



Research paper

# The impact of neighborhood environment on adolescent anxiety and depression: A moderated mediation model involving screen time and family function

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## ABSTRACT

**Objective:** While the relationship between neighborhood environment and adolescent mental health is well-documented, few studies have examined the roles of screen time and family function in this association. This study aims to explore the “environment-behavior-health” pathway by investigating how neighborhood environment, screen time, and family function jointly influence adolescent anxiety and depression.

**Method:** Data were drawn from a large-scale, two-wave survey of 5th–12th grade Chinese adolescents. A moderated mediation model was constructed to examine whether screen time mediates the relationship between neighborhood environment and adolescent anxiety and depression, and whether this indirect effect is moderated by family function.

**Results:** The final sample included 8961 Chinese adolescents. Neighborhood environment was negatively associated with adolescents' screen time ( $b = -0.513, p < 0.001$ ), anxiety ( $b = -0.984, p < 0.001$ ) and depression ( $b = -1.357, p < 0.001$ ). Screen time partially mediated the effects of neighborhood environment on anxiety ( $b = -0.048, 95\% \text{ CI } [-0.075, -0.025]$ ) and depression ( $b = -0.068, 95\% \text{ CI } [-0.102, -0.039]$ ). Moreover, family function significantly moderated the association of neighborhood environment with anxiety ( $b = -0.441, p < 0.01$ ) and depression ( $b = -0.401, p < 0.05$ ), as well as the association of screen time with anxiety ( $b = -0.055, p < 0.01$ ) and depression ( $b = -0.051, p < 0.05$ ).

**Conclusion:** These findings extend the “environment-behavior-health” framework and highlight the need for multi-level strategies to support adolescent mental health.

## 1. Introduction

Adolescence is a pivotal stage of development characterized by profound emotional and social changes that heighten vulnerability to mental health issues. Among these, anxiety and depression are the most prevalent and frequently co-occurring conditions in this age group (World Health Organization [WHO], 2024). Almost 20 % of adolescents meet the diagnostic criteria for anxiety disorders, and the prevalence of depression is estimated to be 14.3 % (Barker et al., 2019). These disorders are not only common but also among the leading causes of illness

and disability in adolescence (WHO, 2024). They can severely impact adolescents' academic performance, social engagement, risk-taking behaviors, and jeopardize long-term health outcomes, thereby placing a significant burden on families and society (Tang et al., 2022; Zhou et al., 2024). These serious consequences underscore the urgent need to identify associated risk and protective factors and to implement effective intervention strategies.

Previous research has primarily focused on individual-level factors influencing adolescent mental health, with psychological therapy or pharmacological treatment commonly recommended for anxiety and

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depression (Barker et al., 2019). While these interventions remain essential components of mental health care, the continued rise in the prevalence of adolescent anxiety and depression has prompted growing attention to the broader contextual factors that also shape mental health outcomes (Franić et al., 2010). According to social ecological theory, health is influenced not only by individual behaviors but also by the surrounding environments (Stokols, 1996). Building on this perspective, this study aims to examine how neighborhood environments affect anxiety and depression among Chinese adolescents, focusing on the potential mediating role of adolescent screen time and the moderating role of family function in this relationship.

### 1.1. Neighborhood environment and adolescent mental health

The growing shift toward environment-based explanations has sparked interest in how local neighborhoods influence individuals' mental health and well-being (Lund et al., 2018; Nordbø et al., 2020). Research across various countries has consistently shown a link between neighborhood environments and multiple mental health outcomes such as anxiety and depression (Sui et al., 2022). Generally, neighborhoods that are safe, visually appealing, equipped with diverse walking and cycling paths, and maintain accessible public spaces are associated with lower rates of anxiety and depression in children and adolescents (Nordbø et al., 2020; Stirling et al., 2015). In contrast, neighborhoods lacking these amenities and resources can increase the risk of anxiety and depressive symptoms among young people (Nordbø et al., 2020; Stirling et al., 2015).

While most existing research in urban studies has measured neighborhood environments using objective indicators like land-use data or remote sensing images (Dai et al., 2024; Ettema and Schekkerman, 2016), subjective approaches, such as questionnaires and open-ended interviews, are increasingly recognized as valuable tools (Peters et al., 2020; Wang et al., 2019). Subjective perceptions of neighborhood characteristics can provide a more comprehensive and accurate assessment of residents' experiences, exposure, and interactions with their environment, which may exert a stronger influence on mental health compared to objective measures (Peters et al., 2020). Furthermore, most studies have neglected to evaluate the overall quality of neighborhood environments, often examining individual neighborhood characteristics in isolation rather than assessing the cumulative impact of multiple factors on mental health (Sui et al., 2022). Studies focused on adults suggest that living in an overall high-quality neighborhood is associated with better mental health (Liu et al., 2022; Zhang and Wu, 2021). However, the extent to which this association applies to adolescents, particularly when using subjective measures of neighborhood environments, has not been thoroughly investigated.

### 1.2. The mediating effect of screen time

Social ecological theory points that individual health is shaped by the dynamic interplay between the environment and behavior (Stokols, 1996). It underscores the “environment-behavior-health” mechanism as a key path through which environmental factors affect health outcomes (Glicksman et al., 2013; Zheng et al., 2020). Empirical studies in adult populations have supported this “environment-behavior-health” mechanism, showing that behaviors such as physical activity mediate the relationship between neighborhood conditions and mental health (Gehris et al., 2023; Zheng et al., 2020). However, despite adolescents' heightened sensitivity to environmental influences and behavioral change (Pei et al., 2019; Sui et al., 2022), the mediating role of behavior in this framework remains underexplored in younger populations.

In today's digital era, screen use is an important behavioral factor influencing adolescents' well-being (Odgers and Jensen, 2020). With digital devices becoming integral to daily life, >50 % of children and adolescents globally exceed the two-hour daily screen time recommendation (Tapia-Serrano et al., 2022). The increasing reliance on

screens—through televisions, smartphones, tablets, computers, or video games—has raised concerns about its impact on mental well-being among young people (Shalani et al., 2021). Previous studies have consistently found that excessive screen time is associated with higher levels of depression and anxiety among adolescents (Santos et al., 2023; Tang et al., 2021). Additionally, neighborhood characteristics such as safety, access to facilities, and a sense of belonging have been found to influence adolescents' screen time (Parajára et al., 2020; Shalani et al., 2021). Taken together, these findings support the hypothesis that screen time may serve as a key mediating pathway through which neighborhood environments influence adolescent anxiety and depression.

