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Urban governance as a determinant of suicidal tendencies among middle-aged and older adults in China: a longitudinal quasi-experimental study

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ABSTRACT

Evaluating the impact of urban policies on severe mental health outcomes is crucial for aging populations. This study evaluates the causal impact of China's Healthy City Pilot Policy (HCPP) on suicidal tendencies among urban middle-aged and older adults. It also explores the underlying macro and micro mechanisms. We used a Difference-in-Differences (DID) approach with propensity score matching (PSM). Our analysis used data from 16,691 participants aged 45 and older, covering five waves (2011–2020) of the China Health and Retirement Longitudinal Study (CHARLS). Suicidal tendency was assessed using a specific item from the Center for Epidemiologic Studies Depression Scale (CES-D). The findings indicate that the HCPP significantly inhibited suicidal tendencies in pilot cities. Mechanism analyses revealed a "dual-pathway" model. The policy reduces suicide risk by increasing urban green coverage at the macro level. It also fosters social participation at the micro level. These protective effects were particularly significant among males, the working population, and individuals with lower incomes. Ultimately, the HCPP serves as an effective socio-ecological intervention. Integrating environmental optimization with social reconstruction can create supportive urban environments that effectively mitigate geriatric suicide risk.

Keywords: Mental Health, China, Health Economics, Health Policy, Health Services Administration and Management, Public Health

INTRODUCTION

In the context of rapid urbanization and population aging, suicide among middle-aged and older urban adults remains a public health crisis [1]. Individual-level risk factors, such as psychiatric disorders, physical comorbidities, and changing social roles, are well-documented [2], but identifying modifiable macro-environmental determinants is increasingly important for population-level prevention. The Socio-ecological Systems Theory (SEST) demonstrates that health behaviors are influenced by interactions between individuals and their environments [3], suggesting suicide risk is structured by both macro-environmental factors (e.g., environmental quality) and micro-behavioral interactions (e.g., social connection).

Traditional suicide research has focused mainly on individual determinants. Recent environmental epidemiology now includes urban risk factors. Studies using

time-series or spatial analyses have shown that environmental stressors, such as air pollution (e.g., PM2.5, PM10) and extreme climate events, increase suicide risk. These factors can induce neuroinflammation or economic stress [4, 5, 6]. In contrast, protective factors like urban green space reduce suicide mortality. Helbich et al. [7] found a negative dose-response relationship between residential greenness and suicide.

Despite these insights, a critical gap remains in the empirical literature. Most existing evidence is derived from observational studies of natural exposures [6, 7]. These designs often fail to address endogeneity issues, such as residential self-selection, in which individuals with better socioeconomic status or mental health tend to choose to live in greener neighborhoods. Until now, there is a scarcity of causal evidence to prove that proactive government intervention, especially systematic urban policies, can successfully manipulate these environmental factors to achieve suicide prevention. As noted by Cero et al[8], suicide research should move towards rigorous causal inference designs like quasi-experiments to accurately identify modifiable targets for prevention. Without such evidence, we are unable to determine whether systematic urban planning is a new factor influencing the suicide rate.

China’s Healthy City Pilot Policy (HCPP) offers a unique opportunity to test these dynamics causally. As a comprehensive urban governance strategy localized from the WHO's movement and initiated in 2016, the HCPP clearly requires improvements in environmental management, health services, and social culture [9]. Previous evaluations utilizing quasi-experimental methods (e.g., DID) confirmed that the HCPP significantly reduced air pollution [10] and improved mental health [11, 12]. However, these studies have omitted the examination of specific, extreme mental health outcomes like suicidal tendencies, leaving their potential as a suicide prevention strategy untested.

This study addresses this problem by using the HCPP as a quasi-natural experiment. We apply a Difference-in-Differences (DID) approach to longitudinal data from the China Health and Retirement Longitudinal Study (CHARLS). Our aims are to: (1) provide causal evidence on the effectiveness of systemic urban governance in reducing suicidal tendencies, and (2) explain the mechanism behind this effect.

Based on the Socio-ecological Systems Theory (SEST) [2], we propose a dual-pathway model involving two modifiable protective factors to clarify how the HCPP reduces suicide risk: Macro-Level Mechanism (Green Infrastructure): Lack of green space is a potential risk factor. The HCPP requires expanding urban green coverage. There is some literature that suggests that improved green environments can reduce depression and suicide by facilitating physiological restoration [13, 7]. Thus, we proposed Hypothesis 1: The HCPP reduces the risk of suicide by increasing the availability of green space.

