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ORIGINAL ARTICLE

Parks and green areas and the risk for depression and suicidal indicators

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Abstract
Objectives There is increasing evidence that parks and green areas have beneficial effects on mental health; however, most studies have been limited to a certain or small geographic area. This study investigated whether parks and green areas were associated with the risk for depression or suicidal indicators among adults.
Methods We used the 2009 Korean Community Health Survey data ($n = 169{,}029$). Residential geographical codes were used to determine the amount of parks and green areas in each administrative district.
Results The median amount of parks and green areas was 19.73 m^2 per capita. Compared with adults living the highest amount of parks and green areas (1st quartile), those living in regions with the lowest amount of parks and green areas (4th quartile) had 16–27% greater odds for depression and suicidal indicators, after adjusting for all potential variables. People without moderate physical activity had higher odds for self-reported depression and suicidal ideation than those with moderate physical activity.
Conclusions We observed protective associations between parks and green areas and depression and suicidal indicators. In addition, moderate physical activity may help to lower the risk for depression and suicidal indicators.

Keywords Natural environment · Community · Mental health · Psychological illness

Introduction

Parks and green areas provide benefits to humans through ecosystem services and health improvements (Bowler et al. 2010; Thompson Coon et al. 2011). A growing body of evidence has suggested such salutary aspects of parks and green areas by showing positive associations between parks and green areas and self-perceived health, cardiovascular disease, number of symptoms and diseases, and mortality (Bowler et al. 2010; Gascon et al. 2015; Kim et al. 2016; Maas et al. 2009; Mitchell and Popham 2008; Tamosiunas et al. 2014; Thompson Coon et al. 2011).

Recently, researchers have become more aware of the link between mental health and parks and green areas. Mental health problem is a public health challenge because nearly 450 million people are affected by it (World Health Organization 2013). Poor mental health has been associated with physical, social, and health outcomes and has been consequently linked to a higher risk for disability, health care burdens, low quality of life, and worse overall survival than would be expected by chance (Anderson and Jane-Llopis 2011; McDaid and Park 2011; World Health Organization 2013). It is clear that mental health problems originate from individual psychological conditions but are intensified by socioeconomic inequality and deprivation (Anderson and Jane-Llopis 2011; World Health Organization 2009). Parks and green areas can encourage physical activity and social contacts/interactions and relive psychological stress (de Vries et al. 2013; Gascon et al. 2015; Sugiyama et al. 2008); moreover, they might help improve mental health. Many studies have supported the idea that people living

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in more green areas had better mental health (Astell-Burt et al. 2013, 2014; Gascon et al. 2015; Richardson et al. 2013), which was independent of genetic and socioeconomic variations (Cohen-Cline et al. 2015; Triguero-Mas et al. 2015). These benefits appear to be immediate and potentially long-lasting (Alcock et al. 2014).

On the basis of the existing evidence for the beneficial effects of parks and green areas on mental health, using large-scale, nationwide data, this study investigated whether parks and green areas were associated with the risk for depression or suicidal indicators among adults. In addition, we examined whether these associations are likely to be mediated by physical activity, which may benefit from parks and green areas.

Depression and suicide are critical mental health problems that have been associated with human, social, and economic losses (Anderson and Jane-Llopis 2011; McDaid and Park 2011; World Health Organization 2013). Previous studies have reported an inverse association between the exposure to parks and green areas and depressive symptoms (Beyer et al. 2014; Cohen-Cline et al. 2015; Maas et al. 2009; McEachan et al. 2016; Reklaitiene et al. 2014); however, most studies have been limited to a certain or small geographic area. Moreover, to our knowledge, there has been no study that has examined the association between parks and green areas and the risk for suicide.

Methods

Study population

We used the data from the 2009 Korean Community Health Survey (KCHS), which was conducted by the Korea Centers for Disease Control and Prevention. The KCHS is a cross-sectional study that has been conducted every year since 2008 with the goals of (i) gathering reliable health-related data at the community level from different geographical regions and, (ii) providing evidence-based public health programs and services. The study participants were recruited from public health centers in sub-communities using the use of stratified sampling method related geographical area (i.e., probability proportional to size, systematic sampling, and proportional allocation). Data has been collected through face-to-face, paper assisted interviews administered by trained interviewers. The collected data included socio-demographic information, life-style indicators (e.g., smoking and alcohol consumption), and self-reported health indicators.

