-Gem dataset, 2005-2013

101x96mm (300 x 300 DPI)

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Page No.
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	2
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	4
Objectives	3	State specific objectives, including any prespecified hypotheses	5
Methods			
Study design	4	Present key elements of study design early in the paper	5, 7
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	6, 7
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	6, 7
Bias	9	Describe any efforts to address potential sources of bias	*6, 7*
Study size	10	Explain how the study size was arrived at	6, 7
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	7
		(*b*) Describe any methods used to examine subgroups and interactions	-
		(*c*) Explain how missing data were addressed	7
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	7
		(*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	8
		(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	17
		(b) Indicate number of participants with missing data for each variable of interest	7
Outcome data	15*	Report numbers of outcome events or summary measures	8, 17
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	8-9, 18

		(*b*) Report category boundaries when continuous variables were categorized	17
		(*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	9
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	11
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	11
Generalisability	21	Discuss the generalisability (external validity) of the study results	11
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	13

*Give information separately for exposed and unexposed groups.

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.