### 1.3. The moderating effect of family function

Social ecological theory emphasizes that human development occurs within nested and interacting environmental systems, ranging from proximal settings such as family to broader contextual influences such as neighborhoods (Stokols, 1996). Within this framework, family and neighborhood environments do not operate in isolation; instead, they interact to influence adolescent behavioral and health outcomes (Leventhal and Brooks-Gunn, 2000).

Family function refers to how well a family operates, including aspects such as conflict resolution, emotional cohesion, organizational structure, and communication quality (Kazak et al., 2003). As the most immediate and influential context in adolescents' lives, the family plays a central role in shaping daily behaviors and psychological well-being (Nordbø et al., 2020). Empirical evidence shows that well-functioning families provide emotional support, model positive behaviors, and foster a secure home environment, which are associated with reduced screen overuse, increased physical activity, and lower levels of anxiety and depression (Campione-Barr et al., 2025; Ding and Li, 2023; Guerrero-Muñoz et al., 2020). In contrast, dysfunctional family environments have been linked to more risky behaviors and poorer mental health outcomes among children and adolescents (Kao et al., 2014; Scully et al., 2020).

Importantly, family function may not only exert direct effects but also shape how adolescents respond to broader environmental and behavioral influences. Previous studies have found that strong family function can buffer the adverse effects of community violence on adolescent behavioral problems (Deane et al., 2018; McIntosh et al., 2021) and moderate the association between neighborhood disorder and risky sexual behaviors (Orihuela et al., 2020). Beyond environmental interactions, family function may also moderate the behavioral pathways to health, amplifying the protective effects of healthy behaviors or mitigating the harms of risky ones (Carter, 2017; Glanz et al., 2015). For example, a recent study of Chinese children with cancer found that family function significantly interacted with screen time to influence negative emotions (Xu et al., 2025).

Together, these findings suggest that family function may moderate both the environmental and behavioral mechanisms through which neighborhood conditions influence adolescent mental health. However, few studies have examined these variables—neighborhood environment, screen time, family function, and mental health—within a single integrated framework.

### 1.4. The present study

In the context of the digital age, the present study aims to explore the “environment-behavior-health” pathway by investigating how the neighborhood environment impacts mental health through screen time among Chinese adolescents. It further examines how family function moderates the associations between neighborhood environment, screen time, and mental health outcomes.

Adolescent mental health has become an increasing public health concern in China. Recent evidence indicates that 26.17 % of children and adolescents report depressive symptoms and 23.5 % report anxiety

symptoms (Tang et al., 2022; Zhou et al., 2024). However, much of the existing research on the relationship between neighborhood environments and adolescent mental health is based on Western contexts, which may not be directly applicable to Asian settings. For instance, Chinese neighborhoods typically have higher population densities and more frequent interactions between neighbors compared to those in Western countries (Liu et al., 2024b). Moreover, in the United States, 95 % of adolescents had access to smartphones, and 90 % had access to desktop or laptop computers as of 2018 (Moreno et al., 2022), whereas in China, adolescent ownership rates in 2021 were 86 % for mobile phones, 71 % for desktop computers, and 51 % for laptops (Ma and Gu, 2023). These differences in digital access suggest that screen time may have varying impacts on adolescent mental health across social contexts. Additionally, traditional Chinese family structures emphasizing filial piety often lead to greater parental involvement and authority (Tang et al., 2020). These sociocultural differences suggest that the relationships among neighborhood environment, screen time, family function, and adolescent mental health may operate differently in China compared to Western countries. Therefore, it is important to investigate whether these associations can be generalized to Chinese adolescents.

The study hypothesizes that: (1) a more favorable neighborhood environment is associated with lower levels of adolescent anxiety and depression; (2) screen time mediates the relationship between neighborhood environment and adolescent mental health; and (3) family function moderates the associations between neighborhood environment, screen time, and adolescent anxiety and depression.

## 2. Methods

### 2.1. Study design and data

This study adopted a prospective design and collected two-wave data from Nanling County, Anhui Province, China. The sample encompassed all adolescents in grades 5 through 12, drawn from 35 primary schools (grades 5 and 6 only), 27 middle schools, and 6 high schools, with no schools excluded from the study. Adolescents without psychiatric diseases or intellectual or physical disability were eligible to participate. Participation was voluntary, and passive informed consent was obtained from the parents of all participants. Students whose parents declined to provide consent were excluded. Data were collected via self-administered electronic questionnaires, which were completed in school computer rooms under the supervision of school psychology counselors and computer teachers.

At baseline (November 2022 to January 2023), data on neighborhood environment, screen time, family function, and sociodemographic characteristics were collected. A total of 30,386 completed the baseline survey. In the follow-up survey (October to November 2023), mental health outcomes, specifically anxiety and depression, were assessed. A total of 11,533 adolescents participated in the follow-up, yielding a follow-up rate of 37.95 %. The primary reason for the low follow-up rate was that students in grades 6, 9, and 12 during wave 1 had graduated by follow-up. Additionally, school transfers and migration to urban areas further reduced participation. After sequentially excluding individuals with missing data on mental health ( $n = 28$ ), screen time ( $n = 871$ ), neighborhood environment ( $n = 1672$ ), and family function ( $n = 1$ ), a total of 8961 participants were retained for the final analysis.