Micro-Level Mechanism (Social Connection): Social isolation can contribute to depression [14]. HCPP supports and promotes healthy communities by developing neighborhood facilities and organizing social events. Based on the findings from Oyama et al. [15] and Vancampfort et al. [16], they found that promoting social participation significantly reduces suicide tendency and mortality in the elderly. Thus, we make Hypothesis 2: The HCPP reduces suicide risk by enhancing social interaction and community cohesion.

METHODS

Data Source

This study utilizes two main datasets. The first one is the China Health and Retirement Longitudinal Study (CHARLS) from 2011 to 2020. The respondents are from 150 counties across 28 provinces and are aged 45 or older. The second one is from the China Urban-Rural Construction Statistical Yearbook and the China City Statistical Yearbook to match individual-level data with city-level indicators such as green space and infrastructure, so we can construct an unbalanced individual-city-year panel.

Data analysis was performed using Stata 18.0. We excluded respondents living in the country and those under 45, those with missing city codes or unmatched macro-data, and individuals with missing values for key variables. The detailed screening process is illustrated in Figure 1. The final analytical sample comprised 16,691 observations.

Measurement

Dependent Variables

The dependent variable in this study is suicidal tendency, which is operationalized by a specific item from the Center for Epidemiologic Studies Depression Scale (CES-D). The selected item asks respondents: "Using the scale below, please indicate how often you have felt this way during the past week". This item captures a profound sense of hopelessness, lethargy, and loss of will to live, which are critical behavioral precursors and proxies for suicidal tendency in middle and older adults. The responses are recorded on a 4-point Likert scale based on frequency of occurrence over the past week. The values are assigned as follows: 1 = "Rarely or None (<1 Day)"; 2 = "Some or A Little (1-2 Days)"; 3 = "Occasionally or a moderate amount of the time (3-4 Days)"; and 4 = "Most of the Time (5-7 Days)." A higher score indicates a higher frequency of feeling this severe negative state, thereby it can reflect a more serious suicidal tendency.

Independent Variables

The primary independent variable in this study is the implementation of the Healthy City Pilot Policy (HCPP). Following the standard framework of quasi-natural experiments, we measure this variable using the interaction term (DID_{it}) of the policy group dummy variable ($Treat_i$) and the time dummy variable ($Post_t$).

First, regarding the group dimension ($Treat_i$), the division is based on the "Notice on

Launching the Pilot Work of Healthy Cities" issued by the National Patriotic Health Campaign Committee Office in July 2016. Respondents residing in the 38 designated pilot cities are divided as the treatment group ($Treat_i$=1), while those living in non-pilot cities serve as the control group ($Treat_i$=0)

Second, regarding the time dimension ($Post_t$), the policy was officially launched in 2016, But considering the time lag required because policy need time to have effect on residents and the survey of the CHARLS also need time, we set 2017 as the cutoff point for the policy intervention. Accordingly, the survey waves conducted in 2011, 2013, and 2015 are defined as the pre-policy period ($Post_t$ = 0), while the waves in 2018 and 2020 are defined as the post-policy period ($Post_t$ = 1). The coefficient of the interaction term ($Treat_i \times Post_t$) shows the net causal effect of the HCPP on the suicidal tendencies of middle-aged and older adults living in cities.

Control Variables

Specific demographic characteristics, socioeconomic status (SES), and health behaviors were selected as control variables to mitigate potential omitted variable bias. Specifically, individual characteristics include gender, marital status, family income, employment status, residence type, Hukou type, education, number of children, retirement status, ability to perform activities of daily living (ADL), smoking, drinking, and self-reported health.

Furthermore, some city characteristics need to be included to test whether they are the mediating factors influencing the effect of HCPP on suicidal tendencies. These city characteristics include green, road, SO2, medical, PM2.5, physical, and social.

Mechanism Variables

Based on Socio-ecological Systems Theory (SEST) [3], the Healthy City Pilot Policy (HCPP) is hypothesized to inhibit suicidal tendencies through macro and micro pathways.

The macro-mechanism focuses on urban ecological infrastructure. We selected log-transformed Per Capita Park Green Space as the proxy variable to evaluate the macro environmental effect. Engemann et al. [17] found that exposure to green space can significantly reduce psychiatric risks due to neuroprotective effects, while South et al. [18] proposed that greening urban land can also reduce residents' feelings of depression and worthlessness. These findings confirm that green spaces in cities can reduce stress and depression through facilitating physiological restoration [17, 18].

