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# Association between mental health and executive dysfunction and the moderating effect of urban–rural subpopulation in general adolescents from Shangrao, China: a population-based cross-sectional study

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## ABSTRACT

**Objectives** To examine the association between mental health and executive dysfunction in general adolescents, and to identify whether home residence and school location would moderate that association.

**Design** A population-based cross-sectional study.

**Setting** A subsample of the Shanghai Children's Health, Education, and Lifestyle Evaluation-Adolescents project. 16 sampled schools in Shangrao city located in downstream Yangtze River in southeast China (December 2018).

**Participants** 1895 adolescents (48.8% male) which were divided into three subpopulations: (A) adolescents who have urban hukou (ie, household registration in China) and attend urban schools (UU, n=292); (B) adolescents who have rural hukou and attend urban schools (RU, n=819) and (C) adolescents who have rural hukou and attend rural schools (RR, n=784).

**Measures** The Depression Anxiety and Stress Scale-21 was used to assess adolescent mental health symptoms, and the Behaviour Rating Inventory of Executive Function (parent form) was applied to measure adolescent executive dysfunction in nature setting.

**Results** Mental health symptoms were common (depression: 25.2%, anxiety: 53.0%, stress: 19.7%) in our sample, and the prevalence rates were lower among UU adolescents than those among the RR and RU, with intersubgroup differences in screen exposure time explaining most of the variance. We found the three types of symptoms were strongly associated with executive dysfunction in general adolescents. We also observed a marginal moderating effect of urban–rural subgroup on the associations: UU adolescents with depression (OR 6.74, 95% CI 3.75 to 12.12) and anxiety (OR 5.56, 95% CI 1.86 to 16.66) had a higher executive dysfunction risk when compared with RR youths with depression (OR 1.93, 95% CI 0.91 to 4.12) and anxiety (OR 1.80, 95% CI 1.39 to 2.33), respectively.

**Conclusions** Rural adolescents experienced more mental health symptoms, whereas urban individuals with mental health problems had a higher executive dysfunction risk.

## STRENGTHS AND LIMITATIONS OF THIS STUDY

⇒ This is a population-based cross-sectional survey using multistage cluster random sampling method.
⇒ This study investigated the moderating effect of urban–rural subpopulation on the association between mental health and executive dysfunction among general adolescents.
⇒ The data were collected from one relatively low socioeconomic development city in China, and the findings might not be generalisable to the national population.
⇒ The study used subclinical cut-offs of executive dysfunction, and the measures of lifestyle behaviours were based on self-report.
⇒ This is a cross-sectional study, we cannot make causal claims and cannot exclude the possibility that the results may be influenced by residual and unmeasured or unknown factors.

## INTRODUCTION

Mental health disorders are the leading cause of global disability burden among youth, and approximately 21% of adolescents are at risk of some kind of mental disorders such as depression and anxiety.[1] One potential consequence of poor mental health is impairment to executive functions (EFs),[2] which refer to a collection of top-down mental processes against one's bottom-up automatic actions (including three core subcomponents: inhibitory control, working memory and cognitive flexibility) that are necessary to make decisions and engage in purposeful, goal-driven and future-oriented behaviours.[3] Executive dysfunction (EDF), also known as EF impairment, can negatively impact physical health (eg, obesity, overeating and poor treatment adherence),[4 5] result in antisocial behaviour (eg, aggression, violence and and

criminality),[6 7] and hinder academic and career success (eg, poor school readiness and work productivity).[8]

While mental health illnesses can increase the risk of EDF, existing studies have been predominantly focused on clinical patients, such as those suffering from major depressive disorder,[9] and few studies were conducted among general adolescents. Nowadays, more and more adolescents are troubled with mental health problems, a significant percentage of which, however, are subclinical symptoms (ie, those not meeting clinical diagnostic criteria). Given that subclinical symptoms of a psychological illness still meaningfully may increase EF impairment, it is crucial to explore whether mental health symptoms can increase EDF among general adolescents at a population level.

The link between mental health issues and EF in general adolescents was investigated by some studies. One community study recently indicated that depressive status as measured by an epidemiological screening scale was associated with lower cognitive flexibility and selective attention.[10] However, another population-based study including adolescents from both urban and rural areas did not find a significant association.[11] One potential reason for these differences may be that certain social factors, such as adolescent living and study environments, may moderate that link, as the distribution of economic, healthcare and educational resources,[12 13] as well as some lifestyle behaviours (eg, physical activity and screen exposure),[14 15] can vary significantly based on an adolescent's home residence or school location, particularly in developing nations with large urban–rural socioeconomic disparities.[16]

Urban regions typically receive a disproportionately larger share of economic investment and have higher quality of healthcare and educational environments than rural regions, which may mitigate the presence or reduce the impact of their mental health symptoms. Meanwhile, urban regions also have a number of stressors including dense population, as well as traffic and air pollution,[17 18] which may aggravate the mental health and EF relationship. In some contexts, rural adolescents relocating to urban areas with or without their parents (migrant) tend to have worse lifestyle behaviours such as more screen exposure time,[15] and may also face a unique set of adverse circumstances such as social stigma threat from peers,[19] which may in turn impact their mental health and EF. In light of these disparities, it is possible that the associations between mental health symptoms and EDF may differ by adolescent home residence and school location, yet no studies have examined their moderating effects on those associations in general sample.