Of 230,715 participants included in this study in the 2009 KCHS (Korea Centers for Disease Control and Prevention 2015), we excluded 11,796 participants because of a lack of other variables of interest. Among them, depressive feelings were responded by all participants, whereas some peoples did not respond the remaining outcome variables. Therefore, the final population to be analyzed differed from outcome variables: 218,919 participants for self-reported depression, 169,026 participants for depressive symptoms by CES-D, 218,729 participants for suicidal ideation, and 196,894 participants for suicidal attempt were finally included for study population. This study was approved by the Institutional Review Board of Seoul National University Hospital.

Exposure measures: parks and green areas

To assess exposure to parks and green areas, we used the 2009 data from the Korean Statistical Information Service, which contained information regarding parks and green areas (m^2) per capita in 214 administrative districts, including cities and counties (Korean Statistical Information Service 2009). The median values (25th–75th percentiles) of the area and population in the administrative districts were 412 km^2 (58–663 km^2) and 171,873 persons (60,372–397,920 persons). Residential geographical codes for the study participants were all matched on the basis of the amount of parks and green areas in each administrative district. The matched parks and green areas and study participants were divided into quartiles: 1st quartile (14.90 m^2/capita or less), 2nd quartile (14.90–22.40 m^2/capita), 3rd quartile (22.41–33.30 m^2/capita), and 4th quartile (33.31 m^2/capita or more). The detailed geographical distribution is presented in Fig. 1.

Outcome measures: depressive feelings, depressive symptoms, suicidal ideation, and suicide attempts

The outcome variables included depression and suicidal indicators. Self-reported depression was identified with a question regarding whether the respondent had experienced feelings of depression during the past 12 months (“yes” or “no”). Depressive symptoms were assessed using the Center for Epidemiologic Studies Depression (CES-D) 20-item scale (Radloff 1977), which has been previously validated in the Korean population (Cho and Kim 1993). The presence of depressive symptoms was defined with a CES-D score of 20 or more as the cut-off value (Park and Kim 2011).

The presence of suicidal ideation was on the basis of a question of whether the respondent had contemplated dying over the past 12 months. Suicide attempts were based on a question regarding whether the respondent had attempted suicide during the past 12 months. Both suicidal indicator variables were coded as dichotomous variables (“yes” or “no”).