The micro-mechanism of strengthening Social Connections is represented by the Social Interaction Scores, which comprise 11 items in the CHARLS questionnaire that measure various dimensions of Social Engagement. For each of these measures, the individual who participated in any given activity within the last month has scored a value of 1. Therefore, each participant will receive a score of 0-11 on their Social

Engagement Measurements; higher scores indicate greater social integration. Some research has found that social connection is a critical protective factor against elder suicide [19], as frequent engagement provides essential emotional support against depressive symptoms caused by perceived isolation in old age [20].

BENCHMARK REGRESSION MODEL

To identify the causal impact of the Healthy City Pilot Policy (HCPP) on the suicidal tendencies of urban middle-aged and older adults, this study employs a Difference-in-Differences (DID) approach. The HCPP was implemented in batches starting from 2016 [9]. And by comparing the variations in suicidal tendencies between the treatment group (pilot cities) and the control group (non-pilot cities) before and after policy implementation, we can effectively isolate the net effect of policy from other confounding factors. The basic econometric model is specified as follows:

$$Y_{it} = \alpha+\beta DID_{it}+\gamma X_{it}+\mu_j+\lambda_t+\epsilon_{it} \quad (1)$$

In Equation (1), the dependent variable Y_{it} represents the suicidal tendency of individual i in city j at year t. The core independent variable DID_{it} is the interaction term of the policy dummy (treat) and the time dummy (post). The coefficient β captures the average treatment effect of the HCPP. If β is significantly negative, it indicates that the healthy city construction effectively inhibits suicidal tendencies among the elderly.

X_{it} denotes a set of individual-level control variables, including individual characteristics. To control for unobservable heterogeneity, we include city fixed effects (μ_j) to absorb time-invariant regional characteristics and year fixed effects (λ_t) to account for macroeconomic shocks impacting all cities. ϵ_{it} is the random error term. Standard errors are clustered at the city level to address potential serial correlation and heteroscedasticity.

We use the mediation analysis methodology, which is proposed by Baron and Kenny (1986) to further explore the underlying processes to find the HCPP impact on suicidal tendencies through the macro-pathway of environmental optimization and the micro-pathway of social connection [21]. We created the subsequent recursive equations based on the baseline model (Equation 1):

$$M_{it} = \alpha+\phi DID_{it}+\gamma X_{it}+\mu_j+\lambda_t+\epsilon_{it} \quad (2)$$

$$Y_{it} = \alpha+\delta DID_{it}+\vartheta M_{it}+\gamma X_{it}+\mu_j+\lambda_t+\epsilon_{it} \quad (3)$$

In these equations, M_{it} represents the mechanism variables for individual i in city j at year t. including macro-level indicators (e.g., Per Capita Park Green Space, Industrial SO_2, PM2.5) and micro-level indicators (e.g., Social Interaction Score). Equation (2) examines the impact of the policy on these mediators. In Equation (3), both the policy variable DID_{it} and the mediator M_{it} are included to estimate the impact of the policy on suicidal tendencies (Y_{it}) after controlling for the mediator. If the coefficient ϕ in

Equation (2) is significant, and the coefficient ϑ in Equation (3) is significant, it indicates there is a mediation effect exists. Furthermore, if the coefficient δ in Equation (3) decreases compared to the baseline coefficient β in Equation (1) or becomes insignificant, it suggests that the HCPP reduces suicide risk partially or fully through the identified mechanism M_{it}.

FINDINGS

Baseline Results

To empirically prove the impact of HCPP on suicidal tendencies, we used the stepwise regression strategy to estimate Equation (1) (Table 3). Although the specific coefficients of the control variables were briefly omitted in Table 3, all the raw data before any cleaning are listed in Table 1, and Table 2 shows the complete set of variables after cleaning. Across all specifications—ranging from the OLS baseline (Column 1) to models incorporating City Fixed Effects (Column 2), Year Fixed Effects (Column 3), and the preferred Two-way Fixed Effects (TWFE) model (Column 4)—the DID coefficients remain consistently negative and statistically significant. In the complete TWFE specification, this policy showed a significant inhibitory effect ($p < 0.01$), providing strong evidence that systematic urban governance has reduced the suicidal tendencies of middle-aged and elderly people living in urban areas.