### 2.2. Measures

#### 2.2.1. Neighborhood environment

The neighborhood environment was assessed using the Physical Activity Neighborhood Environment Scale (PANES), a cumulative measure based on adolescents' self-responses. PANES contains 17 items covering residential density, access to destinations, neighborhood infrastructure, neighborhood safety, social environment, aesthetic qualities, and street connectivity within a 10- to 15-min walk from home

(Sallis et al., 2010). Most items (except items 1 and 11) were rated on a 4-point Likert scale, ranging from 1 (strongly disagree) to 4 (strongly agree), with reverse scores for items 7, 8, 15, and 16. Item 1, originally intended to assess housing type, was recoded to evaluate residential density on a four-point scale (1 = low [apartments or condos of >3 stories]; 2 = low-to-middle [mix of single-family residences and townhouses, row houses, apartments or condos]; 3 = middle-to-high [townhouses, row houses, apartments, or condos of 2–3 stories]; 4 = high [detached single-family housing]). The total score was the mean of all items, excluding item 11, with higher scores indicating a more favorable built environment for physical activity. This scale is one of the most widely used subjective instruments for assessing the built environment (Xu et al., 2016). It is both comprehensive and concise, making it suitable for large-scale use, and has demonstrated good reliability among Chinese children and adolescents across a wide age range—from primary to senior high school (Xu et al., 2016). In this study, the scale also showed acceptable internal consistency, with a Cronbach's alpha of 0.78.

#### 2.2.2. Screen time

Screen time was self-reported by participants, who estimated the time spent on devices such as televisions, computers, tablets, cellphones, or game consoles for entertainment (e.g., watching shows, playing games, using social media, or chatting) on a typical weekday and weekend. These values were weighted across weekdays and weekends to calculate daily screen time using the formula:  $(\text{workday} * 5 + \text{weekend} * 2) / 7$  (in hours).

#### 2.2.3. Family function

Family function was measured using the children's version of the Systemic Clinical Outcome and Routine Evaluation (SCORE) Index of Family Function and Change (Jewell et al., 2013). The 15-item scale assesses three dimensions of family function: strengths and adaptability, overwhelmed by difficulties, and disrupted communication. Items in the first dimension were scored from 1 (very well) to 5 (not at all), while items in the second and third dimensions were reverse-scored so that higher scores indicated poorer family function. The total score was calculated as the mean of all items, ranging from 1 to 5, with lower scores indicating better family function. The scale has demonstrated good reliability among youth aged 8 to 18 years in prior studies (Jewell et al., 2013; Stratton et al., 2014), and demonstrated good reliability in this study (Cronbach's alpha = 0.89).

#### 2.2.4. Anxiety and depression

Anxiety was measured using the General Anxiety Disorder Scale (GAD-7), which contains seven items rated on a 4-point Likert scale (0 = not at all; 1 = several days; 2 = more than half the days; 3 = nearly every day) (Kroenke et al., 2010). The total scores range from 0 to 21, with higher scores indicating greater anxiety. Depression was measured using the Patient Health Questionnaire (PHQ-9), a nine-item tool scored on a 4-point Likert scale (0 = not at all; 1 = several days; 2 = more than half of the days; 3 = nearly every day) (Kroenke et al., 2001). Total scores range from 0 to 27, with higher scores indicating more severe depression. Both the GAD-7 and PHQ-9 have been validated among adolescents and are widely used in clinical and population-based studies (Richardson et al., 2010; Sun et al., 2021). In this sample, both scales demonstrated strong internal consistency, with Cronbach's alpha of 0.92 and 0.90, respectively.

#### 2.2.5. Covariates

Based on previous studies (Liu et al., 2022; Wang et al., 2024), several covariates were included in the analysis: sex (0 = male; 1 = female), grade level (1 = grade 5–6; 2 = grade 7–9; 3 = grade 10–12), singleton status (0 = yes; 1 = no), self-reported family economic status (1 = wealthy; 2 = fair; 3 = poor), health status (1 = excellent; 2 = very good; 3 = good; 4 = fair; 5 = poor), parental marital status (0 = married;

1 = divorced or other), parental education level (1 = primary school or below; 2 = middle school; 3 = high school or above), and paternal and maternal migration status. Parental migration status was determined by asking if the father/mother had been working away (i.e., taken a job away from their hometown and been absent for over six months) (1 = currently working away; 2 = previously worked away; 3 = never worked away).

### 2.3. Statistical analysis

To assess common method bias, Harman's single-factor test was conducted on all the measured items. This analysis identified 15 factors with eigenvalues above 1, with the first factor accounting for 15.94 % of the total variance, well below the critical threshold of 40 %, indicating minimal concern for common method bias (Podsakoff et al., 2012). The variance inflation factor (VIF) was calculated to assess potential multicollinearity. The VIF values for the variables of interest ranged from 1.02 to 1.15, well below the recommended threshold of 5, suggesting no multicollinearity issues (Venkatesh et al., 2012).

Descriptive statistics were first conducted for the full sample. Categorical variables were reported as counts and percentages (%), and continuous variables were reported as means and standard deviations (SD). To examine differences in key variables (i.e., anxiety, depression, screen time, and family function) across sociodemographic characteristics, the Wilcoxon rank sum test and the Kruskal–Wallis H test were

employed due to the non-normal distribution of these key variables. Partial correlation analyses were performed to examine relationships among neighborhood environment, screen time, family function, anxiety, and depression, controlling for all covariates. Mediation analyses were then conducted using the bootstrapping method to test whether screen time mediated the relationship between neighborhood environment and adolescent mental health outcomes. The 95 % confidence interval (CI) for the indirect effects were generated from 5000 bootstrap resamples, with significance determined when the CIs did not include zero (Hayes, 2017). Additionally, moderated mediation analyses were performed to examine whether family function moderated the mediation effect. Simple slope analyses were also used to examine the conditional effects at one SD above and below the mean of family function, evaluating differences in the mediation effect across levels of family function. All analyses were performed using the PROCESS macro (Models 4 and 59) in SPSS 27.0, with statistical significance set at  $p < 0.05$ .

