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Original Research

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Risk of all-cause mortality is associated with multiple health-related lifestyle behaviors and does not differ between urban and rural areas in Korea

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ABSTRACT

BACKGROUND/OBJECTIVES: Urban–rural inequities in health and mortality exist in Korea, a highly centralized developed country. The potential impact of multiple health-related lifestyle behaviors on mortality and difference between urban and rural areas is not fully understood. This study aimed to investigate the effect of high-risk health behaviors on all-cause mortality among residents living in urban and rural in Korea.
SUBJECTS/METHODS: Cross-sectional analyses were conducted on 8,298 adults aged 40 yrs and older from the Korea National Health and Nutrition Examination Survey 2013–2015. High-risk behaviors were defined as having poor diet quality, current smoking, high-risk drinking, or insufficient physical activity. Mortality status was linked to the Cause of Death data followed up to December 31, 2019. The associations between all-cause mortality and high-risk behaviors were evaluated using Cox proportional hazard regression models adjusted for age, sex, education, income, and survey year. Population attributable fractions (PAFs) were calculated, and effect modification analysis was conducted. Participants were stratified by residential area (urban or rural).
RESULTS: During the follow-up (median: 5.4 yrs), 313 deaths occurred. A higher proportion of rural residents than urban residents engaged in multiple high-risk behaviors (28.9% vs. 22.6%; $P < 0.0001$). As individual factors, a greater risk of mortality was associated with poor diet quality, current smoking, and inadequate physical activity, and these tendencies persisted in rural residents, especially for diet quality. Multiple high-risk behaviors were positively associated with a higher risk of mortality in Koreans living in urban and rural areas. PAF (95% confidence interval) was 18.5% (7.35–27.9%) and 29.8% (16.1–40.2%) in urban and rural residents, respectively. No additive or multiplicative effect of the region was observed.
CONCLUSION: The higher prevalence of multiple high-risk lifestyle behaviors in rural residents may explain the higher mortality in rural areas compared to urban areas. Comprehensive public health policies to improve health-related behaviors in rural populations may be needed.

Keywords: Dietary patterns; health behavior; mortality; health inequities; Asian

Conflict of Interest
The authors declare no potential conflicts of interests.

Author Contributions
Conceptualization: Kim S, Park CY; Formal analysis: Kim S; Investigation: Kim S; Methodology; Kim S, Park CY; Supervision: Park CY; Validation: Kim S, Park CY; Writing - original draft: Kim S; Writing - review & editing: Kim S, Park CY.

INTRODUCTION

Living in less urbanized areas is known to be associated with a higher risk of adverse health outcomes [1-6]. This may be due to more adults residing in rural areas practicing unfavorable health-related behaviors than those residing in urban areas [7-10] and the disproportionate distribution of socioeconomic status and health-related resources between urban and rural regions [11-13]. High-risk lifestyle behaviors, such as poor diet, smoking, high-risk drinking, and insufficient physical activity, individually and in combination, are well-established risk factors for morbidity and mortality [14-20]. Little is known about the association of diet quality, assessed by the recently developed Korean Healthy Eating Index (KHEI), with mortality in Koreans in combination with other health-related behaviors [21-26]. In addition, the differences in magnitude of effect of these behaviors on mortality between regions have not been investigated.

South Korea (hereafter Korea) is a relatively small-sized industrialized nation. As with most developed and industrialized countries, Korea is highly centralized around the capital city, Seoul. Fifty percent of the Korean population resides in Seoul and the surrounding metropolitan area, and the population density of Seoul is more than 30 times the national average [27]. Health care resources also tend to be centralized in the Seoul metropolitan area [28]. Conversely, roads and public transportation networks are well-established nationwide [29], and the Korea National Health Insurance Program universally covers most or a large portion of health costs [30]. These may lower barriers to health care access for those residing in rural areas and those with relatively lower socioeconomic status. Nonetheless, substantial regional inequality exists in unmet medical needs [31,32] and premature deaths [4,5], especially preventable deaths [6], in Korea resulting in one of the primary goals of the 5th National Health Plan 2030 of Korea to be reducing regional health inequality [33]. Therefore, Korea is a unique model to assess the effects of various health-related behaviors and regions on mortality in the context of health equity.

