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Original Article

Association between perceived environmental pollution and poor sleep quality: results from nationwide general population sample of 162,797 people

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ABSTRACT

Objective/Background: Perceived environmental pollution may play a significant role in understanding environmentally induced health-related symptoms. This study aimed to determine whether perceived environmental pollution is associated with poor sleep quality.
Methods: We conducted a cross-sectional study using data from a nationwide sample of 162,797 individuals aged ≥19 years from the 2018 Korea Community Health Survey. The Pittsburgh Sleep Quality Index was used for assessing sleep quality. Five types of perceived environmental pollutants involving air, water, soil, noise, and green space were assessed. We investigate the association between perceived environmental pollution and poor sleep quality. We also investigated whether an increasing number of perceived environmental pollutants magnified the odds of poor sleep quality.
Results: The prevalence of poor sleep quality was 42.7% ($n = 69{,}554$), and 15.6%, 10.1%, 11.9%, 23.0%, and 11.5% reported perceived environmental pollution concerning air, water, soil, noise, and green space, respectively. A perception of air, soil, or noise pollution was significantly associated with poor sleep quality. In addition, those perceiving a greater number of environmental pollutants had significantly higher odds of poor sleep quality. Notably, this association was magnified in individuals living in rural areas.
Conclusions: Perceived environmental pollution was significantly associated with poor sleep quality. Our results suggest that a more comprehensive exposure to environmental pollution may not only have a worse effect on health outcomes including sleep quality.

1. Introduction

Global environmental pollution due to human activity, such as air, water, soil, or chemical pollution, is rapidly rising at an alarming rate and is expected to involve major challenges for humanity. In particular, direct and negative effects on human health due to environmental pollution will entail growing health and financial burdens on all peoples [1]. A large number of studies, which have mainly focused on air pollution, have sought to clarify the clinical consequences of environmental pollution. For example, air pollution has been shown to be associated with negative effects on lung function [2], cardiovascular health [3], diabetes [4], cognitive functioning [5], and neurodegenerative disease [6]. As various types of environmental pollution become associated with a wider range of negative health outcomes, emerging studies have focused on the sleep quality as a negative health outcome. A few studies focusing on air pollution [7] as well as lower green space coverage and nighttime noise exposure [8,9] suggested that these types of pollution are associated with poor sleep quality.

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Recently, apart from measured pollution, perceived pollution has also received much attention and discussion. Given the complex interplay between measured pollution, perceived pollution and health risks, and experienced symptoms, the subjective perceptions of pollution play a significant role in understanding environmentally induced health-related symptoms [10,11]. For example, people's perception that negative health effects may be provoked on exposure can itself contribute to environmentally induced health-related symptoms, regardless of the actual exposure and hazard [12,13]. Other studies have suggested that perceived pollution may play a significant role in the understanding of pollution as well as more accurate predictions of environmentally induced symptom experiences [14,15]. Recent studies regarding pollution perception have suggested that perceived pollution indicators were associated with poorer mental health and sleep disturbance [10,15,16].

Meanwhile, perceptions of environmental pollution depend on possible explanatory factors that are not related to the objective level of pollution [17]. For example, lower socioeconomic groups are more likely to live in disadvantaged housing conditions, and their deprived lifestyles in addition to their increased vulnerability of exposure may contribute to poorer health [18]. Hence, living conditions should be appropriately considered in self-reported pollution [19,20].

Given this context, this study aimed to examine the association between perceived pollution and sleep quality. Specifically, it sought to consider perceived pollution in relation to air, water, soil, noise, and green space. In addition, this study examined whether perceiving a greater number of pollutants corresponded to poor sleep quality. Additionally, subgroup analysis was carried out to evaluate possible associations between the number of perceived environmental pollutants and poor sleep quality as stratified according to area of residence. It is likely that there will be enhanced understanding of relevant health-related issues in the general population resulting from this study, especially given the large sample size used.

2. Methods

2.1. Data and study population

For this study, we used raw data from the 2018 Korea Community Health Survey (KCHS), conducted by the Korea Centers for Disease Control and Prevention. The KCHS is a cross-sectional survey, with a study population drawn from multistage, stratified area probability samples of civilian, non-institutionalized Korean households categorized according to geographic area, age, and sex. The survey is conducted annually, and it collects information through in-person (one-on-one) interviews using the computer-assisted personal interview (CAPI) method. Because the population sample is extracted from national survey data, samples are considered as representative of the Korean population [21].