## 3. Results

### 3.1. Sample characteristics

Table 1 shows the characteristics of the sample and the differences in screen time, family function, anxiety and depression across sociodemographic characteristics. In the total sample of 8961, 47.86 % of the

**Table 1**  
Descriptive statistics.

	N (%)	Screen time		Family function		Anxiety		Depression	
		mean ± SD	P value	mean ± SD	P value	mean ± SD	P value	mean ± SD	P value
Total sample	8961 (100)	2.162 ± 2.606		2.186 ± 0.703		5.290 ± 4.919		3.950 ± 4.235	
Sex			0.001 <sup>a</sup>		<0.001 <sup>a</sup>		<0.001 <sup>a</sup>		<0.001 <sup>a</sup>
Male	4672 (52.14)	2.261 ± 2.677		2.152 ± 0.683		3.390 ± 4.086		4.677 ± 4.799	
Female	4289 (47.86)	2.055 ± 2.522		2.224 ± 0.723		4.557 ± 4.310		5.948 ± 4.962	
Grade			<0.001		<0.001		<0.001		<0.001
5-6th grade	2757 (30.77)	2.500 ± 2.756		2.043 ± 0.695		2.762 ± 3.875		3.737 ± 4.513	
7-9th grade	2692 (30.04)	1.980 ± 2.545		2.238 ± 0.740		3.772 ± 4.283		5.039 ± 4.918	
10-12th grade	3512 (39.19)	2.038 ± 2.504		2.259 ± 0.663		5.015 ± 4.202		6.689 ± 4.830	
Singleton			0.925 <sup>a</sup>		0.114 <sup>a</sup>		0.130 <sup>a</sup>		0.094 <sup>a</sup>
Yes	3639 (40.61)	2.158 ± 2.593		2.174 ± 0.709		3.881 ± 4.236		5.187 ± 4.884	
No	5322 (59.39)	2.166 ± 2.614		2.195 ± 0.699		3.995 ± 4.233		5.353 ± 4.942	
Parental marital status			<0.001 <sup>a</sup>		<0.001 <sup>a</sup>		<0.001 <sup>a</sup>		<0.001 <sup>a</sup>
Married	7957 (88.80)	2.118 ± 2.571		2.160 ± 0.694		3.845 ± 4.147		5.167 ± 4.837	
Divorced or widowed	1004 (11.20)	2.514 ± 2.841		2.397 ± 0.738		4.773 ± 4.800		6.228 ± 5.435	
Paternal migration status			0.034		<0.001		<0.001		<0.001
Work away from home	2545 (29.08)	2.214 ± 2.698		2.209 ± 0.718		4.026 ± 4.328		5.412 ± 5.105	
Used to work away from home	2940 (33.58)	2.180 ± 2.606		2.230 ± 0.700		4.186 ± 4.291		5.609 ± 4.939	
Never work away from home	3268 (37.34)	2.086 ± 2.473		2.115 ± 0.683		3.626 ± 4.082		4.843 ± 4.700	
Maternal migration status			<0.001		<0.001		<0.001		<0.001
Work away from home	1233 (14.27)	2.520 ± 2.970		2.233 ± 0.715		4.283 ± 4.226		5.667 ± 5.037	
Used to work away from home	2747 (31.79)	2.116 ± 2.618		2.247 ± 0.701		4.224 ± 4.256		5.644 ± 4.939	
Never work away from home	4661 (53.94)	2.053 ± 2.445		2.123 ± 0.692		3.661 ± 4.133		4.922 ± 4.797	
Paternal education level			<0.001		<0.001		0.049		0.009
Primary school or below	1241 (14.17)	2.391 ± 2.677		2.391 ± 2.677		4.172 ± 4.327		5.638 ± 5.089	
Middle school	5430 (62.02)	2.122 ± 2.543		2.122 ± 2.543		3.910 ± 4.153		5.242 ± 4.841	
High school or above	2084 (23.81)	2.079 ± 2.588		2.079 ± 2.588		3.192 ± 4.409		5.167 ± 5.019	
Maternal education level			0.002		<0.001		<0.001		<0.001
Primary school or below	1782 (20.57)	2.189 ± 2.476		2.264 ± 0.699		4.272 ± 4.282		5.751 ± 4.979	
Middle school	5022 (57.96)	2.136 ± 2.567		2.160 ± 0.689		3.816 ± 4.074		5.137 ± 4.785	
High school or above	1860 (21.47)	2.072 ± 2.638		2.160 ± 0.729		4.013 ± 4.608		5.209 ± 5.183	
Family economic status			0.014		<0.001		<0.001		<0.001
Wealthy	2068 (24.07)	2.248 ± 2.707		2.083 ± 0.721		3.701 ± 4.363		4.920 ± 5.056	
Moderate	5381 (62.64)	2.095 ± 2.517		2.172 ± 0.674		3.867 ± 4.088		5.169 ± 4.718	
Poor	1142 (13.29)	2.297 ± 2.750		2.444 ± 0.739		4.851 ± 4.635		6.595 ± 5.420	
Health status			<0.001		<0.001		<0.001		<0.001
Excellent	2318 (26.98)	2.112 ± 2.591		1.904 ± 0.674		2.709 ± 3.750		3.613 ± 4.314	
Very good	2565 (29.86)	2.102 ± 2.491		2.079 ± 0.618		3.301 ± 3.663		4.517 ± 4.117	
Good	2239 (26.06)	2.032 ± 2.411		2.299 ± 0.627		4.451 ± 4.207		5.895 ± 4.731	
Fair	1311 (15.26)	2.462 ± 2.799		2.606 ± 0.698		6.119 ± 4.718		8.120 ± 5.625	
Poor	158 (1.84)	3.057 ± 4.288		2.996 ± 0.853		8.025 ± 5.685		10.171 ± 6.459	

Note: SD: standard deviation. <sup>a</sup> Indicates that the Wilcoxon rank sum test was used for this variable; all other p-values were calculated using Kruskal–Wallis H tests.

participants were girls. Participants were distributed across educational stages, with 30.77 % in primary school (grades 5–6), 30.04 % in junior high school (grades 7–9), and 39.19 % in high school (grades 10–12). The majority of adolescents had siblings (59.39 %) and lived with married parents (88.80 %). More than half of adolescents reported coming from families with a moderate economic status (62.64 %). Adolescents' self-reported health statuses varied, with 26.98 % rating their health as excellent and 1.84 % as poor. Parental education levels were relatively low, with 62.02 % of fathers and 57.96 % of mothers having completed middle school. Most parents had never taken jobs outside their hometown, with 37.34 % of fathers and 53.94 % of mothers never being away for over six months.