Robustness Check

Placebo Test

We performed a placebo test by randomly changing the Healthy City pilot status 500 times to rule out the influence of unobserved omitted variables [22]. The resulting placebo coefficients generally followed a normal distribution centered around zero. On the other hand, these placebo estimations differed considerably from the genuine benchmark estimator (-0.084). This finding demonstrates that the HCPP's observed inhibitory effect on suicide risk is strong and not the result of chance.

PSM-DID Analysis

We use the PSM-DID approach to address potential endogeneity because of the non-random selection of pilot cities [23]. Using kernel matching to limit the comparison to a shared support area after confirming the parallel trends assumption. As shown in Column 5 of Table 3, the results indicate that the calculated coefficient remains statistically significant and negative. This similarity with the baseline regression demonstrates that the inhibitory impact of HCPP is resistant to selection bias.

Heterogeneity Analysis

To explore whether the Healthy City Pilot Policy (HCPP) has differential impacts across specific demographic groups, we conducted heterogeneity analyses by income, education, work status, and gender. Table 4 reports the regression results for the subgroups that showed significant HCPP effects.

Income Level

Heterogeneity analysis reveals that HCPP significantly reduces suicidal tendencies among high-income and low-income groups, and it doesn't have a significant impact on the middle-income group, but they have different mechanisms. For low-income individuals, the policy functions as a "compensation effect" [24]. Public goods, such as better construction and improved environments, can provide essential resources to relieve their stress. Conversely, for high-income groups, the effect is "demand upgrading" [25], in which people have greater health awareness, enabling them to use new green spaces and sports infrastructure to improve mental well-being and life satisfaction.

Educational Attainment

Second, regarding educational attainment, the results show that the policy significantly reduces suicidal tendencies for people whose education level is lower than primary school. Individuals with lower levels of education often have lower health awareness and tend to live in neighborhoods with poor construction. The environmental interventions mandated by the HCPP likely address this problem, providing external support to benefit those with limited knowledge and resources to improve their mental health [26].

Employment Status

Third, regarding employment status, the analysis reveals that the HCPP significantly reduces the tendency for working people. This is likely because working individuals often suffer from chronic psychophysiological stress due to job demands. The HCPP mandates expanding urban green spaces and parks, which serve as restorative environments. According to Ulrich et al. (1991)[27], exposure to natural settings can foster rapid physiological and emotional recovery from stress, allowing workers to replenish depleted cognitive resources.

Gender Difference

Finally, we discovered that the strategy considerably decreased male suicide tendencies. This implies that males are more receptive to the growth of outdoor fitness centers, consistent with research showing that men are far more likely than women to engage in vigorous physical activity in public parks [28]. As a result, these facilities probably give males an important way to decompress and improve their mental health.

The Mechanism Analysis

Based on the Socio-ecological Systems Theory (SEST) [3], this study found that the Healthy City Pilot Policy (HCPP) inhibits suicidal tendencies through two distinct pathways: improving the physical environment and modifying individual social behaviors. We conducted an empirical analysis to verify these mechanisms. Table 5 presents the results, with Panel A reporting the impact of HCPP on potential mediators

and Panel B showing the results when these mediators are incorporated into the regression model for suicidal tendency.

Macro-Level Mechanism: Environmental Optimization

At the macro level, HCPP promotes the expansion of urban ecological infrastructure. The results in Table 5 (Panel A) show that the policy has significantly increased the Green Coverage Rate in pilot cities. Panel B reveals that higher green coverage has a significant negative impact on suicidal tendencies.

This finding supports Hypothesis 1, demonstrating that the HCPP reduces suicide risk by increasing the availability of urban green space. Consistent with Helbich et al. [7], greater green space provides a better living environment, helping mitigate daily stress. By providing areas for relaxation and restoration, the expanded green infrastructure helps alleviate depressive symptoms and blocks the environmental pathway that leads to suicide risk [14].

Micro-Level Mechanism: Social Connection

At the micro level, HCPP aims to enhance community facilities and organize collective activities. The regression results in Table 5 (Panel A) indicate that the policy promotes residents' social activities. Furthermore, Panel B shows that more frequent social participation significantly reduces suicidal tendencies, which can show the mediating effect of social interaction.

This result supports Hypothesis 2, which proposed that the HCPP reduces suicide risk by promoting social interaction among middle-aged and older adults in cities. As noted by Oyama et al. [15], social and leisure activities within communities reconstruct better interpersonal connections among the elderly. Social interaction enhances community cohesion and provides essential emotional support, which effectively alleviates loneliness and reduces the psychological stress that leads to suicidal ideation [14, 16].