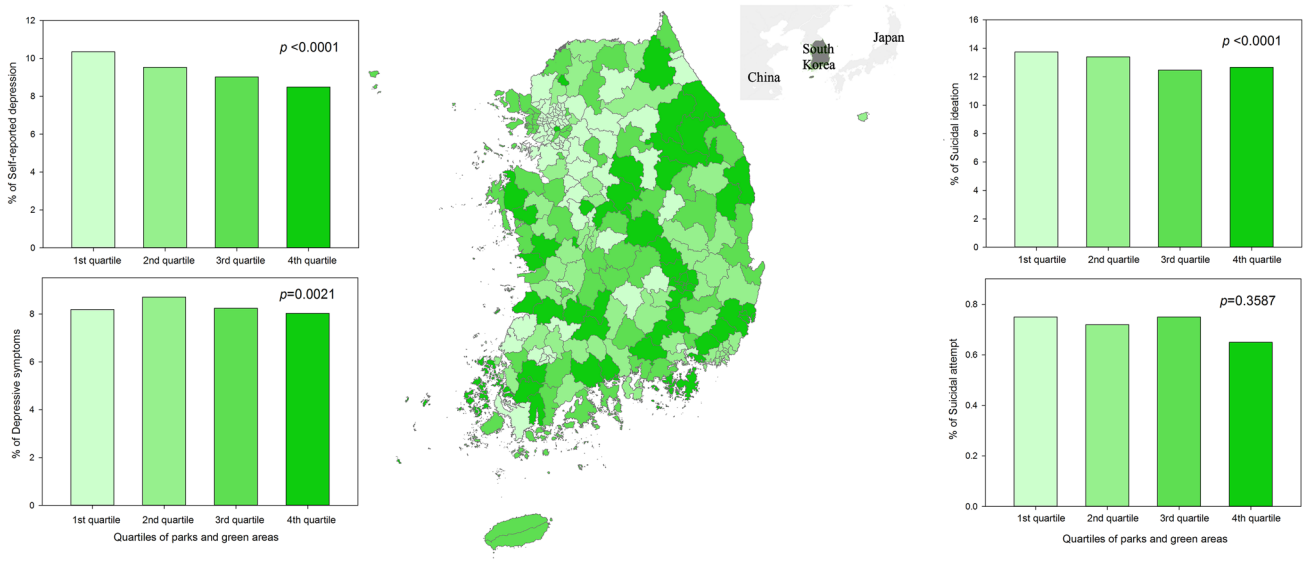

Fig. 1 Prevalence (%) of depression and suicidal indicators according to the quartiles for park and green areas. The *X*-axis means quartiles of parks and green areas: 1st quartile (14.90 m^2/capita or less), 2nd quartile (14.90–22.40 m^2/capita), 3rd quartile (22.41–33.30 m^2/capita), and 4th quartile (33.31 m^2/capita or more). South Korea 2009

Covariables

The variables of interest included age (20–29, 30–39, 40–49, 50–59, or ≥60 years), gender, marital status (married, divorced/widowed, or never married), education (less than high school, high school, or college or higher), and monthly income (1st quartile, 1,000,000 South Korean won per month or less; 2nd quartile, 1,000,001–2,000,000 South Korean won per month; 3rd quartile, 2,000,001–3,500,000 South Korea won per month; or 4th quartile, 3,500,0001 South Korea won per month or more). The working classes included white-collar (managerial, professional, or clerical), pink-collar (services or sales), blue-collar (manual labor), or the military. The life-style indicators included moderate physical activity ("yes" or "no"), smoking status (current, former, or never), and alcohol consumption (currently drinker or currently non-drinker). Moderate physical activity was based on the number of days per week on which individuals participated in moderate activities (i.e., leisure sports, including swimming, tennis, volleyball, badminton, and ping-pong etc.) for at least 10 min. Individuals with ≥1 day per week of moderate physical activity were assigned as the moderate physical activity group. The history of disease was defined as diseases, such as hypertension, diabetes mellitus, dyslipidemia, and vascular diseases (i.e., stroke, myocardial infarction, or angina), previously diagnosed by a physician. Gross domestic product (GDP) per capita at administrative district level were included as area-based indicators of socioeconomic status and categorized into three groups (1st tertile 20,000,000 South Korean won or less; 2nd tertile, 20,000,001–27,000,000 South Korean won; 3rd tertile, 27,000,001 South Korean won or more).

Statistical analysis

Participants were divided into quartiles with respect to parks and green areas. The differences in the characteristics of the participants were calculated using the Chi square test. We performed unadjusted and multivariate-adjusted logistic regression analyses to measure the likelihood of depression and suicidal indicators and stratified the finding by the quartiles of parks and green areas. Odds ratio (OR), with the corresponding 95% confidence interval (95% CI) of the risk for depression and suicidal indicators were generated by considering the quartile with the highest amount of parks and green areas (4th quartile) as the reference group throughout the analysis. The model 1 was adjusted for socio-demographic factors (i.e., age, gender, marital status, education, income, and job classification). The model 2 was further adjusted for life-style indicators (i.e., physical activity, smoking, and alcohol consumption), history of disease, and GDP per capita. We also calculated the adjusted OR (95% CI) for depression and suicidal indicators across the quartiles of parks and green areas stratified by moderate physical activity (yes or no). All analyses were performed using the SAS 9.2 software (SAS Institute, Cary, NC, USA), and the statistical significance level was set at $\alpha = 0.05$.

Results

The median (25–75th percentiles) of parks and green areas was 19.73 m^2 (14.30–31.28 m^2) per capita. The proportions of self-reported depression, depressive symptoms by CES-D, suicidal ideation, and suicide attempts were 7.5% ($n=16{,}515$), 8.3% ($n=14{,}041$), 10.5% ($n=22{,}918$), and 0.6% ($n=1084$), respectively.

Table 1 displays the characteristics of the study population by depression and suicidal indicators. Participants with self-reported depression or depressive symptoms by CES-D were more likely to be older (≥60 years), female, and divorced/widowed, to have less education (elementary or less) and lower income, and not to do any economic activity. A high proportions of people with depression indicators had no physical activity, never smoked, or were currently non-drinkers, and had no history of a vascular disease, and lived in regions with the lowest GDP per capita. The characteristics of participants with suicidal ideation or suicide attempts were very similar to those with depression or depressive symptoms. However, participants who attempted suicide exhibited a little different characteristic, with the highest proportion of attempted suicide observed in those aged 50–59 years and who were current smokers and drinkers. All variables, except drinking alcohol in suicide attempts and GDP per capita in suicidal indicators, were significantly different ($p<0.05$) between participants with and without depression or between those with and without suicidal indicators.