China is one of the most populous low-income and middle-income countries and has a large number of adolescent students that belong to all three of these subpopulation categories (ie, local urban, local rural and rural–urban migrant), which gave us a unique opportunity to investigate the association between mental health and EDF across different urban–rural subgroups. Specifically, in China, a household registration system (ie, hukou) established officially in 1958 classifies each Chinese citizen as either urban or rural origin according to his/her permanent residential area.[19] By taking into account adolescent hukou and school location, we can define three subgroups: (A) adolescents who have urban hukou and attend urban schools (UU); (B) adolescents who have rural hukou and attend urban schools (RU) and (C) adolescents who have rural hukou and attend rural schools (RR). Therefore, using a population-based Chinese sample, we aimed to measure whether or not the associations between three common mental health symptoms (ie, depression, anxiety and stress) and EDF among general adolescents vary across different urban–rural subpopulations.

## METHODS

### Participants

Participants were part of the Study of the Shanghai Children's Health, Education and Lifestyle Evaluation-Adolescents, which is a population-based cross-sectional survey investigating risk factors of the physical and mental health of general adolescents. This study was conducted in Shangrao (December 2018), a relatively socioeconomically underdeveloped city located in downstream Yangtze River in southeast China. The multistage cluster random sampling method we used was reported in prior study.[20] Briefly, based on the per capita disposable income of Chinese residents in 2016, four districts/counties were selected, and four schools (two lower secondary and two upper secondary) stratified by rural and urban areas were randomly chosen from each district/county, then one class from each grade in the sampled 16 schools was randomly selected, and finally, all students in the selected classes were invited to participate in the survey.

### Main variables

#### Urban–rural subgroups

We obtained the hukou information through parent report and school location data by referring to the official administrative urban–rural designations, and then divided the final sample into three major subpopulations (figure 1): UU (n=292), RU (n=819) and RR (n=784). Due to a small number of adolescents who had urban hukou and attended rural schools (n=14), we did not include them in the current analysis.

#### Mental health symptoms

The Depression Anxiety and Stress Scale-21 that has been validated among the Chinese student population was used to measure three common mental health conditions (ie, depression, anxiety and stress).[21] Each domain has seven items for which adolescents indicated how often they experienced the described symptom in the last week on a 4-point scale from 0 'does not apply to me at all' to 3 'applies to me very much or most of the time'. The score for each domain was summed and multiplied by 2, and

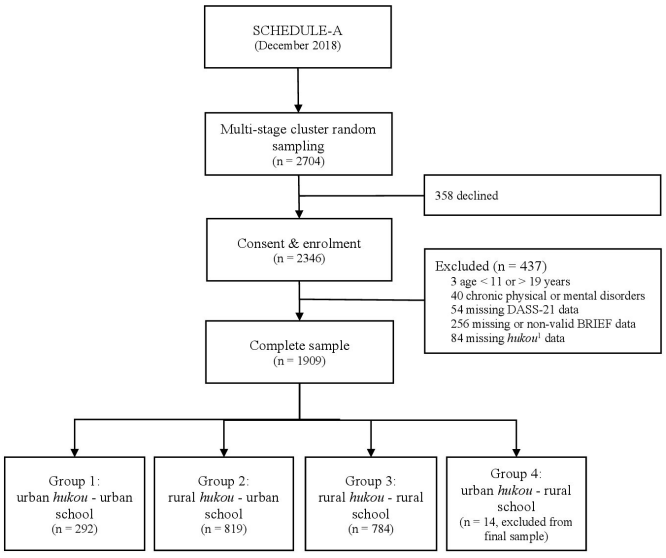


**Figure 1** Flow chart of the participants. One household registration system in China that was established officially in 1958, based on it each Chinese citizen can be classified into urban or rural origin according to his/her permanent residential area. BRIEF, Behaviour Rating Inventory of Executive Function; DASS-21, Depression Anxiety and Stress Scale-21; SCHEDULE-A, the Study of the Shanghai Children's Health, Education and Lifestyle Evaluation-Adolescents.

adolescents who scored 'moderate to extremely severe' by cutoffs of ≥14, ≥10 and ≥19 were classified as having potential depression, anxiety and stress conditions, respectively.