In conclusion, the mechanism analysis verifies that HCPP lowers suicide tendencies via a dual-pathway mechanism: fostering social connection at the micro level and expanding urban green space at the macro level. This validation demonstrates that the HCPP is a comprehensive intervention that successfully reduces residents' suicidal tendency by fusing social support with environmental enhancements.

Sensitivity Analysis

To further ensure the accuracy of the analysis, this study employed sensitivity analysis to quantify the severity of the omitted variable bias. Considering the significant impact of self-rated health on individual mental health [29], self-rated health (SRH) was used as the benchmark variable. This means that if the explanatory power of the omitted variable is less than self-rated health, the study's estimates are valid. As shown in Table 6, RV_q values indicate that in the worst case, omitted variables must

additionally explain 2.2% of the residuals to negate the observed HCPP inhibitory effects. Moreover, the partial R^2 of the confounder with the treatment ($R^2_{dz,x}$) is extremely close to zero, indicating that the policy implementation is largely exogenous to health confounders. Furthermore, visualization in Figure 2 shows the robustness of our findings. Figure 2(a) illustrates that while the presence of an omitted variable three times stronger than self-rated health would slightly lower the estimated magnitude of the coefficient, Figure 2(b) confirms that the result remains highly significant (t-statistic = -2.94 at 3x SRH), well beyond the critical threshold. This indicates that the presence of omitted variables does not interfere with the baseline results, supporting the reliability of the baseline findings.

DISCUSSION

This study fills a critical gap in the empirical literature by leveraging China's Healthy City Pilot Policy (HCPP) as a quasi-natural experiment to establish a causal link between macro-environmental determinants and suicidal tendencies among middle-aged and older adults in cities. While previous research has largely relied on observational designs, which are vulnerable to residential self-selection bias, we use a rigorous Difference-in-Differences (DID) framework to longitudinal CHARLS data from 2011 to 2020. It can provide robust evidence that proactive systemic urban governance can effectively inhibit suicidal tendencies with a net reduction effect of 0.084 units.

Theoretically, these findings verify the Socio-ecological Systems Theory (SEST) by demonstrating that suicide risk is not only an individual manifestation but is also structured by modifiable macro-environmental factors. By treating the HCPP as an external shock, we deconstructed the dual-pathway mechanism through which systematic urban planning operates: at the macro level, it optimizes green infrastructure to reduce residents' stressful emotions; at the micro level, it fosters social connections to alleviate social role loss. This dual intervention effectively reduces the neuroinflammation and social isolation, which will lead to suicidal ideation. This finding is also aligned with the "Neurourbanism" perspective, which advocates for restorative physical and social urban environments.[30]

Furthermore, the heterogeneity analysis reveals that such systemic interventions can mitigate health inequalities. The policy provides compensation for low-income groups by providing better public goods, while facilitating lifestyle upgrading for high-income individuals. The significant benefits are also observed among the working population and men, highlighting the potential need for urban planning to alleviate occupational stress.

Despite these significant contributions, it is important to recognize some limitations of this study. First, rather than using clinical diagnoses or records of suicide attempts, the assessment of suicidal tendency was based on a single item from the CES-D scale. It

is possible that our estimates may be less accurate because it is a proxy for suicide risk rather than a clinical result. Second, using self-reported data raises the possibility of social desirability bias and recollection bias, since respondents could be reluctant to admit extreme psychological suffering. Third, unobserved time-varying factors may still affect outcomes even when the DID paradigm controls for time-invariant confounders.

In conclusion, this research proves that systematic urban governance is a powerful, modifiable determinant for population-level suicide prevention, offering a scalable model for countries to reduce suicidal tendency with the dual challenges of rapid urbanization and an aging population.

IMPLICATIONS

Regarding clinical and public health implications, urban planning should prioritize social community development over just expanding infrastructure. In order to prevent geriatric suicide, governments should use public spaces like parks and community centers to promote group physical and social activities. This is because fostering social capital and community cohesion should be viewed as an intervention as important as traditional medical treatments.

Furthermore, it is essential to implement targeted interventions tailored to the unique characteristics of specific vulnerable demographic groups. To optimize the compensating effect, the government must guarantee the availability and gratuitousness of health and recreational facilities for low-income groups. In keeping with the healthy urban design concepts promoted by Giles-Corti et al. (2016) [31], urban design could further encourage active commuting infrastructure to incorporate stress alleviation into everyday routines for the working population.