We hypothesized that residents of rural areas are more susceptible to effects of high-risk lifestyle behaviors regarding all-cause mortality. This study aimed to assess the individual and combined effects of high-risk lifestyle behaviors on all-cause mortality according to residential area (urban or rural) in Korean adults aged ≥ 40 yrs old using nationally representative data.

SUBJECTS AND METHODS

Study design and participants

Data were derived from the Korea National Health and Nutrition Examination Survey (KNHANES) 2013–2015 linked Cause of Death data (version 1.2) obtained from Statistics Korea [34] due to the availability of diet quality data. The KNHANES is a nationally representative cross-sectional study of the civilian noninstitutionalized Korean population. The surveys were conducted by the Korea Disease Control and Prevention Agency (KDCA) and included health interviews, health examinations, and nutrition surveys [35]. Participants included were aged 40 yrs or older at enrollment, had available vital status, were nonpregnant, and did not have a history of cardiovascular disease or cancer (**Fig. 1**). Participants with missing data for diet quality, smoking, drinking, physical activity, and covariates were excluded from the analysis. After these exclusions, data from 8,298

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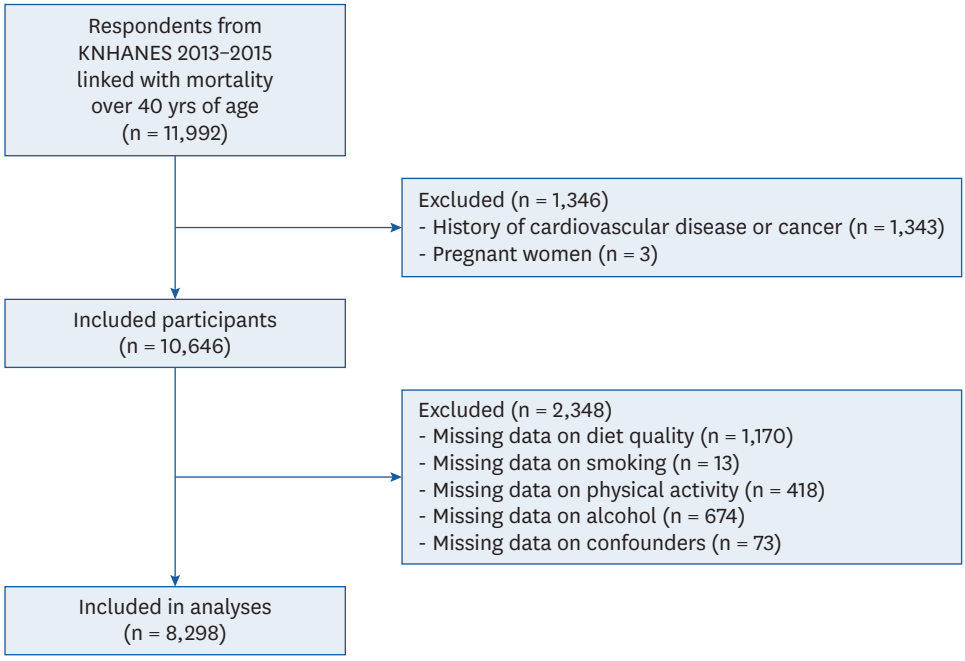

Fig. 1. Flow diagram of participants included in the analyses.
KNHANES, Korea National Health and Nutrition Examination Survey.

participants were available for analysis. Informed consent was obtained from all participants before their enrollment. The protocol for all KNHANES content was approved by the KDCA Institutional Review Board (IRB) (IRB number 2013-07CON-03-4C, 2013-12EXP-03-5C), and this study was approved by the IRB of Chonnam National University (IRB number 1040198-220613-HR-067-01).

Assessment of mortality

Vital status was obtained through linkage to the Cause of Death data obtained from Statistics Korea [34,36]. All-cause mortality was ascertained and tracked up to December 31, 2019.