This study included individuals aged ≥19 years. From an initial total of 228,340 potential participants, respondents without data on the relevant variables were excluded from the study, leaving a total of 162,797 participants eligible for inclusion in the present study (see details in Fig. 1).

2.2. Measures

2.2.1. Sleep quality

Sleep quality was measured using a 19-item self-reported Pittsburgh Sleep Quality Index (PSQI) questionnaire to measure the quality and patterns of sleep over a 1-month duration. The PSQI has been widely used in general population-based epidemiological studies. It consists of 19 items and 7 sleep components: subjective sleep quality, sleep latency, sleep duration, sleep efficiency, sleep disturbances, use of sleep medication, and daytime dysfunction. Each component is scored on a scale of 0–3. A global score of overall sleep quality can be calculated through adding these components, yielding scores ranging from 0 to 21. Considering that PSQI global scores >5 are generally used to indicate poor sleep, those individuals with a PSQI global score of >5 were classified as having poor sleep quality. The Korean version of the PSQI has shown high sensitivity and specificity, and has been validated previously [22,23].

2.2.2. Perceived environmental pollution

Five types of perceived environmental pollution, including air, water, soil, noise, and green space, were assessed using one question: “How would you rate the quality of the environment of the community in which you live?” Responses were provided on a five-point scale (“excellent,” “good,” “fair,” “poor,” and “bad”). The responses were then grouped as “Good” (i.e., “excellent,” “good,” and “fair”) or “Bad” (i.e., “poor” and “bad”). Furthermore, the respondents were provided the following additional explanation to help inform their responses: “air pollution is pollution due to factory soot, dust, sulfur dioxide (SO_2), or carbon monoxide (CO); water pollution is the pollution of water intended for drinking, or the pollution of rivers and the sea by factory wastewater or domestic sewage; soil pollution is pollution caused by litter, industrial wastes, or factory waste; noise pollution is pollution caused by automobiles, aircraft, subways, markets, or entertainment areas; and green space pollution refers to the satisfaction observed in surrounding green spaces such as parks or the trees along streets.” We calculated the number of perceived environmental pollutants from the sum of the five types of perceived environmental pollutants and grouped the number of perceived environmental pollutants as 0, 1, 2, or ≥ 3. For example, if participants responded with “good” to all five types of environmental pollution, they were placed into the “0” group; if participants responded with “bad” to more than three types of environmental pollution, they were grouped into the “≥ 3” group. Higher values indicated that more types of environmental pollution had been perceived.

Each type of perceived pollution was represented by a single item rather than an index; thus, this single item did not include detailed information on each type of perceived pollution. However, based on the evidence suggesting that the worry and stress evoked by perceptions of certain exposures being hazardous (regardless of whether they are actually hazardous) leads to health symptoms, perceived pollution has been successfully utilized in previous population-based studies [14,15,24,25]. In addition, taking into account that objectively measuring the diverse types of environmental pollution affecting the general population nationwide is very difficult, perceived pollution is easier to use in large population groups, such as with a nationwide survey, because of its simplicity. Thus, evaluating perceived pollution may detect vulnerable populations affected by the health impacts of pollution.

2.2.3. Covariates

The following variables were used in our analysis: age (19–29 years, 30–39 years, 40–49 years, 50–59 years, 60–69 years, ≥ 70 years), sex (male, female), education (uneducated, elementary school, middle school, high school, college and over), income (low, middle low, middle high, high), marital status (married, divorced/widowed/separated, never married), job classification (white-, pink-, or blue-collar, or unemployed), living arrangements (one, two, or three generations in the one household), and subjective health status (good, bad). Area of residence was divided into stratified variable in KCHS so we used it as indicated in KCHS, which was not self-reported, and classified as urban (administrative