Figure 1 shows the prevalence (%) of depression and suicidal indicators according to the quartiles for parks and green areas. The overall prevalence of participants reporting self-reported depression, depressive symptoms, and suicide attempts was the lowest in 4th quartile. However, there was no clear linear trend of prevalence in the other three quartiles.

Table 2 shows the OR (95% CI) of depression and suicidal indicators in the quartiles for parks and green areas. Compared with the unadjusted OR, each adjusted OR for self-reported depression, depressive symptoms, suicidal ideation, and suicide attempts increased and were more robust after adjusting for potential variables. Participants living in the 1st quartile (≤14.90 m^2 per capita) of parks and green areas had a 16–27% increase in the likelihood of all outcomes compared with those living in the 4th quartile (≥33.31 m^2 per capita). For depressive indicators, participants living in the 2nd quartile had an 11% increased likelihood compared with those living in the 4th quartile of parks and green areas, but the likelihood was disappeared in the 3rd quartile. Suicidal indicators were not significantly different in population living in the 2nd or 3rd quartile of park and green areas. Except suicide attempt, there was apparent trend in depression and suicidal ideation with increasing dose of parks and green areas ($p<0.0001$). Table 3 shows the OR (95% CI) of depression and suicidal indicators in the quartiles for parks and green areas, stratified by moderate physical activity (yes or no). When we compared the groups with and without moderate physical activity, participants living in the 1st quartile (≤14.90 m^2 per capita) of parks and green areas had a 12–29% increased likelihood of depression indicators and suicidal ideation, compared with those living in the 4th quartile (≥33.31 m^2 per capita). No significant likelihood was observed in participants with moderate physical activity and suicidal attempt. The incidence for depressive symptoms and suicidal ideation in participants with moderate physical activity was lower than those with no moderate physical activity.

Discussion

This study investigated the association of parks and green areas with depression and suicidal indicators, using a nationally representative data set from South Korea. The prevalence of depression or suicide was higher in adults living in lower parks and green areas; for depression, participants living in the lowest parks and green areas (1st quartile) had 25 and 13% greater odds for self-reported depression and depressive symptoms respectively than those living in regions with the highest amount of parks and green areas (4th quartile). For suicide, participants living in the lowest parks and green areas (1st quartile) had 18 and 25% greater odds for suicide ideation and suicidal attempts respectively than those living in regions with the highest amount of parks and green areas (4th quartile). In addition, we found that the incidence of depressive symptoms and suicidal ideation in participants with moderate physical activity was lower than those with no moderate physical activity. Thus, our findings supported previous work demonstrating the beneficial effects of parks and green areas on depression and suggested the novel result that a lack of parks and green areas may be linked to an increased risk for suicide. Moreover, the effect of parks and green areas on depression and suicidal indicators could be somewhat mediated by moderate physical activity.

Several studies have demonstrated the potential effect of parks and green areas on improving physical and mental health statues or mitigating health inequalities (Astell-Burt et al. 2013, 2014; Bowler et al. 2010; Cohen-Cline et al. 2015; Gascon et al. 2015; Maas et al. 2009; Mitchell and Popham 2008; Richardson et al. 2013; Tamosiunas et al. 2014; Thompson Coon et al. 2011; Triguero-Mas et al. 2015). Our findings were consistent with the view that an exposure to parks and green areas in terms of the amount, proximity, or access to green and park areas, significantly reduced the risk for depressive symptoms (Beyer et al.

Table 1 Characteristics of the study population[a] by depression and suicidal indicators; *n* (%). South Korea 2009