Finally, policymakers should establish a long-term mental health monitoring mechanism. Given the observed demand for upgrading in higher socioeconomic groups, future Healthy City constructions should systematically incorporate mental health indicators into the core evaluation criteria. This comprehensive approach ensures that urban areas can continuously develop into truly psychologically restorative cities.

Data Availability: Data are available in a public, open access repository. Data used in this study are available from the CHARLS website (https://charls.charlsdata.com/pages/data/111/en.html).

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Contributors: Hu Chun-Chieh and Wen Xiaoai both designed the study, cleaned the data, performed the statistical analyses, and interpreted the results. All authors contributed to the writing and revisions and have approved the submission.

Additional Information

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Ethics approval and informed consent: As this study utilized publicly available, anonymized secondary data from the China Health and Retirement Longitudinal Study (CHARLS), the requirement for new ethical approval was waived. The original

CHARLS study was approved by the Biomedical Ethics Review Committee of Peking University, and all participants provided written informed consent prior to participation. All methods were carried out in accordance with relevant guidelines and regulations.

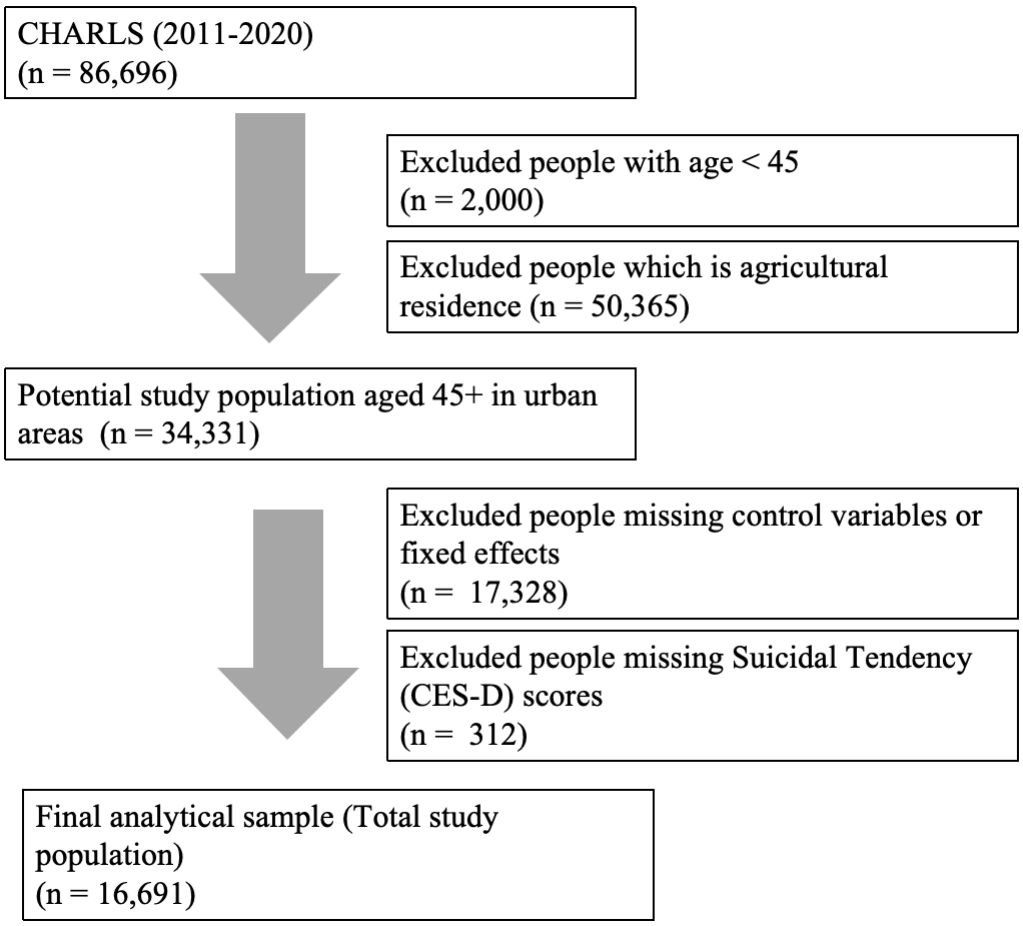


Figure 1. Flowchart of the sample selection process.