In our sample, participants reported an average daily screen time of 2.162 h (SD = 2.606). Screen time was generally longer among males, younger adolescents, left-behind adolescents, those in poor health, those with divorced or widowed parents, and individuals from socioeconomically disadvantaged backgrounds. The mean family function score was 2.186 (SD = 0.703), while average scores for anxiety and depression were 3.950 (SD = 4.235) and 5.290 (SD = 4.919), respectively. Higher scores in family function, anxiety, and depression—indicating poorer family environments and mental health—were more common among females, older adolescents, and those with absent or less-educated parents, as well as those from lower-income households.

3.2. Correlation tests

As shown in Table 2, the neighborhood environment was negatively correlated with adolescents' screen time ( $r = -0.068, p < 0.01$ ), family function ( $r = -0.286, p < 0.01$ ), anxiety ( $r = -0.087, p < 0.01$ ), and depression ( $r = -0.105, p < 0.01$ ). Screen time was positively correlated with family function ( $r = 0.143, p < 0.01$ ), anxiety ( $r = 0.064, p < 0.01$ ), and depression ( $r = 0.080, p < 0.01$ ). Family function showed a positive correlation with both anxiety ( $r = 0.281, p < 0.01$ ) and depression ( $r = 0.300, p < 0.01$ ). Additionally, higher levels of anxiety were strongly linked to higher levels of depression ( $r = 0.849, p < 0.01$ ).

3.3. Mediation analyses

Table 3 Panel A shows that the neighborhood environment was negatively associated with both anxiety ( $b = -0.984, p < 0.001$ ) and depression ( $b = -1.357, p < 0.001$ ). Moreover, neighborhood environment was also negatively related to adolescents' screen time ( $b = -0.513, p < 0.001$ ), which, in turn, was positively associated with both anxiety ( $b = 0.093, p < 0.001$ ) and depression ( $b = 0.132, p < 0.001$ ). As presented in Table 4, bootstrap analysis indicated significant indirect effects through screen time in the associations between neighborhood environment and anxiety ( $b = -0.048, 95\% \text{ CI } [-0.075, -0.025]$ ) and depression ( $b = -0.068, 95\% \text{ CI } [-0.102, -0.039]$ ). These findings suggest that screen time partially mediated the associations between neighborhood environment and mental health, accounting for approximately 4.6 % of the total effect on anxiety and 4.8 % on depression.

Table 2  
Partial correlations analyses of interested variables.

	1	2	3	4	5
1. Neighborhood environment	1				
2. Screen time	-0.068***	1			
3. Family function	-0.286***	0.143***	1		
4. Anxiety	-0.087***	0.064***	0.281***	1	
5. Depression	-0.105***	0.080***	0.300***	0.849***	1

Note: Partial correlation analyses were conducted, controlling for sex, grade, singleton status, family economic status, health status, parental marital status, parental education level, and parental migration status.

\*\*\*  $p < 0.001$  (2-tailed).

Table 3  
Results of the moderated mediation analyses.

Predictor	Panel A						Panel B								
	Model 1: Screen time		Model 2: Anxiety		Model 3: Depression		Model 1: Screen time		Model 2: Anxiety		Model 3: Depression				
	b	SE	b	SE	b	SE	b	SE	b	SE	b	SE			
Sex	-0.310	0.057	0.091	0.091	1.014	0.103	<0.001	-0.319	0.057	0.948	0.087	<0.001	0.999	0.099	<0.001
Grade	-0.295	0.035	0.056	0.056	1.151	0.064	<0.001	-0.308	0.035	0.837	0.054	<0.001	1.080	0.061	<0.001
Singleton	0.070	0.060	0.087	0.094	0.156	0.107	0.146	0.057	0.059	0.050	0.091	0.583	0.112	0.103	0.278
Parental marital status	0.227	0.113	0.044	0.177	0.044	0.202	<0.001	0.131	0.112	0.593	0.172	0.001	0.714	0.195	<0.001
Paternal work status	0.062	0.043	0.150	0.068	-0.106	0.078	0.172	0.070	0.043	0.003	0.066	0.961	-0.071	0.075	0.338
Maternal work status	-0.219	0.049	<0.001	0.078	0.004	0.088	0.018	-0.204	0.049	-0.184	0.075	0.014	-0.163	0.085	0.055
Paternal education level	-0.111	0.055	0.041	0.086	-0.053	0.098	0.590	-0.113	0.054	-0.043	0.083	0.604	-0.065	0.094	0.489
Maternal education level	-0.034	0.052	0.509	0.182	0.149	0.093	0.107	-0.037	0.051	0.170	0.078	0.030	0.135	0.089	0.129
Family economic status	-0.090	0.050	0.069	0.078	-0.018	0.089	0.843	-0.118	0.049	-0.155	0.075	0.040	-0.130	0.086	0.128
Health status	0.121	0.028	<0.001	0.829	0.069	0.050	<0.001	0.027	0.029	0.533	0.044	0.000	0.713	0.050	<0.001
Neighborhood environment	-0.513	0.085	<0.001	-0.984	0.134	0.152	<0.001	-0.113	0.240	-0.879	0.368	0.017	-0.601	0.418	0.151
Screen time			0.093	0.018	0.132	0.020	<0.001			0.171	0.055	0.001	0.191	0.063	0.002
Family function								0.668	0.303	3.077	0.470	<0.001	3.288	0.534	<0.001
Neighborhood environment × Family function								-0.051	0.104	-0.441	0.160	0.006	-0.401	0.181	0.027
Screen time × Family function															
F value		16.808***				129.874***			24.773***						
R <sup>2</sup>		0.023				0.164			0.039						
															157.210***
															0.229

Note: SE: standard error.  
\*\*\*  $p < 0.001$ .