	All	Depressive symptoms		Suicide indicators	
		Self-report	CES-D	Ideation	Attempt
Age (years)					
20–29	27,048 (12.36)	1687 (6.24)	1349 (6.77)	1755 (6.49)	110 (0.43)
30–39	39,913 (18.23)	2424 (6.07)	1619 (5.54)	3049 (7.64)	150 (0.41)
40–49	46,009 (21.02)	3165 (6.88)	2155 (6.33)	4030 (8.77)	251 (0.60)
50–59	39,868 (18.21)	3155 (7.91)	2186 (7.20)	4201 (10.55)	232 (0.65)
≥60	66,081 (30.19)	6084 (9.21)	6732 (12.14)	9883 (14.97)	341 (0.60)
Gender					
Male	101,597 (46.41)	5387 (5.30)	4335 (5.88)	7705 (7.59)	415 (0.44)
Female	117,322 (53.59)	11,128 (9.49)	9706 (10.19)	15,213 (12.98)	669 (0.65)
Marital status					
Married	155,636 (71.09)	10,404 (6.68)	7547 (6.44)	14,397 (9.26)	650 (0.46)
Divorced/widowed	31,068 (14.19)	4019 (12.94)	4654 (16.81)	6194 (19.97)	277 (1.10)
Never married	32,215 (14.72)	2092 (6.49)	1840 (7.65)	2327 (7.23)	157 (0.52)
Education					
Elementary or less	60,796 (27.77)	6029 (9.92)	6709 (12.93)	9823 (16.18)	387 (0.75)
Middle–High school	92,578 (42.29)	6814 (7.36)	5072 (7.14)	9073 (9.81)	548 (0.65)
College or higher	65,545 (29.94)	3672 (5.60)	2260 (4.90)	4022 (6.14)	149 (0.24)
Monthly income					
1st quartile	58,545 (26.74)	6618 (11.30)	7200 (14.53)	9987 (17.08)	532 (1.09)
2nd quartile	52,648 (24.05)	3941 (7.49)	3029 (7.38)	5403 (10.28)	246 (0.52)
3rd quartile	46,811 (21.38)	2662 (5.69)	1858 (5.33)	3498 (7.48)	145 (0.33)
4th quartile	60,915 (27.83)	3294 (5.41)	1954 (4.49)	4030 (6.62)	161 (0.28)
Job categories					
White-collar	40,598 (18.54)	2099 (5.17)	1145 (4.10)	2298 (5.66)	90 (0.23)
Pink-collar	28,293 (12.92)	2017 (7.13)	1271 (5.97)	2604 (9.21)	144 (0.56)
Blue-collar	64,077 (29.27)	3591 (5.60)	2676 (5.49)	5794 (9.05)	258 (0.44)
Military	1056 (0.48)	35 (3.31)	13 (2.02)	33 (3.13)	1 (0.10)
No economic activity	84,895 (38.78)	8773 (10.33)	8936 (12.70)	12,189 (14.37)	591 (0.81)
Moderate physical activity					
Yes	64,119 (29.29)	4387 (6.84)	3106 (6.34)	5979 (9.33)	284 (0.49)
No	154,800 (70.71)	12,128 (7.83)	10,935 (9.11)	16,939 (10.95)	800 (0.58)
Cigarette smoking					
Current smoker	52,327 (23.9)	3714 (7.10)	3120 (7.88)	5236 (10.02)	384 (0.81)
Former smoker	29,935 (13.67)	1909 (6.38)	1623 (7.31)	2821 (9.43)	123 (0.45)
Never smoker	136,657 (62.42)	10,892 (7.97)	9298 (8.67)	14,861 (10.89)	577 (0.47)
Alcohol drinking					
Currently drinker	110,107 (50.3)	7086 (6.44)	5114 (6.19)	9791 (8.90)	550 (0.55)
Currently non-drinker	108,812 (49.7)	9429 (8.67)	8927 (10.33)	13,127 (12.08)	534 (0.56)
History of disease					
Hypertension	43,809 (20.01)	4268 (9.74)	4329 (11.97)	6551 (14.97)	272 (0.73)
Diabetes	15,894 (7.26)	1794 (11.29)	1852 (13.96)	2700 (17.00)	124 (0.93)
Hyperlipidemia	14,204 (6.49)	1626 (11.45)	1303 (11.25)	2124 (14.97)	117 (0.96)
Vascular disease	9337 (4.27)	1527 (16.35)	1733 (21.06)	2148 (23.04)	107 (1.47)
GDP per capita					
1st tertile	71,134 (32.49)	5595 (7.87)	4916 (8.80)	7461 (10.50)	379 (0.59)
2nd tertile	67,302 (30.74)	5147 (7.65)	3956 (7.70)	7125 (10.59)	330 (0.55)
3rd tertile	80,483 (36.76)	5773 (7.17)	5169 (8.37)	8332 (10.36)	375 (0.52)

[a]The final population to be analyzed differed from outcome variables: 218,919 participants for self-reported depression, 169,026 participants for depressive symptoms by CES-D, 218,729 participants for suicidal ideation, and 196,894 participants for suicidal attempt