High-risk behaviors

Participants were defined to have a high-risk lifestyle behavior if they met at least one of the following criteria: poor diet quality, current smoking, high-risk drinking, or insufficient physical activity. These four high-risk behaviors were selected as they are modifiable and have been prioritized in public health policy to achieve regional health equity [33,37] and to decrease the burden of disease [38]. Data on dietary intake were determined from a single, 24-h diet recall conducted by dietitians in the home of the participant 1 week after the health interview and health examination. Energy and nutrient intake were calculated based on the Korean Food Composition Database [39]. The KHEI, which was used to assess the overall diet quality, was developed based on the 2015 Dietary Reference Intakes for Koreans and validated [40-42]. The KHEI score ranges from 0 to 100 and consists of 14 subcomponents: eight adequacy components (breakfast consumption; mixed grain intake; total fruit intake; fresh fruit intake; total vegetable intake; vegetable intake excluding kimchi and pickles; meat, fish, egg and bean intake; and milk and dairy intake), three moderation components (saturated fatty acid-to-energy intake ratio, sodium intake, and ratio of energy intake from sugar and beverages), and three balance components (percentage energy intake from carbohydrates, percentage energy intake from fat, and appropriate energy intake). Higher

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KHEI scores indicate better diet quality. As there is no cutoff for 'poor diet quality' using the KHEI, the weighted KHEI scores for the study population were divided into tertiles as were in previous studies [43] and ensuring a sufficient number of deaths within groups, and scores within the lowest tertile (KHEI < 61.48) were considered as poor diet quality.

Other high-risk health behaviors (current smoking, high-risk drinking, and inadequate physical activity) were defined based on the leading indicators of healthy lifestyles in the 5th National Health Plan 2030 of Korea [33]. Data on smoking, drinking, and physical activity were collected through the health interview. High-risk drinking was defined as more than seven and five alcoholic drinks for males and females, respectively, in one setting more than twice a week during the previous year. Insufficient physical activity was defined as participating in less than 150 min of moderate-intensity aerobic physical activity (including walking), 75 min of vigorous-intensity aerobic physical activity, or some equivalent combination of moderate- and vigorous-intensity aerobic physical activity per week.

Covariates

Body mass index (BMI) was calculated using height and weight measured on a stadiometer (Seca 225; Seca, Hamburg, Germany) and weight scale (GL-6000-20; G-tech, Seoul, Korea), respectively. BMI was categorized into non-obese (BMI < 25.0 kg/m^2) or obese (BMI ≥ 25.0 kg/m^2). Information on age, sex, education level, household income status, and history of cardiovascular disease and cancer were collected during the health interview. Education level was categorized into two groups (middle school or below and high school or above). Household income level was assessed by comparing the equivalent median disposable income for each year, taking into account the number of family members, and divided into two groups (< 100% or ≥ 100%), as previously reported by Kim *et al.* [44].

Residential area

Residential areas were classified as urban or rural according to the administrative divisions of Korea, which consist of the Seoul metropolitan city, 6 metropolitan cities, and 9 '*Do*'s. The Seoul metropolitan city has only 'Self-Governing *Gu*'s, while the 6 metropolitan cities have 'Self-Governing *Gu*'s and sometimes additional '*Gun*'s as subdivisions. Urban areas were defined as the Seoul metropolitan city and only 'Self-Governing *Gu*'s of the 6 metropolitan cities; the remaining areas were defined as rural according to a previous report by Kim [45]. Among subdivisions of metropolitan cities, '*Gun*'s were not included in urban areas as they do not meet the criteria for 'Self-Governing *Gu*'s owing to related criteria, such as the low population (< 500,000) and financial status [46].