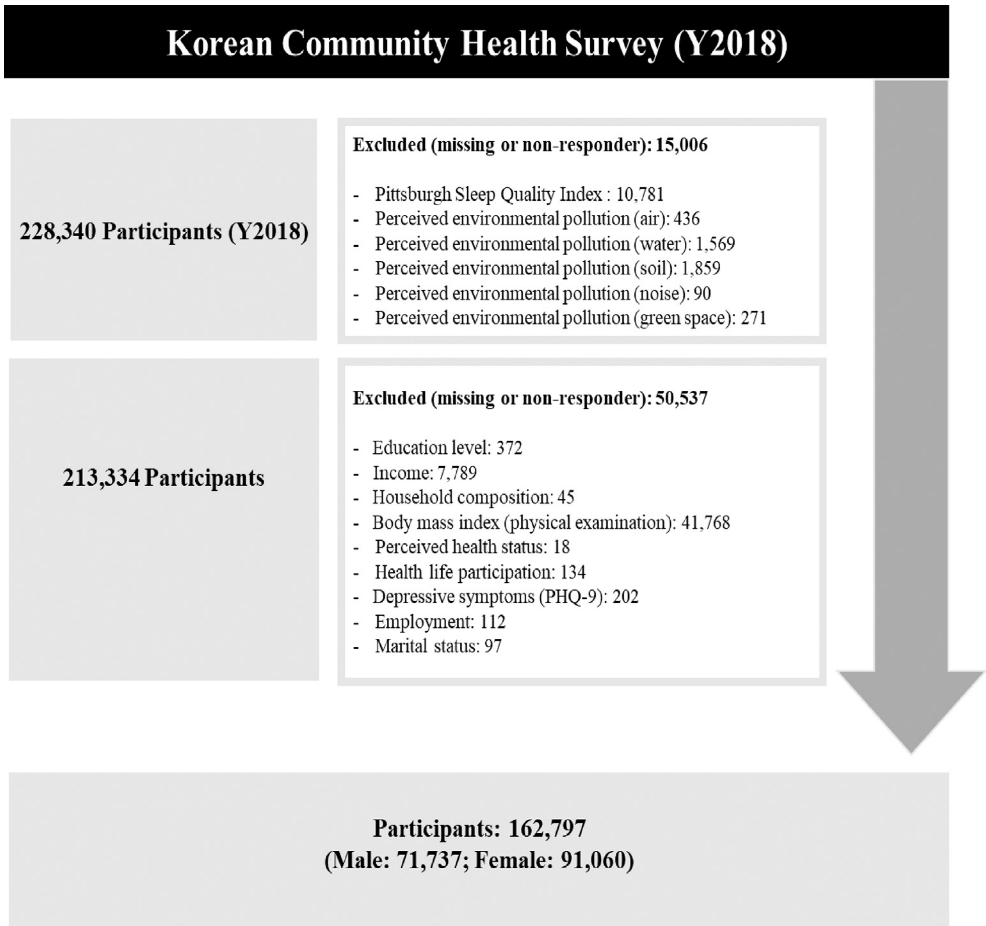

Fig. 1. Flow-chart of study participants selection process.

division of city) and rural (areas not classified as administrative division of a city) based on the administrative district. Regarding how living a healthy life was assessed, those who did not smoke and who did not engage in high-risk drinking, and those who had walked more than 30 min per day for more than 5 days in the last week were classified as “Yes”, indicating a healthy life style. High-risk drinking was defined as drinking >60 g of pure alcohol per occasion for men and >40 g of pure alcohol per occasion for women, more often than two occasions per week. Depressive symptoms were measured using the patient health questionnaire (PHQ)-9 that has been widely used in population-based studies [26]. The presence of depressive symptoms was indicated by a score of $\geq$10. In addition, body mass index (BMI) was calculated through measuring height and weight directly, and not through self-reported information.

2.3. Statistical analyses

We first examined the distribution of each categorical variable. A chi-squared test was used to identify significant differences between groups. Next, a multivariable logistic regression analysis was used to investigate the association between perceived environmental pollution and poor sleep quality while controlling for potential confounding variables such as age, sex, education level, income, household composition, BMI, healthy life participation, depressive symptoms, employment status, marital status, and area of residence. We also investigated whether increasing numbers of perceived environment pollutants magnified the odds of poor sleep quality. In addition, to consider the substantial effect of an individual's area of residence, we also investigated the association between the number of perceived environmental pollutants and poor sleep quality through introducing an interaction terms into the models. Then, subgroup analysis was performed between the number of perceived environmental pollutants and poor sleep quality as stratified according to area of residence. In addition, multi-collinearity was tested using a variance inflation factor, which provided an index of the degree to which the variance of an estimated regression coefficient increased due to collinearity. All analyses were performed using SAS 9.4 (SAS Institute, Cary, NC, USA). P-values were two-sided and considered significant at $p < 0.05$.