Table 2 Odds ratio (95% CI) of depression and suicidal indicators in the quartiles for parks and green areas. South Korea 2009

	Unadjusted model	Adjusted	
		Model 1	Model 2
Parks and green area (1000 m^2 per capita)			
Self-reported depression ($n=218,919$)			
1st quartile (≤14.90)	1.21 (1.14–1.29)	1.29 (1.21–1.37)	1.27 (1.20–1.36)
2nd quartile (14.90–22.40)	1.15 (1.08–1.23)	1.14 (1.07–1.22)	1.11 (1.04–1.18)
3rd quartile (22.41–33.30)	0.99 (0.92–1.07)	1.00 (0.93–1.08)	0.98 (0.91–1.06)
4th quartile (≥33.31)	Reference	Reference	Reference
p value for trend	<0.0001	<0.0001	<0.0001
Depressive symptoms by CES–D ($n=169,026$)			
1st quartile (≤14.90)	1.05 (0.99–1.13)	1.20 (1.12–1.28)	1.20 (1.12–1.28)
2nd quartile (14.90–22.40)	1.14 (1.07–1.23)	1.13 (1.06–1.22)	1.11 (1.03–1.19)
3rd quartile (22.41–33.30)	0.94 (0.87–1.02)	0.95 (0.87–1.03)	0.96 (0.88–1.05)
4th quartile (≥33.31)	Reference	Reference	Reference
p value for trend	<0.0001	<0.0001	<0.0001
Suicidal ideation ($n=218,729$)			
1st quartile (≤14.90)	1.07 (1.02–1.13)	1.20 (1.13–1.26)	1.16 (1.10–1.23)
2nd quartile (14.90–22.40)	1.00 (0.95–1.06)	0.99 (0.94–1.05)	1.00 (0.95–1.06)
3rd quartile (22.41–33.30)	0.87 (0.81–0.92)	0.87 (0.81–0.92)	0.85 (0.79–0.90)
4th quartile (≥33.31)	Reference	Reference	Reference
p value for trend	<0.0001	<0.0001	<0.0001
Suicidal attempt ($n=196,894$)			
1st quartile (≤14.90)	1.12 (0.91–1.38)	1.28 (1.04–1.58)	1.27 (1.02–1.57)
2nd quartile (14.90–22.40)	1.24 (0.99–1.54)	1.24 (0.99–1.54)	1.24 (0.99–1.55)
3rd quartile (22.41–33.30)	1.13 (0.88–1.45)	1.15 (0.90–1.47)	1.13 (0.88–1.45)
4th quartile (≥33.31)	Reference	Reference	Reference
p value for trend	0.3014	0.113	0.1384

Model 1 adjusted for age, gender, marital status, education, monthly income, and job categories

Model 2 adjusted for model 1 + moderate physical activity, smoking, drinking, history of disease and GDP per capita

2014; Cohen-Cline et al. 2015; Maas et al. 2009; McEachan et al. 2016; Reklaitiene et al. 2014; Triguero-Mas et al. 2015). More specifically, Maas et al. (2009) investigated whether physician-assessed diseases were associated with the amount of green areas among the Dutch population (Maas et al. 2009). The prevalence of 15 of the 24 disease clusters was lower in regions with more green areas in a 1 km radius. For example, people living in area with only 10% green area in a 1 km radius around their home had a 25% greater risk for depression than those with 90% green area in a 1 km radius. A Kaunas city study revealed that among women who used the park for ≥4 h/week, those who lived ≥300 m away had a higher risk for self-reported depressive symptoms than women residing closer to the park (<300 m) (Reklaitiene et al. 2014). These studies have associated the importance of green space proximity to people's homes to the prevalence of depressive symptoms (Maas et al. 2009; Reklaitiene et al. 2014). In results from the Survey of the Health of Wisconsin, higher levels of neighborhood greenness, measured as the normalized difference vegetation index or percent of tree canopy were associated with better mental health outcomes, including depression, anxiety, and stress (Beyer et al. 2014). Depression showed the strongest negative association with green areas, with the beta coefficient ranging from −4.02 to −5.52 indicating fewer depressive symptoms for adults who lived in the highest amount of parks and green areas than those who lived in the least amount of parks and green areas. The association with depression appeared to be evident after controlling for genetic or shared childhood environmental factors. For example, greater access to green areas was associated with decreased depression among the within-identical twin pair, whereas there was no within-pair monozygotic effect for stress or anxiety (Cohen-Cline et al.