Statistical analysis

All analyses were performed in the total population and stratified by residential area. Participant characteristics were described as mean ± SE for continuous variables and frequency and weighted percentage for categorical variables. Differences were investigated according to the residential area using the Rao–Scott χ^2 test or independent *t*-test. Comparisons of KHEI were assessed using a one-way analysis of variance (ANOVA) and the Tukey–Kramer *post hoc* test. Cox proportional hazard models were used to calculate the hazard ratio (HR) and 95% confidence interval (CI) for the risk of mortality associated with individual or multiple unhealthy behaviors. The proportional hazards assumption was evaluated and confirmed using time-dependent interaction terms. Survival time (person-years) was calculated from the examined date to the date of death or December 31, 2019, whichever came first. All multivariable models were adjusted for the following potential

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confounding variables: age, sex, education level, household income status, and survey year. Further adjustment for BMI was performed in all multivariable models, as we potentially considered it a mediator rather than a confounder. For trend tests, *P*-values were calculated by treating ordinal score variables as continuous in models. Participants with two or more high-risk lifestyle behaviors were combined in the analyses due to the small number of deaths of these participants. Population attributable fraction (PAF) was calculated using the following formula provided by Miettinen [47] and Khosravi *et al.* [48], where P_c is the prevalence of multiple high-risk behaviors among deaths, and HR is the adjusted HR for all-cause mortality associated with multiple high-risk behaviors.

$$\text{PAF}\ (\%) = P_c\left(\frac{\text{HR}-1}{\text{HR}}\right)\times 100$$

The method based on Bonferroni inequality was used to calculate the 95% CI for PAF [49]. The effect modification analyses were reported according to previous recommendations [50,51]. Interaction on the additive scale was investigated by calculating the relative excess risk due to interaction (RERI), and the corresponding 95% CI was calculated based on the delta method [52]. RERI effects were considered significant when the 95% CI of RERI did not contain zero. Interaction on the multiplicative scale was evaluated as the ratio of HRs within the strata of residential areas, and the statistical significance of the product term was assessed. Sensitivity analyses were conducted by excluding deaths that occurred within the first year of follow-up to assess the influence of reverse causation. All analyses were computed using the PROC SURVEY of SAS version 9.4 (SAS Institute, Inc., Cary, NC, USA) according to the directions of the KNHANES procedure to account for the complex sampling design applied in KNHANES [53]. The value of $P < 0.05$ was considered statistically significant.

RESULTS

Participant characteristics

Among the 8,298 participants included in the study, 313 deaths (3.8%) occurred during the 44,551 person-years of follow-up (mean: 5.4 yrs; median: 5.4 yrs). Almost a quarter of the participants had 2 or more high-risk lifestyle behaviors, whereas 38.3% of the participants were free of these behaviors (**Table 1**). A higher proportion of participants living in rural areas were males, were living with obesity, had lower education status, had poor diet quality, were current smokers, had insufficient physical activity, and had multiple high-risk behaviors compared to those living in urban areas. Participants who were current smokers, high-risk drinkers, and/or had insufficient physical activity had lower mean KHEI scores than those who did not, regardless of residential area (**Supplementary Table 1**).

Association between each high-risk lifestyle behavior and mortality

The effects of each high-risk behavior on all-cause mortality were assessed after adjusting for socioeconomic status and the other three high-risk health behaviors (**Table 2**). Poor quality diet, current smoking, and insufficient physical activity were associated with an increased risk of mortality compared to those practicing healthy behaviors. When stratified by residential area, these tendencies persisted in those living in rural areas, especially for diet quality. For urban residents, only insufficient physical activity was associated with a higher risk of mortality (HR, 1.99; 95% CI, 1.27–3.11).

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Table 1. Participant characteristics of Korean adults 40 yrs and older according to residential area in KNHANES 2013–2015