2.4. Ethical approval

The Korea Community Health Survey (KCHS) data are openly published. Participants' data were fully anonymized prior to release. Our study was excluded from the review list pursuant to Article 2.2 of the Enforcement Rule of Bioethics and Safety Act in Korea, since the data was exempted from IRB review.

All procedures performed in studies involving human participants were in accordance with the ethical standards of the national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Table 1
General characteristics of the study population.

Variables	Total		Poor Sleep Quality (PSQI > 5)				P-value
			Yes		No		
	N	%	N	%	N	%	
Perceived air pollution							<0.001
Good	137,414	84.4	57,575	41.9	79,839	58.1	
Bad	25,383	15.6	11,979	47.2	13,404	52.8	
Perceived water pollution							<0.001
Good	146,308	89.9	61,696	42.2	84,612	57.8	
Bad	16,489	10.1	7858	47.7	8631	52.3	
Perceived soil pollution							<0.001
Good	143,374	88.1	59,932	41.8	83,442	58.2	
Bad	19,423	11.9	9622	49.5	9801	50.5	
Perceived noise pollution							<0.001
Good	125,439	77.1	51,791	41.3	73,648	58.7	
Bad	37,358	23.0	17,763	47.6	19,595	52.5	
Perceived green space pollution							<0.001
Good	144,147	88.5	60,664	42.1	83,483	57.9	
Bad	18,650	11.5	8890	47.7	9760	52.3	
Number of types of perceived pollution							<0.001
0	102,097	62.7	41,075	40.2	61,022	59.8	
1	30,616	18.8	13,835	45.2	16,781	54.8	
2	14,806	9.1	7098	47.9	7708	52.1	
3+	15,278	9.4	7546	49.4	7732	50.6	
Age							<0.001
19–29	16,008	9.8	5662	35.4	10,346	64.6	
30–39	19,059	11.7	7301	38.3	11,758	61.7	
40–49	24,961	15.3	9111	36.5	15,850	63.5	
50–59	31,138	19.1	12,729	40.9	18,409	59.1	
60–69	31,491	19.3	13,952	44.3	17,539	55.7	
70+	40,140	24.7	20,799	51.8	19,341	48.2	
Sex							<0.001
Male	71,737	44.1	25,923	36.1	45,814	63.9	
Female	91,060	55.9	43,631	47.9	47,429	52.1	
Education							<0.001
Uneducated	18,971	11.7	10,887	57.4	8084	42.6	
Elementary school	27,423	16.8	13,628	49.7	13,795	50.3	
Middle school	18,348	11.3	8313	45.3	10,035	54.7	
High school	51,879	31.9	20,147	38.8	31,732	61.2	
College and over	46,176	28.4	16,579	35.9	29,597	64.1	
Income							<0.001
Low	43,681	26.8	23,145	53.0	20,536	47.0	
Middle low	36,844	22.6	15,807	42.9	21,037	57.1	
Middle high	40,688	25.0	15,608	38.4	25,080	61.6	
High	41,584	25.5	14,994	36.1	26,590	63.9	
Household composition							<0.001
Living alone, or Couple	80,682	49.6	37,034	45.9	43,648	54.1	
Couple with children	70,989	43.6	27,867	39.3	43,122	60.7	
More	11,126	6.8	4653	41.8	6473	58.2	
Objectively measured body mass index							<0.001
BMI < 18.5	6969	4.3	3161	45.4	3808	54.6	
18.5 ≤ BMI < 25.0	99,092	60.9	41,565	42.0	57,527	58.1	
25.0 ≤ BMI < 50.0	56,736	34.9	24,828	43.8	31,908	56.2	
Subjective health status							<0.001
Good	56,063	34.4	16,649	29.7	39,414	70.3	
Bad	106,734	65.6	52,905	49.6	53,829	50.4	
Participation in healthy life							<0.001
No	106,922	65.7	46,476	43.5	60,446	56.5	
Yes	55,875	34.3	23,078	41.3	32,797	58.7	
Depressive symptoms (PHQ-9)							<0.001
No (PHQ9 score 0–9)	156,565	96.2	63,993	40.9	92,572	59.1	
Yes (PHQ9 score ≥ 10)	6232	3.8	5561	89.2	671	10.8	
Job classification							<0.001
White	29,176	17.9	10,259	35.2	18,917	64.8	
Fink	19,289	11.9	7661	39.7	11,628	60.3	
Blue	50,785	31.2	20,481	40.3	30,304	59.7	
Unemployed	63,547	39.0	31,153	49.0	32,394	51.0	
Marital status							<0.001
Married	109,340	67.2	44,380	40.6	64,960	59.4	
Divorce, widowed, or separated	30,308	18.6	16,660	55.0	13,648	45.0	
Unmarried	23,149	14.2	8514	36.8	14,635	63.2	
Area of residence							<0.001
Urban	89,066	54.7	37,783	42.4	51,283	57.6	
Rural	73,731	45.3	31,771	43.1	41,960	56.9	
Total	162,797	100.0	69,554	42.7	93,243	57.3	