Table 3 Odds ratio (95% CI) of depression and suicidal indicators in the quartiles for parks and green areas, stratified by moderate physical activity (yes or no)

	Moderate physical activity (yes)	Moderate physical activity (no)
Self-reported depression ($n=218,919$)		
1st quartile (≤14.90)	1.23 (1.11–1.37)	1.29 (1.20–1.39)
2nd quartile (14.90–22.40)	1.03 (0.92–1.16)	1.14 (1.05–1.23)
3rd quartile (22.41–33.30)	0.89 (0.77–1.02)	1.01 (0.93–1.10)
4th quartile (≥33.31)	Reference	Reference
p value for trend	<0.0001	<0.0001
Depressive symptoms by CES-D ($n=169,026$)		
1st quartile (≤14.90)	1.10 (0.96–1.24)	1.24 (1.15–1.33)
2nd quartile (14.90–22.40)	0.95 (0.84–1.09)	1.16 (1.07–1.26)
3rd quartile (22.41–33.30)	0.81 (0.70–0.94)	1.01 (0.91–1.11)
4th quartile (≥33.31)	Reference	Reference
p value for trend	<0.0001	<0.0001
Suicidal ideation ($n=218,729$)		
1st quartile (≤14.90)	1.12 (1.01–1.35)	1.15 (1.08–1.22)
2nd quartile (14.90–22.40)	0.99 (0.89–1.10)	1.01 (0.95–1.08)
3rd quartile (22.41–33.30)	0.79 (0.70–0.89)	0.86 (0.80–0.93)
4th quartile (≥33.31)	Reference	Reference
p value for trend	<0.0001	<0.0001
Suicidal attempt ($n=196,894$)		
1st quartile (≤14.90)	1.54 (0.99–2.38)	1.18 (0.92–1.51)
2nd quartile (14.90–22.40)	1.36 (0.88–2.09)	1.20 (0.93–1.56)
3rd quartile (22.41–33.30)	1.90 (0.53–1.53)	1.20 (0.91–1.60)
4th quartile (≥33.31)	Reference	Reference
p value for trend	0.055	0.4608

South Korea 2009

Adjusted for age, gender, marital status, education, monthly income, job categories, smoking, drinking, history of disease and GDP per capita

2015). Another recent study showed that higher levels of residential greenness were associated with a 18–23% reduction in the number of reported depressive symptoms during pregnancy (McEachan et al. 2016). The beneficial association of greenness was clearer for pregnant women with lower education or who were physically active (McEachan et al. 2016). Thus, these findings implied that participants who lacked exposure to parks and green areas were at a risk for depression or depressive symptoms.

Several mechanisms may explain why parks and green areas are linked to a reduced risk for self-reported or clinically assessed depression. Parks and green areas can promote psychological restoration, such as improving mood and reducing stress and anxiety (Barton and Pretty 2010; Roe and Aspinall 2011; Roe et al. 2013). Parks and green areas can also create or improve social contacts with others through formal or informal settings. Social interaction or the avoidance of social isolation has been associated with positive effects on the risk for depression (Chou et al. 2011; Teo et al. 2013). Another important explanation is physical activity (Gascon et al. 2015; Sugiyama et al. 2008). Many studies have confirmed the association between park proximity and physical activity (Brownson et al. 2001; Diez Roux et al. 2007; McCormack et al. 2010). Physical activity has been shown to decrease the likelihood for depressive symptoms in clinical and non-clinical populations through physiological pathways including neuroendocrine stress hormone secretion (Strohle 2009; Teychenne et al. 2008). Our data also showed the potential role of physical activity in mitigating self-reported depression, which was related to parks and green areas. Participants with moderate physical activity were less likely to have self-reported depression compared with those with no moderate physical activity (OR 1.23; 95% CI 1.11–1.37 vs. OR 1.29; 95% CI 1.20–1.39 in Table 3). Nevertheless, there are conflicting reports regarding the benefits of parks and green areas on physical activity (de Vries et al. 2013; Richardson et al. 2013). De Vries et al. (2013) explored three mechanisms through which green areas

exert a positive effect on health: stress reduction, social cohesion, and physical activity. Their results suggested that stress reduction and social cohesion were the strongest effective mediators linking green areas and health, while total physical activity did not have much effect (de Vries et al. 2013). In a New Zealand Health Survey study, people living in greener neighborhoods were found to be more physically active, but physical activity did not completely explain the association between green areas and improved health (Richardson et al. 2013). Our study cannot determine the mechanisms by parks and green areas exert their positive effect on depression. However, judging from the existing evidence, it appears that several mechanisms could be synergistically working to attenuate the risk for depression.