**Table 4**  
Conditional effects at different levels of family function.

Outcomes	Effects	Levels of moderator	b	Boot SE	95 % confidence interval	
					Lower	Upper
Anxiety	Total indirect effect		-0.048	0.013	-0.075	-0.025
		Well (-1 SD)	0.229	0.172	-0.108	0.566
	Conditional direct effect	Moderate (mean)	-0.078	0.134	-0.341	0.185
		Poor (+1 SD)	-0.385	0.177	-0.731	-0.039
		Well (-1 SD)	-0.017	0.012	-0.045	0.001
		Conditional indirect effect	Moderate (mean)	-0.012	0.007	-0.027
	Poor (+1 SD)	-0.003	0.008	-0.022	-0.001	
	Total indirect effect		-0.068	0.016	-0.102	-0.039
Depression		Well (-1 SD)	0.010	0.195	-0.372	0.392
		Conditional direct effect	Moderate (mean)	-0.269	0.152	-0.567
		Poor (+1 SD)	-0.548	0.200	-0.941	-0.156
		Well (-1 SD)	-0.022	0.014	-0.053	0.001
	Conditional indirect effect	Moderate (mean)	-0.018	0.009	-0.037	-0.003
		Poor (+1 SD)	-0.011	0.010	-0.036	-0.003

Note: SD: standard deviation; SE: standard error.

3.4. Moderated mediation analyses

As shown in Table 3 Panel B and Fig. 1, the interaction between neighborhood environment and family function was significantly associated with anxiety ( $b = -0.441, p < 0.01$ ) and depression ( $b = -0.401, p < 0.05$ ), but not with screen time ( $b = -0.051, p = 0.622$ ). The interaction between screen time and family function was also significantly associated to anxiety ( $b = -0.055, p < 0.01$ ) and depression ( $b = -0.051, p < 0.05$ ). Fig. 2 further illustrates these results, showing predicted levels of anxiety and depression in relation to neighborhood environment for adolescents from well- and poorly-functioning families. For adolescents from poorly-functioning families (+1 SD), neighborhood environment had significant effects on anxiety ( $b = -0.385, 95\% \text{ CI } [-0.731, -0.039]$ ) and depression ( $b = -0.548, 95\% \text{ CI } [-0.941, -0.156]$ ), whereas these effects were non-significant for those from well-functioning families (-1 SD; see Table 4). Similarly, the indirect effects of screen time were significant among adolescents from poorly-functioning families (+1 SD; anxiety:  $b = -0.012, 95\% \text{ CI } [-0.027, -0.001]$ ; depression:  $b = -0.018, 95\% \text{ CI } [-0.037, -0.003]$ ), but not among those from well-functioning families (+1 SD). These results

indicate that poor family function intensified the impact of neighborhood environment and screen time on adolescent anxiety and depression.

4. Discussion

In response to growing concerns over adolescent mental health, this study drew on large-scale, two-wave data from Chinese adolescents to examine how neighborhood environment, screen time, and family function jointly influence anxiety and depression. Guided by social ecological theory, our findings reveal that neighborhood environment significantly influences mental health outcomes, with screen time acting as a partial mediator. This underscores the importance of considering lifestyle behaviors within the “environment-behavior-health” framework. Notably, family function moderated both direct and indirect pathways, highlighting the interplay between proximal (family) and distal (neighborhood) environmental systems, as well as the interaction between individual behavior and context. To our knowledge, this study is the first to simultaneously investigate these factors within a single model, offering new insights into the mechanisms linking environment

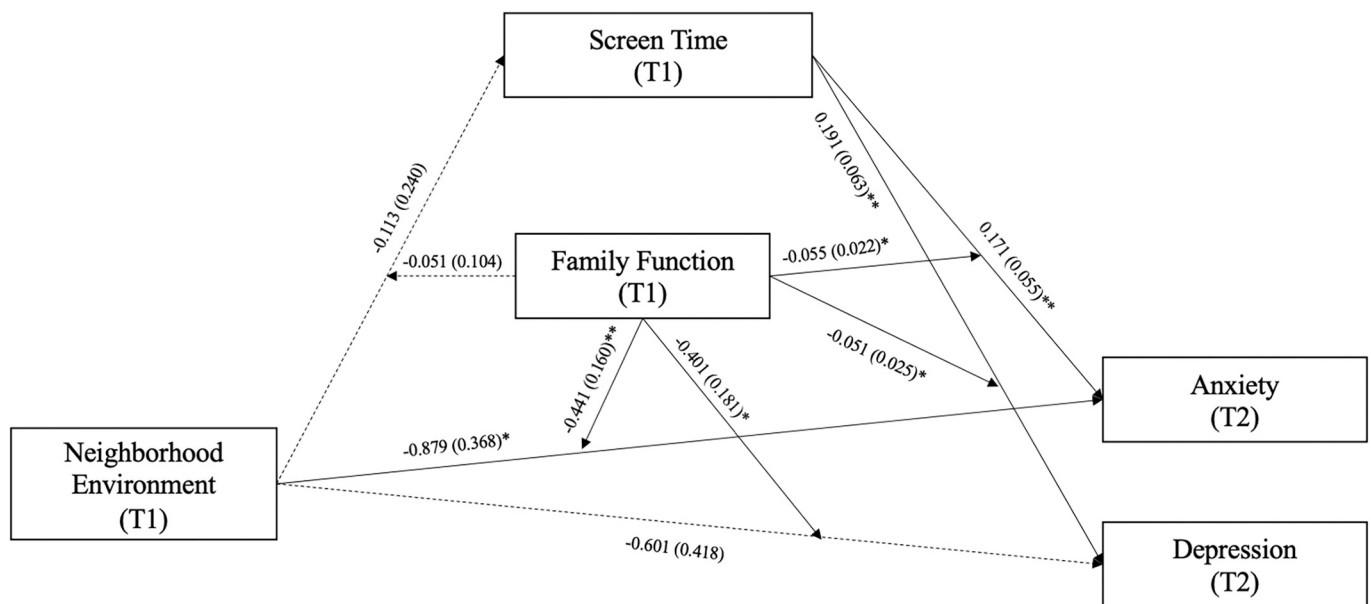


Fig. 1. Moderated mediation model

Note: T1 refers to the baseline survey conducted between November 2022 and January 2023, and T2 refers to the follow-up survey conducted between October and November 2023. \* $p < 0.05$ , \*\* $p < 0.01$ , \*\*\* $p < 0.001$ .