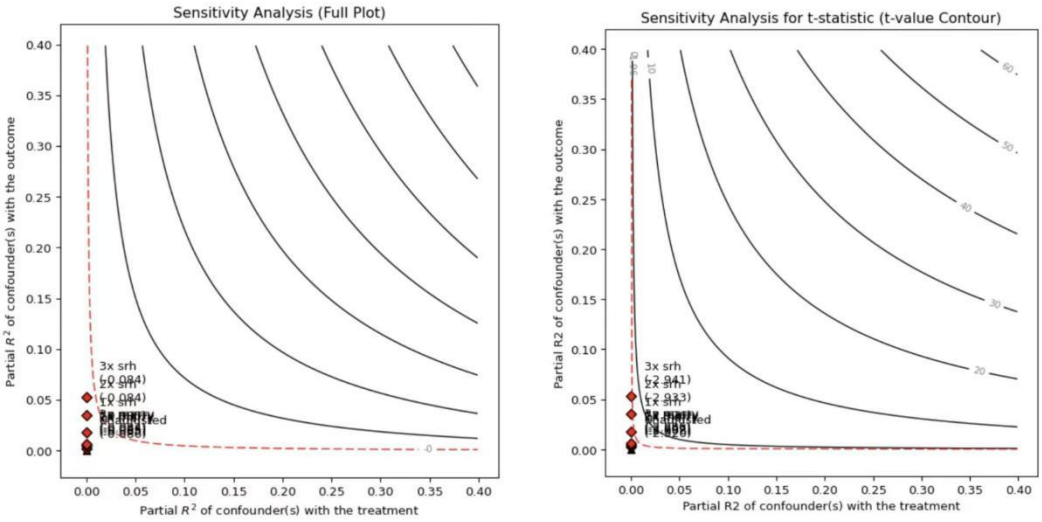


Figure 2: Sensitivity analysis contour. (a) Contour plot for the point estimate; (b) Contour plot for the t-statistic. The red dashed line in (b) represents the threshold where the t-statistic becomes statistically insignificant (at the 5% level). Black dots indicate the omitted variable that could explain the residual from estimation at

different levels: no omitted variable/one time/two times/three times as self-rated health.

Table 1: Descriptive Statistics of the Total Raw Sample

Variables	Definition	Obs	Mean	S.D.	Min	Max
Individuals						
Suicidal tendency	Score on "I feel I could not get going" (1–4)	77140	1.36	0.821	1	4
Gender	Male = 1; Female = 0	85386	0.477	0.499	0	1
Marital status	Married = 1; Other = 0	85380	0.865	0.342	0	1
Family Income	Household income per capita, deflated by the 2011 CPI index and logarithmized	49685	8.562	1.63	-1.151	14.871
Work status	Currently working = 1; Other = 0	85386	0.644	0.479	0	1
Recidence	Agricultural = 1; Non-agricultural = 0	85386	0.588	0.492	0	1
Hukou type	Agricultural Hukou = 1; Non-agricultural = 0	81492	0.765	0.424	0	1
Education	Level of education (1–4)	85327	2.036	1.058	1	4
Number of children	Number of living children	85386	2.571	1.38	0	15
Retirement	Retired = 1; Other = 0	84560	0.148	0.355	0	1
ADL	The higher the score, the worse the ability to perform activities of daily living (ADL)	84105	0.398	1.049	0	6
Smoking	Current smoker = 1; Other = 0	81575	0.261	0.439	0	1
Drinking	Current drinker = 1; Other = 0	85271	0.347	0.476	0	1
Self-rated health	Self-rated health score (1–5)	80550	3.057	0.981	1	5
Mediator						
Green	Green coverage rate in built-up areas (%)	565	40.396	4.657	19.63	57.1
Road	Road area per capita (square meter)	565	17.34	6.895	4.04	46.04
SO_2	Industrial sulfur dioxide	541	44766.16	57053.59	424	531340

	emissions (tons)					
Medical	Number of hospitals/health centers per capita	452	0.442	0.349	0.054	3.108
PM2.5	Annual mean PM2.5 concentration (μg/m³)	565	48.153	18.802	15.04	108.393
Physical	Frequency/Score of exercise activities (0–8)	86696	0.791	1.014	0	8
Social	Frequency/Score of social activities (0–11)	86696	0.697	1.068	0	9

Note: This table includes all observations in the dataset without any exclusion criteria.