Of particular interest was the significant association between parks and green areas and suicidal indicators. We found that participants living in regions with the highest amount of parks and green areas were at reduced odds for suicidal ideation and suicide attempts, after adjusting for potential variables. We are unaware of any available results on the effect of parks and green areas on suicide; therefore, it has been impossible to compare our findings with those of others. However, the potential mechanisms for the link between parks and green areas and depression could support this observed association. For example, parks and green areas can promote physical activity (Brownson et al. 2001; Diez Roux et al. 2007; McCormack et al. 2010). Many studies have suggested a protective association between physical activity and suicidal indicators (Ro et al. 2015; Simon et al. 2004), in which increased physical activity induced direct or indirect changes in the positive physiological or mental status (Ro et al. 2015; Simon et al. 2004). In our study, lower odds for suicidal ideation in participants having moderate physical activity (OR 1.12; 95% CI 1.01–1.35) than those having no moderate physical activity (OR 1.15; 95% CI 1.08–1.22), even in living in regions with the lowest parks and green areas, could be understood in this context. In addition to physical activity, it was plausible that parks and green areas helped in restoring emotional balance by improving mood or reducing stress and anxiety levels, which lead to a lower risk for suicide. People who had a psychiatric condition, such as mood, anxiety, or stress, were more likely to attempt suicide (Nepon et al. 2010; Otsuka et al. 2015; Rihmer 2007). Social isolation and the lack of social interaction or contact is also a key factor for suicide (Tsai et al. 2014, 2015). Prospective cohort studies estimated that people who was socially well-integrated had a 2–3 fold reduced risk for suicide mortality than those who had the lowest amount of social integration (Tsai et al. 2014, 2015). On the basis of this circumstantial evidence, benefits, such as increases in physical activity, a promotion of psychological restoration, and the encouragement of social interaction, of parks and green areas may be protective factors against suicidal indicators, as observed in our findings.

This is the first study to demonstrate the protective association of parks and green areas are associated with a decreased risk for depression or suicidal indicators among adults. Our results are based on the objective assessment of parks and green areas obtained from national statistical data and have high external validity due to representativeness of the sample. However, several limitations should be considered. First, the study was based on a cross-sectional design. We could not establish the causality of these observed associations or explain the extent to which the population had physical and visual exposure to natural or green environments throughout their lives. The second limitation was the assessment of parks and green areas. Because there was no data to assess the actual amount of parks and green areas around each individual, we used the average parks and green areas of 200 administrative districts, with the matching geographical sectors for the study participants. The parks and green areas may have been objective and accurate in terms of administrative boundaries; however, we could not consider the impact of accessibility and the specific qualities, such as biodiversity and walkability, of the green areas at personal-level. Third, the KCHS included only self-reported data, which might be distorted by recall bias or misclassification or complicated by over- or under-reporting. The reliability of the psychometric measures of feelings of depression and suicidal ideation/attempts as used in the KCHS was implicitly assumed rather than explicitly ascertained. Screening that uses only a single question to assess a respondents' psychological condition, such as depression and suicide, may be unable to identify people who are potentially at risk for these behaviors. Since this health survey only included those who either had not committed suicide or had survived it, our study could not adequately assessed whether green areas were associated with the risk for suicide. Moreover, we could not rule out the possibility of residual confounding effects by unmeasured confounders. Finally, although our study analyzed the nationally representative sample data, missing variables (mostly related to CES-D items) did not completely at random. Therefore, we could not generalize our results to depressive symptoms of the entire population.

In conclusion, we observed protective associations between parks and green areas and depression and suicidal indicators. A higher amount of parks and green areas was significantly associated with lower odds for self-reported depression, depressive symptoms, suicidal ideation, and suicide attempts in adults. Physical activity could be mediated by the observed protective association. Although further studies are necessary to confirm our current findings and to determine the mechanisms underlying the observed

association, our study provided evidence regarding the potential role of parks and green areas in alleviating the risk for depression and suicidal indicators.

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Compliance with ethical standards

Conflict of Interest KB Min has received research grants from by Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education, Science and Technology. KB Min declares that he has no conflict of interest.

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

Informed consent This study used the public anonymous data and was exempted from obtaining informed consent from ethics review.

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