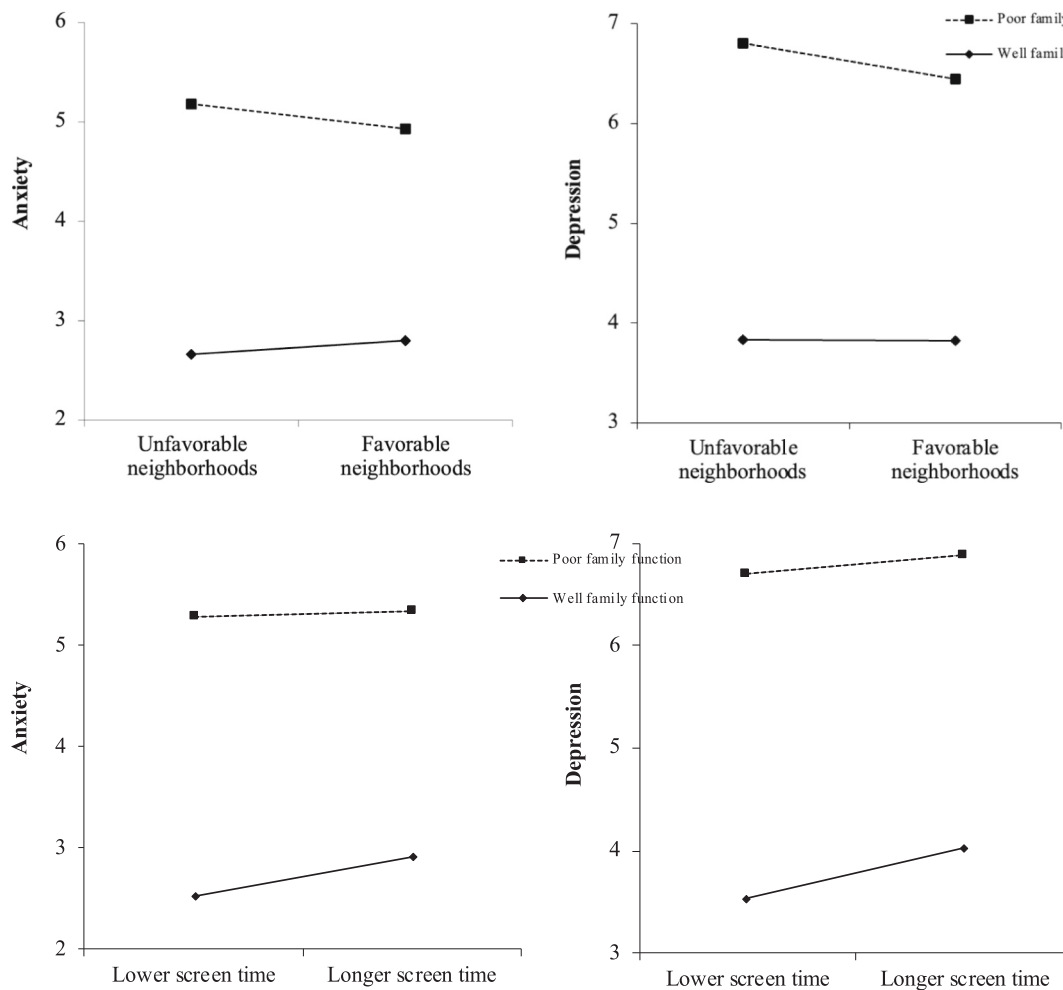


Fig. 2. Family function as a moderator in the associations of neighborhood environment with anxiety and depression.

and adolescent mental health.

Our study found a significant negative association between adolescents' perceived neighborhood environment and their levels of anxiety and depression, consistent with prior research on neighborhood influences and adolescent mental health (Nordbø et al., 2020; Stirling et al., 2015). This finding reinforces the role of neighborhood context as a key social determinant of adolescent mental well-being. In our sample, the average depression score (5.290) exceeded the threshold of 5 for mild depression (Kroenke et al., 2010), suggesting substantial mental health concerns. Notably, a one-point increase in the neighborhood environment score was associated with a 1.357-point reduction in depression scores, potentially shifting average levels below the clinical threshold. Well-designed neighborhoods may thus serve as a modifiable target for reducing adolescent anxiety and depression. Compared to adult populations, this effect may be more pronounced in adolescents, who spend more time in their residential surroundings and are more sensitive to environmental conditions (Liu et al., 2022; Sui et al., 2022; Zhang and Wu, 2021). Importantly, improving neighborhood conditions may offer a scalable and population-level strategy to enhance adolescent mental health (Lund et al., 2018).

The finding that screen time partially mediates the relationship between neighborhood environment and adolescent mental health highlights the role of individual behavior as a key mechanism linking environmental context to psychological outcomes. Previous research has identified various mediators, including environmental exposure, psychological processes, and behavioral mechanisms, in the pathway from environmental to mental health (Dupéré et al., 2012; Liu et al., 2022;

Vanaken and Danckaerts, 2018). Among these, individual lifestyle behaviors, such as screen use, are particularly modifiable and thus offer greater potential for protective interventions (Firth et al., 2020; Gehris et al., 2023). Screen time is commonly perceived as an indoor activity that may be less directly influenced by outdoor environments. However, our findings challenge this view: even indoor behaviors can be shaped by outdoor neighborhood characteristics and subsequently influence mental health. By incorporating screen time—an increasingly prevalent behavior—into our model, our study broadens the “environment-behavior-health” framework (Hoare et al., 2016), highlighting the need to consider both indoor and outdoor behavioral mechanisms.

The family environment, alongside the neighborhood, is a crucial context for adolescent development. Adolescents' living environments are interrelated and often overlap in complex ways (Leventhal and Brooks-Gunn, 2000), highlighting the need to consider both family and neighborhood influences when examining behavioral and emotional outcomes. Building on this perspective, our study revealed a significant interaction between neighborhood environment and family function in shaping adolescent mental health. The protective effect of a favorable neighborhood environment on anxiety and depression was particularly evident among adolescents from families with lower levels of functioning. Lacking emotional support and cohesion at home, these adolescents may seek social engagement in their surrounding community (Lyell et al., 2020), rendering neighborhood conditions especially influential. When both family and neighborhood environments are unsupportive, adolescents may face compounding stressors that intensify psychological vulnerability (Lima et al., 2010; Nurius et al., 2015).