3. Results

After excluding cases with missing data, a total of 162,797 participants were included in the present study. Table 1 shows the characteristics of the study population. Of 162,797 participants, the prevalence of poor sleep quality was found to be 42.7% ($n = 69,554$). Among the study population, 15.6%, 10.1%, 11.9%, 23.0%, and 11.5% of participants reported having perceived environmental pollution concerning air, water, soil, noise, and green space, respectively, with those having perceived environmental pollution more likely to have poor sleep quality. Additional general characteristics regarding perceived environmental pollution according to area of residence are shown in Supplementary Table S1.

Table 2 shows the results of the multivariable logistic regression analysis of the association between perceived environmental pollution and poor sleep quality. A perception of air, soil, or noise pollution was significantly associated with poor sleep quality. The individuals who reported perceived air pollution had significantly higher odds of poor sleep quality compared with those who did not report perceived air pollution (odds ratio (OR) = 1.10, 95% confidence interval (CI) 1.06–1.15). In addition, those individuals reporting perceived soil or noise pollution also had significantly higher odds of poor sleep quality (perceived soil pollution: OR = 1.17, 95% CI 1.11–1.23; perceived noise pollution: OR = 1.20, 95% CI 1.15–1.24).

Fig. 2 shows the results of the multivariable logistic regression analysis of the association of the number of perceived pollutants with poor sleep quality. Those individuals who reported a greater number of perceived environmental pollutants (3 or more) had significantly higher odds of poor sleep quality compared to those who did not report any perceived environmental pollution (number of perceived environmental pollutants ≥ 3: OR = 1.45, 95% CI 1.38–1.52; 2: OR = 1.39, 95% CI 1.33–1.46; 1: OR = 1.29, 95% CI 1.25–1.34; 0: reference category; p for trend = $p < 0.001$).

The subgroup analysis results are shown in Fig. 3. As the interaction test proved to be statistically significant, a subgroup analysis was performed between the number of perceived environmental pollutants and poor sleep quality as stratified according to area of residence (p for interaction, $p = 0.002$). Those individual reporting a greater number of perceived environmental pollutants (3 or more) and who lived in rural areas had significantly higher odds of poor sleep quality compared to those not reporting perceived any environmental pollutions and who lived in rural areas (number of perceived environmental pollutants ≥ 3: OR = 1.60, 95% CI 1.43–1.78). In urban areas, a similar trend was observed (number of perceived environmental pollutants ≥ 3: OR = 1.43, 95% CI 1.36–1.51).

After all the analyses were performed, additional analysis including the missing values was performed to confirm the robustness of the findings. A similar trend was observed (Supplementary Tables S2, S3, and S4).