Table 2: Descriptive Statistics of the Final Analytical Sample

Variables	Obs	Mean	S.D.	Min	Max
Suicidal tendency	16691	1.292	0.746	1	4
Gender	16691	0.453	0.498	0	1
Marital status	16691	0.844	0.363	0	1
Family Income	16691	9.224	1.447	-0.746	14.871
Work status	16691	0.457	0.498	0	1
Recidence	16691	0	0	0	0
Hukou type	16691	0.482	0.5	0	1
Education	16691	2.330	1.122	1	4
Number of children	16691	2.379	1.302	0	10
Retirement	16691	0.362	0.481	0	1
ADL	16691	0.302	0.86	0	6
Smoking	16691	0.236	0.424	0	1
Drinking	16691	0.342	0.475	0	1
Self-rated health	16691	3.096	0.943	1	5
Mediator					
Green	16691	40.71	4.642	19.63	57.1
Road	16691	17.627	6.949	4.04	46.04
SO2	15460	37428.212	56347.161	424	531340
Medical	11171	0.423	0.32	0.054	3.108
PM2.5	16691	44.725	18.133	15.04	108.393
Physical	16691	0.958	1.105	0	8
Social	16691	0.712	1.12	0	9

Note: The sample is restricted to urban residents aged 45+. Observations with missing values have been excluded.

Table 3: Baseline Model Results and PSM-DID Results

	(1)	(2)	(3)	(4)	(5)
VARIABLES	Suicide	Suicide	Suicide	Suicide	Suicide

Treat × Post	-0.079**	-0.082***	-0.080***	-0.084***	-0.069**
	(0.033)	(0.029)	(0.029)	(0.029)	(0.029)
City Fixed Effect	NO	YES	NO	YES	YES
Year Fixed Effect	NO	NO	YES	YES	YES
Control	YES	YES	YES	YES	YES
Observations	16,691	16,691	16,691	16,691	16690
R-squared	0.115	0.131	0.116	0.132	0.103

*Note: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors are in parentheses.

Table 4: Heterogeneity Analysis

	(1)	(2)	(3)	(4)	(5)
	Low Income	High Income	Low Edu	Working	Male
Treat × Post	-0.247**	-0.070**	-0.143***	-0.151***	-0.121***
	(0.109)	(0.029)	(0 .065)	(0.055)	(0.038)
Observations	2853	8935	5471	7629	7563
R-squared	0.119	0.094	0.138	0.099	0.127

*Note: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors are in parentheses. Standard errors are in parentheses. Control variables and Fixed Effects are included but not reported.

Table 5: Mechanism Analysis

Panel A: Impact of HCPP on Mechanism Variables

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Road	Green	SO_2	Medical	PM2.5	Social	Physical
Treat × Post	-2.341***	0.407***	-8489.671***	0.145***	-4.857***	-0.088*	-0.030
	(0.097)	(0.068)	(1209.123)	(0.006)	(0.227)	(0.048)	(0.050)
Observations	17003	17003	15759	11483	17003	17003	17003
R-squared	0.867	0.796	0.682	0.560	0.941	0.293	0.127

Panel B: Mechanism Analysis on Suicidal Tendency

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Road	Green	SO_2	Medical	PM2.5	Social Act	Physical
Road	-0.0003						
	(0.002)						
Treat × Post	-0.085***	-0.081***	-0.061**	-0.043	-0.089***	-0.085***	-0.085***
	(0.030)	(0.029)	(0.031)	(0.037)	(0.029)	(0.029)	(0.029)
Green		-0.007***					
		(0.003)					
SO_2			-0.0000002				
			(0.000)				

Medical				-0.018			
				(0.034)			
PM2.5					-0.001		
					(0.001)		
Social						-0.011**	
						(0.005)	
Physical							-0.013***
							(0.005)
Observations	16691	16691	15460	11171	16691	16691	16691
R-squared	0.126	0.127	0.127	0.119	0.126	0.126	0.127

*Note: *** p<0.01, ** p<0.05, * p<0.1. Robust standard errors are in parentheses

Table 6: Sensitivity analysis results.

Variable	Suicidal Tendency
R2yd.x	0.001
RV_q	0.022
R2dz.x	
1 * self-rated health	0.000001
2 * self-rated health	0.000003
3 * self-rated health	0.000004
R2yz.dx	
1 * self-rated health	0.0176
2 * self-rated health	0.0352
3 * self-rated health	0.0529