In contrast, adolescents from well-functioning families may derive substantial support from their household environment (Guerrero-Muñoz et al., 2020; Ye et al., 2023), mitigating the influence of neighborhood conditions.

We further found that the adverse impact of prolonged screen time on adolescent mental health was moderated by family function. Specifically, a well-functioning family environment buffered the negative psychological effects of excessive screen use. The interaction underscores the dynamic and reciprocal nature of the “environment–behavior–health” framework, where environmental exposures and behavioral patterns jointly shape adolescent well-being (Carter, 2017). Notably, the mediating role of screen time in the relationship between neighborhood environment and mental health was observed only among adolescents from poorly-functioning families. Combined with the finding that neighborhood-family interaction was not significantly associated with adolescents' screen time, this suggests that the influence of neighborhood conditions on screen time may be diminished in well-functioning families.

Adolescents are naturally drawn to electronic devices, and managing screen time often depends on active parental monitoring and structured family routines (Jones et al., 2021). In poorly functioning families, characterized by low communication and insufficient supervision, screen use may be less regulated, increasing adolescents' exposure to behavioral risks (Liu et al., 2024a). In such cases, the neighborhood environment may exert a greater influence on screen time, thereby indirectly affecting mental health outcomes. Conversely, in well-functioning families, both the behavioral effects of neighborhood exposure and the psychological consequences of excessive screen time appear to be mitigated. These findings collectively highlight the critical role of the family environment in shaping adolescent behavioral pathways and protecting mental health.

#### 4.1. Implications

These findings have several practical implications. First, our results underscore the need for urban planners and policymakers to prioritize youth-friendly neighborhood development. Ensuring that neighborhoods are safe, well-maintained, and equipped with green spaces can significantly enhance adolescent mental health and yield long-term benefits (Nordbø et al., 2020). However, children and adolescents have long been marginalized in policy-making processes, and most existing evidence comes from cities in Europe and the United States (Powell, 2024). By using data from a large sample of Chinese adolescents, this study provides valuable insights into the development of youth-friendly neighborhoods and cities in developing countries.

Second, this study identifies screen time as a key behavioral pathway linking the neighborhood environment to adolescent mental health. Although the indirect effect of screen time was relatively modest (4.6 % for anxiety and 4.8 % for depression), even small effect sizes can be meaningful in the social sciences (Ellis, 2010). Given the pervasive use of digital devices among adolescents (Lu et al., 2021), even a minor reduction in screen time could lead to substantial improvements in mental health, particularly for those in less supportive neighborhood environments.

Third, the interplay between neighborhood environment, screen time, and family function suggests that improving family dynamics could help mitigate the adverse effects of neighborhood disadvantage and excessive screen use. Programs that promote family cohesion, communication, and emotional support could strengthen adolescents' resilience to external stressors and enhance mental well-being (Guerrero-Muñoz et al., 2020). Interventions targeting screen time should also incorporate components that foster supportive and well-functioning family environments.

#### 4.2. Limitations

This study has several limitations. First, focusing exclusively on school-attending adolescents limits the generalizability of the findings to out-of-school youth and other adolescent groups. Second, although data were collected at two time points, and the mediator was assessed concurrently with the independent variable, which may compromise the precision of the mediation analyses (Maxwell and Cole, 2007). Third, although adolescents' subjective assessments of neighborhood environment may better reflect their living experiences, the use of self-reported data rather than objective measures may have introduced social desirability bias. Fourth, retrospective self-reports of screen time might be inaccurate and fail to capture the complexity of adolescents' digital use behaviors. Future research should incorporate multiple measurement waves and combine both subjective and objective assessments of neighborhood environments. It should also employ more comprehensive assessments of screen use behaviors to enhance the validity of findings.

#### 5. Conclusion

Drawing on social ecological theory, this study demonstrates that screen time and family function serve as key mediators and moderators in the association between neighborhood environment and adolescent mental health. Theoretically, these findings extend the “environment–behavior–health” framework by incorporating emerging lifestyle behaviors and emphasizing the “person-in-environment” perspective in child and adolescent research. This study highlights the roles of both distal and proximal environments and the dynamic interplay between context and behavior in shaping health outcomes. Practically, the results provide evidence of the need to develop youth-friendly neighborhoods that promote adolescents' well-being. While living conditions are usually constrained by family economic status, adolescents in disadvantaged neighborhoods may still benefit from improvements in social and behavioral environments. Effective strategies should equip parents to cultivate nurturing home environments and support adolescents in adopting healthy lifestyles that strengthen mental resilience. These findings underscore the importance of a multi-level approach—integrating community development, family support, and individual behavioral interventions—to promote adolescent mental health.

#### CRedit authorship contribution statement

**Qian-Wen Xie:** Writing – original draft, Supervision, Resources, Project administration, Methodology, Funding acquisition, Conceptualization, Writing – review & editing. **Xu Li Fan:** Writing – original draft, Formal analysis, Methodology, Software, Visualization, Writing – review & editing. **Yuan Sun:** Writing – review & editing, Formal analysis. **Yawen Xuan:** Writing – review & editing, Validation. **Jingjing Lu:** Writing – review & editing, Validation, Data curation. **Xudong Zhou:** Writing – review & editing, Funding acquisition, Data curation, Project administration, Supervision.

#### Ethical approval

Ethical approval of this study was obtained from the ethics committee of the School of Public Health, Zhejiang University (project number: ZGL202108–1). Written informed consent was obtained from all subjects and/or their legal guardian(s). All methods in our study were performed in accordance with the guidelines and regulations of Declaration of Helsinki.

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## Declaration of competing interest

The authors declare no competing interest.

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## Data availability

The datasets generated and/or analyzed during the current study are not publicly available but are available from the corresponding author on reasonable request.

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