4. Discussion

Although there have been extensive studies on the health effects of environmental pollution, these have mainly focused on air pollution, with little research conducted on poor sleep quality in relation to perceived environmental pollution. This nationwide population-based study using a large sample size is, to the best of our knowledge, the first to examine the association between perceived environmental pollution and poor sleep quality. There are three main findings. First, perceived environmental pollution involving air, soil, and noise pollution was associated with poor sleep quality. Second, those individuals who reported a greater number of perceived environmental pollutants (3 or more) had significantly higher odds of poor sleep quality compared to those who did not report any perceived environmental pollution. Third, it was notably the case that the demonstrated association between a greater number of perceived environmental pollutants (3 or more) and higher odds of poor sleep quality in individuals living in rural areas.

The results of this study were consistent with some studies reporting that environmental pollutants were associated with poorer quality sleep health. A longitudinal analysis involving adults in the United States reported that people exposed to higher ambient air pollution ($PM_{2.5}$) had greater odds of having sleep apnea [27]. In addition, a cross-sectional study involving children in China also reported that exposure to ambient air pollution was associated with increased odds of sleep disorders and sleep-disorder symptoms [28]. A study using Bayesian modeling revealed that perceived pollution exposure to multiple noise sources is linked to self-reported mental health, including sleep disturbance [29]. With respect to noise pollution, one study has reported that it plays an important role in causing annoyance, mood changes, and decreased well-being [30]. Other previous studies have suggested that noise-related annoyance is a better marker of stress-related noise impacts and is an important mediating factor for subjective sleep complaints in relation to noise [31,32]. In particular, nocturnal noise pollution has been shown to clearly cause fragmented sleep and, as a consequence, negatively affect sleep architecture as well as sleep quality [33]. As another type of environmental pollution, previous study suggested that neighborhood green space could attenuate the adverse effects of perceived stress on sleep quality [8]. Meanwhile, the findings of a study considering many types of environmental pollutants suggested that the number of co-occurring perceived environmental pollution, including air, noise, and water pollution, could contribute to a deteriorating quality of life [34].

The association between environmental pollution with sleep health remains unclear, although several studies have offered potential explanations. Concerning air pollution, PM comes into direct contact with the skin and respiratory or throat mucosa, causing oxidative damage, or inflammatory damage [35], which may contribute to sleep disturbances through causing sleep apnea or airway obstruction during sleep. One study reported that higher exposure levels to air pollution influenced breathing during sleep, and suggested that environmental factors may also contribute to the variation in sleep disorders [27]. In accordance with that finding, the participants in this study who experienced perceived air pollution tended more often to report poor sleep quality. Meanwhile, attempts have been made to investigate the effects of noise pollution and soil contamination on health outcomes, but the mechanisms involved remain unclear [36,37]. Further studies on the association between poor sleep quality and air or soil pollution are needed.

Other studies have suggested that perceived levels of environmental pollution play a key role in self-rated health [14,15,25]. One mechanism proposed to explain this role is that the mere perception of pollution, regardless of the direct health effects induced by exposure, may cause health-related symptoms as a protective mechanism. For example, if an encountered source were to be perceived as unpleasant, it would likely have a negative effect on health through arousing annoyance, stress, and worry as protective mechanisms [38]. Hence, perceiving environmental pollutants as unpleasant may be considered to cause psychological stress, which might in turn generate negative health-related symptoms including poor sleep quality. Meanwhile, induced stress may have a role in sleep problems. A recent study involving a representative sample of the German population reported that air pollution affects chronic stress levels [39]. Recent experimental evidence has shown

Table 2
Results of the multivariable logistic regression analysis of the association between perceived environmental pollution and poor sleep quality.