Characteristics	Total (n = 8,298)	Urban (n = 3,558)	Rural (n = 4,740)	*P*-value
Men	47.8 (0.5)	46.2 (0.8)	49.0 (0.7)	0.009
Age (yrs)	55.1 ± 0.18	55.3 ± 0.25	54.9 ± 0.26	0.26
≥ 60	30.2 (0.7)	31.3 (1.1)	29.3 (1.0)	0.17
BMI (kg/m^2)	24.1 ± 0.04	24.0 ± 0.07	24.2 ± 0.06	0.02
≥ 25	35.2 (0.6)	33.8 (0.9)	36.4 (0.8)	0.04
Household income status ≥ 100%	41.8 (1.1)	42.3 (1.8)	41.3 (1.4)	0.64
Education status ≥ high school	63.2 (0.9)	65.6 (1.3)	61.3 (1.4)	0.02
KHEI score	65.9 ± 0.19	66.5 ± 0.29	65.3 ± 0.24	0.001
Poor diet quality	34.7 (0.7)	32.5 (1.0)	36.6 (0.9)	0.003
Current smoker	20.7 (0.6)	19.1 (0.8)	22.0 (0.8)	0.01
High-risk drinking	11.7 (0.5)	11.0 (0.7)	12.4 (0.6)	0.15
Insufficient physical activity	28.3 (0.7)	24.1 (1.0)	31.7 (0.9)	< 0.0001
Number of high-risk lifestyle behaviors	1.22 ± 0.01	1.13 ± 0.02	1.29 ± 0.02	< 0.0001
0	38.3 (0.7)	42.2 (1.0)	35.2 (0.9)	< 0.0001
1	35.6 (0.6)	35.3 (1.0)	35.9 (0.8)	
≥ 2	26.1 (0.6)	22.6 (0.9)	28.9 (0.9)	

Data are shown as % (SE) or mean ± SE with unweighted numbers for overall and subgroup sample sizes. All models accounted for the complex sampling design and weights of KNHANES. The total percentages may exceed 100% due to rounding. Household income level was evaluated by comparison with equivalent median income corresponding to each survey year.
KNHANES, Korea National Health and Nutrition Examination Survey; BMI, body mass index; KHEI, Korean Healthy Eating Index.

Table 2. Association between each high-risk behavior and risk of all-cause mortality in Korean adults aged 40 yrs and older by residence area in KNHANES 2013–2015 linked mortality data through 2019

High-risk behaviors	Total (n = 8,298)		Urban (n = 3,558)		Rural (n = 4,740)	
	HR (95% CI)	*P*-value	HR (95% CI)	*P*-value	HR (95% CI)	*P*-value
Poor diet quality[1)]	1.61 (1.21–2.15)	0.001	1.19 (0.72–1.96)	0.50	1.93 (1.37–2.71)	0.0002
Current smoker[2)]	1.67 (1.23–2.27)	0.001	1.63 (0.98–2.74)	0.06	1.66 (1.14–2.43)	0.008
High-risk drinking[3)]	0.75 (0.43–1.31)	0.31	1.01 (0.51–2.01)	0.97	N.A.	
Insufficient physical activity[4)]	1.69 (1.29–2.20)	0.0001	1.99 (1.27–3.11)	0.003	1.53 (1.11–2.11)	0.01

Data are presented with unweighted numbers for overall and subgroup sample sizes. All models accounted for the complex sampling design and weights of KNHANES and were adjusted for sex, age, household income, education level, survey year, and the three other high-risk health behaviors. The number of deaths in high-risk drinkers of rural areas was < 10 and inappropriate to analyze.
KNHANES, Korea National Health and Nutrition Examination Survey; HR, hazard ratio; CI, confidence interval; N.A., not applicable.
[1)]Sample sizes and deaths for exposed participants were 2,766 and 160 for total, 1,088 and 46 for urban, and 1,678 and 144 for rural participants, respectively.
[2)]Sample sizes and deaths for exposed participants were 1,355 and 79 for total, 545 and 31 for urban, and 810 and 48 for rural participants, respectively.
[3)]Sample sizes and deaths for exposed participants were 759 and 18 for total, 327 and 13 for urban, and 432 and N.A. for rural participants, respectively.
[4)]Sample sizes and deaths for exposed participants were 2,496 and 155 for total, 903 and 48 for urban, and 1,593 and 107 for rural participants, respectively.