### Executive dysfunction

The Behaviour Rating Inventory of Executive Function (BRIEF) was used to assess adolescent EF performance,[22] which has demonstrated an acceptable reliability and validity among Chinese youth.[23] Unlike the traditional task-based testing conducted by a well-trained professional within a highly structured laboratory, the BRIEF, a questionnaire-based measurement, was designed to capture an individual's everyday behavioural and emotional aspects of EF in nature environment, and is a reliable and practical tool used in a large epidemiological study. In this study, we used the parent report form with 86 items, and for each item, parents were asked to rate their adolescents' specific behaviours in the past 6 months using a 3-point scale (ie, never, sometimes and often). We checked the raw data based on two validity indexes (ie, negativity <5 and inconsistency <7) to reduce reporting bias according to the BRIEF manual. We calculated the overall raw score (ie, global executive composite) by adding up the following eight index scores: inhibit, emotional control, shift, initiate, working memory, plan/organise, organisation of materials and monitor. T-scores were computed based on sex-specific and age-specific norms, and we defined T-scores >60 and >65 as potentially subclinical and clinical EDF, respectively.

### Covariates

Parents or other primary caregivers reported sociodemographic information, including parental education level, gross family income, as well as the adolescent's age, sex and chronic disease history. Adolescents were asked to report their lifestyle behaviours. Screen exposure time was measured by two widely used questions: in the last month, on average, the total time he/she spent per day on (1) sitting and watching television or videos and (2) playing games using device such as cellphone, iPAD, PlayStation, etc.[24] Each response was then dichotomised, with exposure time above 2 hours/day indicating excessive passive and interactive screen time, respectively. The average night sleep duration was calculated by a weighted formula (5×weekdays+2×weekends)/7 based on responses to the questions 'At what time do you usually go to bed and get up on weekdays and weekends, respectively?' We defined shorter sleepers as students whose average night sleep duration was less than 9, 8 and 7 hours for students aged 12–13, 14–17 and ≥18 years, respectively.[25] Physical activity was examined using the short Chinese version of the International Physical Activity Questionnaire, and then categorised into low, moderate and high levels.[26]

### Statistical analysis

Participant characteristics stratified by the three urban–rural subgroups were presented by means (standard deviation, SD) and frequencies (%) and their differences across the subgroups were tested by analysis of variance (ANOVA) or Kruskal-Wallis and $\chi^2$ test for continuous and categorical variables, respectively.

To achieve our objectives, we first explored risk factors of mental health symptoms and EDF using a logistic model with cluster-robust SE. The potential risk factors were urban–rural subgroup, sociodemographic characteristics (ie, age, sex, parental education level and gross family income), and individual behaviours (screen time, night sleep duration and physical activity). Second, we measured the association of urban–rural subgroup and mental health symptoms with sub-clinical EDF (due to a low prevalence of clinical EDF, see table 1). Third, we examined the moderating effect of urban–rural subgroup on the relationship of mental health symptoms and EDF (ie, adding an interactive term in each model, such as RR*depression). Finally, we determined the simple effect of the association between mental health symptoms and EDF stratified by urban–rural subgroup. Furthermore, we also performed a multiple imputation using chained equations with 20 imputed datasets and 10 burn-ins for each dataset to estimate the missing values. To test whether substantial differences existed due to imputation, we compared the results before and after the data imputation.

All data analyses were performed with Stata V.15.0, and $p<0.05$ with two sided was set as statistical significance.