Variables	Poor Sleep Quality (PSQI > 5)			
	Adjusted-OR*	95% CI		
Perceived air pollution				
Good	1.00		–	
Bad	1.10	1.06	–	1.15
Perceived water pollution				
Good	1.00		–	
Bad	1.04	0.99	–	1.10
Perceived soil pollution				
Good	1.00		–	
Bad	1.17	1.11	–	1.23
Perceived noise pollution				
Good	1.00		–	
Bad	1.20	1.15	–	1.24
Perceived green space pollution				
Good	1.00		–	
Bad	0.99	0.95	–	1.04
Age				
19–29	1.00		–	
30–39	1.14	1.07	–	1.21
40–49	1.03	0.96	–	1.10
50–59	1.11	1.04	–	1.20
60–69	1.05	0.98	–	1.14
70+	1.10	1.01	–	1.20
Sex				
Male	1.00		–	
Female	1.35	1.31	–	1.39
Education				
Uneducated	1.00		–	
Elementary school	0.92	0.87	–	0.97
Middle school	0.88	0.83	–	0.94
High school	0.74	0.69	–	0.78
College and over	0.69	0.64	–	0.74
Income				
Low	1.00		–	
Middle low	0.90	0.86	–	0.94
Middle high	0.81	0.77	–	0.85
High	0.80	0.76	–	0.85
Household composition				
Living alone, or Couple	1.00		–	
Couple with children	0.99	0.96	–	1.03
More	1.05	0.99	–	1.12
Objectively measured body mass index				
18.5 ≤ BMI < 25.0	1.00		–	
BMI < 18.5	1.00	0.94	–	1.07
25.0 ≤ BMI < 50.0	1.06	1.03	–	1.10
Subjective health status				
Good	1.00		–	
Bad	1.93	1.87	–	1.99
Participation in healthy life				
No	1.00		–	
Yes	0.87	0.85	–	0.90
Depressive symptoms (PHQ-9)				
No (PHQ9 score 0–9)	1.00		–	
Yes (PHQ9 score ≥ 10)	9.47	8.43	–	10.63
Job classification				
White	1.00		–	
Fink	0.98	0.93	–	1.03
Blue	1.00	0.95	–	1.04
Unemployed	1.08	1.03	–	1.13
Marital status				
Married	1.00		–	
Divorce, widowed, or separated	1.21	1.16	–	1.26
Unmarried	1.04	0.99	–	1.10
Area of residence				
Urban	1.00		–	
Rural	0.92	0.89	–	0.96

Notes: *Adjusted odds ratios were calculated using logistic regression analysis and adjusted for perceived air pollution, perceived water pollution, perceived soil pollution, perceived noise pollution, perceived green space pollution, age, sex, education, income, household composition, objectively measured body mass index, subjective health status, participation in healthy life, depressive symptoms, job classification, marital status, and area of residence.

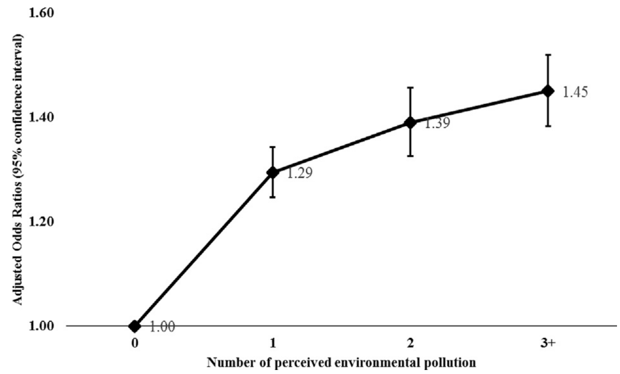

Fig. 2. The results of the multivariable logistic regression analysis of the association of number of perceived pollution with poor sleep quality. Notes: *Adjusted odds ratios were calculated using logistic regression analysis and adjusted for age, sex, education, income, household composition, objectively measured body mass index, subjective health status, participation in healthy life, depressive symptoms, job classification, marital status, and area of residence.

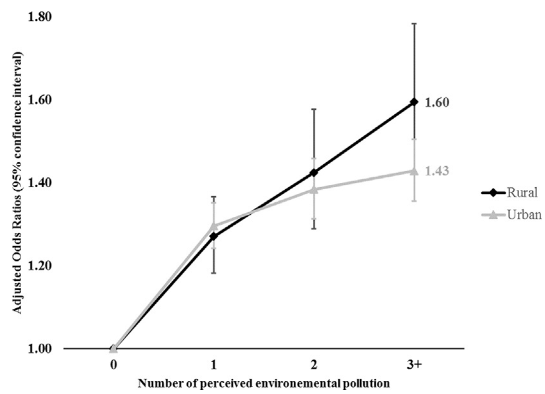

Fig. 3. The results of the multivariable logistic regression analysis of the association of number of perceived pollution with poor sleep quality by area of residence. Notes: *Adjusted odds ratios were calculated using logistic regression analysis and adjusted for age, sex, education, income, household composition, objectively measured body mass index, subjective health status, participation in healthy life, depressive symptoms, job classification, and marital status.

that noise pollution contributes to severe discomfort and stress [40]. Given that sensitivity of the sleep system related to cognitive and emotional processes, uncomfortable emotions evoked by prolonged stress may affects sensitive sleep systems thereby augmenting the sleep problems [41].