Association between the number of high-risk lifestyle behaviors and mortality

The number of high-risk lifestyle behaviors was positively associated with all-cause mortality in older Korean adults, regardless of residential area (**Table 3**). Participants with two or more high-risk behaviors had a 153% higher risk of death (95% CI, 1.77–3.60) compared to those

Table 3. Association between the number of high-risk behaviors and risk of all-cause mortality by residential area in KNHANES 2013–2015 linked with mortality data through 2019

Number of high-risk behaviors	Total (n = 8,298)	Urban (n = 3,558)	Rural (n = 4,740)
0[1)]	1.00 (Reference)	1.00 (Reference)	1.00 (Reference)
1[2)]	1.37 (0.99–1.90)	1.34 (0.84–2.13)	1.39 (0.88–2.20)
≥ 2[3)]	2.53 (1.77–3.60)	2.07 (1.19–3.61)	2.80 (1.76–4.47)
P trend	< 0.0001	0.01	< 0.0001
PAF (95% CI)	25.5 (16.6–33.1)	18.5 (7.35–27.9)	29.8 (16.1–40.2)

Data are shown as HR (95% CI) with unweighted numbers for overall and subgroup sample sizes. All models accounted for the complex sampling design and weights of KNHANES and were adjusted for sex, age, income, education level, and survey year. High-risk lifestyle behaviors included poor diet quality, current smoking, high-risk drinking, and insufficient physical activity.
KNHANES, Korea National Health and Nutrition Examination Survey; HR, hazard ratio; CI, confidence interval; PAF, population attributable fraction.
[1)]Sample sizes and deaths for exposed participants were 3,353 and 72 for total, 1,594 and 34 for urban, and 1,759 and 38 for rural participants, respectively.
[2)]Sample sizes and deaths for exposed participants were 3,020 and 108 for total, 1,255 and 37 for urban, and 1,765 and 71 for rural participants, respectively.
[3)]Sample sizes and deaths for exposed participants were 1,925 and 133 for total, 709 and 41 for urban, and 1,216 and 92 for rural participants, respectively.

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Table 4. Modification effect of the region on mortality according to number of high-risk lifestyle behaviors in Korean adults aged 40 yrs and older in KNHANES 2013–2015 linked with mortality data through 2019 (n = 8,298)

Region	Number of high-risk behaviors		HR (95% CI) within strata of regional area
	≤ 1	≥ 2	
	HR (95% CI)	HR (95% CI)	
Urban[1] (n = 3,558)	1.00 (Reference)	1.93 (1.17–3.19)	1.77 (1.06–2.98)
		P = 0.01	*P* = 0.03
Rural[2] (n = 4,740)	1.15 (0.81–1.62)	2.54 (1.68–3.85)	2.31 (1.67–3.20)
	P = 0.44	*P* < 0.0001	*P* < 0.0001

Measure of effect modification on the additive scale: RERI (95% CI) = 0.46 (−0.57, 0.69).
Measure of effect modification on the multiplicative scale: ratio of HRs = 1.30; *P* = 0.64.
Data are presented with unweighted numbers for subgroup sample sizes. All models accounted for the complex sampling design and weights of KNHANES and were adjusted for sex, age, income, education level, and survey year. High-risk lifestyle behaviors included poor diet quality, current smoking, high-risk drinking, and insufficient physical activity. Data from KNHANES 2013–2015 linked with mortality were used.
KNHANES, Korea National Health and Nutrition Examination Survey; HR, hazard ratio; CI, confidence interval; RERI, relative excess risk due to interaction.
[1]Number of participants (deaths/survived): 71/ 2,778 with ≤ 1 high-risk behaviors and 41/668 with ≥ 2 high-risk behaviors.
[2]Number of participants (deaths/survived): 109/ 3,415 with ≤ 1 high-risk behaviors and 92/1,124 with ≥ 2 high-risk behaviors.