Based on the results of our subgroup analysis, we also found that the association between a greater number of perceived environmental pollutants and higher odds of poor sleep quality was more pronounced in those individuals living in rural areas. Previous studies have reported that individuals living in rural areas are more likely to report poor sleep quality compared to individuals living in urban areas [42,43]. Several studies have offered potential explanations for this finding. It has been suggested that neighborhood factors, including living in poorer communities, also contribute to the variations in sleep disturbances, possibly contributing to health outcome disparities. Disadvantaged neighborhoods comprising residents living at a poorer socio-economic level tend to be exposed to a greater burden of air pollution including greater psychosocial stressors [27,44,45]. In addition, a suggested mechanism to explain the greater likelihood of sleep disturbances in this context may be to do with the potential capacity to cope with risk related to one's physical or psychological well-being. It has been reported that where a person faced stressful circumstances and that person perceived that their coping capacity was not adequate for tackling their situation in an adaptive way, the resulting psychological stress might exacerbate health-related symptoms or cause anxiety and fear [46]. Hence, for people living in rural areas where their ability to cope with a deteriorating environment involving a greater number of environmental pollutants is relatively limited, the effects of their limited agency may manifest in poorer sleep quality through exposure to more psychological stress.

This study has some strengths compared to previous studies. We used a nationwide general population sample, which is likely to enhance the value of our results in relation to research on environmental health. However, there were some limitations. First, using objective methods of measuring sleep quality would have been ideal; however, we had no choice but to measure self-reported sleep quality based on interviews. Objectively measuring the quality of sleep for the general population nationwide has never been attempted and is very difficult. Second, as this study was cross-sectional in design, causal inferences cannot be made on the relationship between perceived environmental pollution and sleep quality. Third, the actual level of environmental pollution could not be assessed owing to limitations in available data. Thus, it was not possible to identify whether objectively measured environmental pollution was also associated with sleep quality. For the same reason, we were also unable to identify the concentrations and amounts of environmental pollutants. In addition, we focused on five types of perceived environmental pollution (air, water, soil, noise, and green space) since data related to other dimensions of pollution were not available. Fourth, this study analyzed the perceptions of environmental pollutants through a one-time measurement. Thus, participants may have responded based on external environmental factors such as the season at the time of the survey rather than the overall pollution level in their area of residence. For example, air pollutants are especially higher during spring and winter than during summer in Korea [47]. Hence, the respondents' responses could have resulted in an underestimation of the perception of environmental pollution. In addition, the duration for which participants had been exposed to pollution could not be determined. Future studies that consider comprehensive sources of environmental pollution may offer further insights. Our findings should be considered with caution and should be further verified in future studies with various designs.

Using a nationwide general sample of the Korean adult population, this study demonstrated an association between perceived environmental pollution and poor sleep quality. Exposure to a greater number of perceived environmental pollutants tended to enhance the likelihood of poor sleep quality compared to no exposure to perceived environmental pollutants. It is important to note, therefore, that a more comprehensive exposure to environmental pollution may not only have a worse effect on health outcomes including sleep quality.

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CRediT authorship contribution statement

Yeong Jun Ju: Conceptualization, Methodology, Formal analysis, Investigation, Data curation, Writing - original draft, Writing - review & editing, Visualization, Validation. **Joo Eun Lee:** Investigation, Methodology, Writing - review & editing, Data curation. **Dong-Woo Choi:** Writing - review & editing. **Kyu-Tae Han:** Writing - review & editing. **Soon Young Lee:** Supervision, Validation.

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Abbreviations list

PSQI	Pittsburgh Sleep Quality Index
PHQ-9	patient health questionnaire-9
PM	particulate matter
KCHS	Korea Community Health Survey
BMI	body mass index

Conflict of interest

None declared.

The ICMJE Uniform Disclosure Form for Potential Conflicts of Interest associated with this article can be viewed by clicking on the following link: https://doi.org/10.1016/j.sleep.2021.01.043.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.sleep.2021.01.043.

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