without high-risk lifestyle behaviors. When stratified by residential area, the HR of all-cause mortality in adults with 2 or more high-risk behaviors was 2.07 (95% CI, 1.19–3.61) in urban residents and 2.80 (95% CI, 1.76–4.47) in rural residents. The PAFs for mortality were 25.5% (95% CI, 16.6–33.1) in the total population and 18.5% (95% CI, 7.35–27.9) and 29.8% (95% CI, 16.1–40.2) in adults residing in urban and rural regions, respectively. The results were similar when further adjusted for BMI or after excluding participants who died within 1 yr of follow-up in both residential area types (**Supplementary Table 2**). Rural residents with more than one high-risk behavior had a 2.54 times (95% CI, 1.68–3.85) higher risk of mortality than urban residents with one or fewer high-risk behaviors (**Table 4**). However, no additive or multiplicative interaction between residential area and high-risk behaviors was observed in relation to risk of death (RERI, 0.46; 95% CI, −0.57 to 0.69; ratio of HRs, 1.30; *P* = 0.64).

DISCUSSION

This study assessed the effect of four high-risk lifestyle behaviors—poor diet quality, smoking, high-risk drinking, and inadequate physical activity—on all-cause mortality according to the region in a relatively small-sized industrialized country, Korea. Poor diet, smoking, and inadequate physical activity were independently associated with a higher risk of mortality in rural residents, whereas only inadequate physical activity was associated with a higher risk of mortality in urban residents. There is a strong positive association between the number of high-risk lifestyle behaviors and risk of mortality, with no additive or multiplicative effect of residential area.

In contrast to our expectations, residential area itself did not modify the effect of multiple high-risk lifestyle behaviors on mortality. Our results showing that multiple high-risk behaviors increase mortality risk in Koreans are consistent with previous studies, despite difference in race or ethnicity [14,15,54-57]. This is the first study to assess the effect of the region on this association. We acknowledge that the current study has a relatively short follow-up; thus, it is possible that regional disparities may appear with a longer follow-up as the magnitude of effects of cumulative high-risk behaviors on all-cause mortality was greater in residents living in rural areas than in urban areas. Still, the unexpected lack of effect of region on the risk of mortality may be due to the lower barriers to healthcare, such as relatively well-established transportation infrastructure and universal health insurance in Korea [29,30]. Despite the imbalance in unmet medical needs [31,32], this may not result in

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differences in mortality. Assessing the relationship between health behaviors and morbidity by region may help distinguish the effect of access to or quality of medical care or other regional characteristics that may affect mortality; however, the currently available data does not have follow-up on disease onset. Nonetheless, according to the PAF calculation, a quarter of deaths and an additional 10% reduction in regional inequalities in mortality are expected if those with multiple high-risk behaviors improve their health-related lifestyle behaviors by reducing the number of their high-risk behaviors to less than two. Together, our results support engaging in healthy behaviors regarding diet, smoking, drinking, and physical activity in order to reduce the risk of not only preventable deaths but also regional health inequality. Therefore, at the societal level, the provision of policies and infrastructure to support health behavior change, especially in adults with multiple high-risk behaviors, is necessary. Residents of rural areas have a greater risk of mortality than those living in urban regions, possibly due to worse health-related lifestyles rather than other environmental factors unrelated to these health behaviors.

Despite the similar risk of mortality between urban and rural residents when multiple behaviors were assessed, the association between mortality risk and diet quality was only observed in rural residents. Poor diet quality alone was associated with a higher risk of mortality in Koreans in previous studies [21-23], despite Asians having a relatively higher diet quality than other ethnic groups [58-60]. The discrepancy in the association of diet with mortality between regions may be due to the variation in the individual components measuring diet quality among regions. Rural residents in Korea have a lower diet quality characterized by lower intakes of mixed grains, fruits, vegetables (excluding kimchi and pickled vegetables), high-protein foods (meat, eggs, fish, and beans), and dairy and higher intakes of carbohydrates than urban residents [23,61,62]. Therefore, greater mixed grains, fruits, vegetables, protein, and dairy intake may decrease the risk of mortality in rural areas [63]. As no difference between urban and rural areas is observed regarding food security [61,62], the provision of policies that aim to change meal-related habits in rural residents may be necessary. Conversely, urban residents have lower scores on the breakfast intake component of the KHEI compared to rural-dwelling residents [61,62]. The number of meals or timing between meals has become a topic of interest but may not be strongly associated with mortality, especially in healthy adults [64]. In addition, our results in urban residents are in line with a previous study in males residing in Seoul [25], where diet as a single factor was not associated with mortality. Improving awareness and providing assistance to plan and prepare balanced meals, especially in adults dwelling in rural areas, may increase diet quality and decrease regional disparities regarding premature mortality [4-6].

On the other hand, smoking, high-risk drinking, and inadequate physical activity individually tended to have a similar relationship with mortality regardless of region. The weaker association between smoking and mortality in urban residents may be attributable to differences in the duration of smoking or the number of cigarettes smoked between urban and rural smokers. Although this has not been separately examined, smoke-free policies are implemented in indoor and outdoor public facilities and transportation are at higher density in urban areas [65,66], whereas, in rural areas, it is easier to find open-air spaces to smoke cigarettes. Regarding high-risk drinking, its lack of association with mortality may be due to the low number of participants and deaths of those who pursued this behavior. Insufficient physical activity was associated with a higher risk of mortality in both urban and rural residents, similar to previous studies [67,68]. Although some individual factors lacked statistically significant associations with mortality, the cumulative health effect may become

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manifest in the analyses of multiple risk behaviors. Previous studies have shown that the effect of smoking, drinking, physical activity, and diet on mortality can be potentially additive [14,69-72]. The effect of health-related behaviors as an independent factor on all-cause mortality may be underestimated, especially in those with two or more high-risk behaviors. A comprehensive approach to improve lifestyle behaviors, especially in those with more than one high-risk lifestyle behavior, is needed, regardless of residential area.

Several limitations in our study should be acknowledged. First, our findings are restricted to a relatively short follow-up period, resulting in an inadequate number of deaths to analyze according to the cause of death. Second, only a few participants had three or four high-risk lifestyle behaviors. Therefore, we had to combine those who had two or more high-risk lifestyle behaviors into one category and were unable to examine a possible dose–response relationship according to the number of high-risk behaviors. Third, we did not assess some potential risk behaviors known to be associated with mortality, such as sleep duration. A previous study showed that insufficient or prolonged sleep time is associated with other risk factors and higher risk of mortality in Koreans [26]. However, when adding sleep as a health behavior, too few participants and only a very small number of deaths occurred in those that adhered to all healthy lifestyle behaviors. Fourth, reverse causality may have affected our results, although we excluded those with a history of cardiovascular disease or cancer. Excluding deaths occurring within 1 yr of follow-up, did not change the main results. Finally, residual confounding factors related to insufficient information may have modified the relationship. All 4 health behaviors were self-reported at baseline only. Although we adjusted for confounding factors in all models, these approaches may not fully address unmeasured confounding factors. Furthermore, repeated measures diet, physical activity, smoking status, and alcohol consumption, would increase the explanatory power by reflecting possible changes during the follow-up period [73]. However, the KNHANES data does not currently have follow-up data. Despite these limitations, our study is the first to analyze the relationship between multiple health-related lifestyle behaviors and mortality and assess the effect of region on this association using nationally representative data in a centralized developed nation.

This is the first study to examine the effect of multiple health-related lifestyle factors on all-cause mortality according to the residential area in Korean older adults. The higher prevalence of multiple high-risk lifestyle behaviors in rural residents may explain the higher rate of mortality in this region compared to urban areas. Regional disparities in mortality may be prevented by improving health-related behaviors in rural areas of Korea. Our study strongly supports adherence to current health guidelines and dietary recommendations, especially among rural residents, to mitigate regional health inequity.

SUPPLEMENTARY MATERIALS

Supplementary Table 1

Mean KHEI score for each high-risk lifestyle behavior and number of high-risk lifestyle behaviors according to residential area among Korean adults aged 40 yrs and older in KNHANES 2013–2015 (n = 8,298)

Supplementary Table 2

High-risk behaviors and risk of mortality excluding participants that died within 1 yr of follow-up area in KNHANES 2013–2015 linked with mortality data through 2019 (n = 8,269)

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