Table 1 Participant characteristics stratified by urban–rural subgroup

| | Total (n=1895) | Urban–rural subgroup | | | | |
|---|---|---|---|---|---|---|
| | | UU (n=292) | RU (n=819) | RR (n=784) | χ2 | P value |
| Sociodemographics | | | | | | |
| Age, years | 15.33±1.76 | 15.53±1.62 | 15.56±1.69 | 15.02±1.83 | 46.86 | **<0.001** |
| Sex | | | | | 1.03 | 0.598 |
| Boys | 925 (48.8) | 144 (49.3) | 409 (49.9) | 372 (47.5) | | |
| Girls | 970 (51.2) | 148 (50.7) | 410 (50.1) | 412 (52.6) | | |
| Parental education level | | | | | 268.24 | **<0.001** |
| Lower than high school | 1338 (72.9) | 118 (41.0) | 606 (76.6) | 614 (81.1) | | |
| High school or higher | 498 (27.1) | 170 (59.0) | 185 (23.4) | 143 (18.9) | | |
| Gross family income (RMB) | | | | | 79.39 | **<0.001** |
| <50 000 | 921 (58.7) | 95 (38.6) | 397 (56.7) | 429 (69.0) | | |
| ≥50 000 | 647 (41.3) | 151 (61.4) | 303 (43.3) | 193 (31.0) | | |
| Individual behaviours | | | | | | |
| Screen time | | | | | | |
| Passive screen time, ≥2 hours | 836 (44.1) | 65 (22.3) | 335 (40.9) | 436 (55.7) | 102.49 | **<0.001** |
| Interactive screen time, ≥2 hours | 715 (37.8) | 41 (14.0) | 259 (31.6) | 415 (53.0) | 160.43 | **<0.001** |
| Night sleep duration, short | 984 (52.5) | 207 (70.9) | 490 (60.1) | 287 (37.3) | 129.62 | **<0.001** |
| Physical activity | | | | | 22.01 | **<0.001** |
| Low | 547 (28.9) | 85 (29.1) | 222 (27.1) | 240 (30.7) | | |
| Moderate | 709 (37.5) | 136 (46.6) | 315 (38.5) | 258 (33.0) | | |
| High | 637 (33.7) | 71 (24.3) | 282 (34.4) | 284 (36.3) | | |
| Mental health symptoms* | | | | | | |
| Depression, mean score | 8.48±8.10 | 7.42 ± 7.94[a] | 8.14±8.05[ab] | 9.22 ± 8.15[c] | 19.99 | **<0.001** |
| ≥14 | 478 (25.2) | 59 (20.2) | 205 (25.0) | 214 (27.3) | 5.70 | 0.058 |
| Anxiety, mean score | 10.78±7.91 | 8.70 ± 7.20[a] | 10.58±8.05[b] | 11.76 ± 7.86[c] | 36.68 | **<0.001** |
| ≥10 | 1004 (53.0) | 120 (41.1) | 427 (52.1) | 457 (58.3) | 25.67 | **<0.001** |
| Stress, mean score | 12.40±8.30 | 11.07 ± 8.03[a] | 12.45±8.76[b] | 12.83±7.85[b] | 11.86 | **0.003** |
| ≥19 | 374 (19.7) | 42 (14.4) | 168 (20.5) | 164 (20.9) | 6.28 | **0.043** |
| Executive dysfunction* | | | | | | |
| Global Executive Composite, mean score | 50.77±10.19 | 50.80±9.86[ab] | 49.81 ± 10.42[a] | 51.78±9.97[b] | 15.44 | **<0.001** |
| Subclinical, >60 | 400 (21.1) | 54 (18.5) | 162 (19.8) | 184 (23.5) | 4.69 | 0.096 |
| Clinical, >65 | 180 (9.5) | 23 (7.9) | 88 (10.7) | 69 (8.8) | 2.82 | 0.245 |

The bold words represent p values less than 0.05.
*Multiple comparison across the three urban–rural subgroups was conducted using non-parametric independent sample median tests. Columns with the same letters (ie, the superscripts a, b, c in the table) are not significantly different (p≥0.05).
RR, rural hukou and rural school group; RU, rural hukou and urban school group; UU, urban hukou and urban school group.

## Patient and public involvement

Patients or the public were not involved in the design, conduct, reporting or dissemination plans of this study.

## RESULTS

### Sociodemographic and behavioural characteristics

Overall, of the final 1895 adolescents, the mean age was 15.33±1.76 years, and 925 (48.8%) were male. Additionally, 72.9% of adolescents' parents obtained lower education levels than high school, and 58.7% of their family income was lower than RMB50 000. Moreover, 44.1% and 37.8% participants had excessive passive and interactive screen time, respectively; 52.5% were shorter night sleepers and 28.9% displayed low physical activity. There were significant sociodemographic and behavioural differences across the three urban–rural subgroups (except for sex). Specifically, the RR adolescents were younger and more likely to have parents with lower education level and family income. Furthermore, excessive screen time was more prevalent among the RU and RR adolescents, whereas short night sleep duration and less high physical activity were more common among the UU youths (table 1).

### Prevalence and risk factors of mental health symptoms

Overall, the prevalence of the three types of mental health symptoms was 25.2%, 53.0% and 19.7% for depression,

anxiety and stress, respectively. There were significant differences across the three urban–rural subgroups, that is, depression (UU, RU and RR rates: 20.2%, 25.0% and 27.3%; $\chi^2$=5.70; p=0.058), anxiety (41.1%, 52.1% and 58.3%; $\chi^2$=25.67; p<0.001) and stress (14.4%, 20.5% and 20.9%; $\chi^2$=6.28; p=0.043) (table 1).

However, after adjusting for confounders, all significant differences disappeared (online supplemental table S1). We further conducted a post-hoc analysis by adjusting factors step by step and found that the RR adolescents had a higher risk of depression, the RR and RU had a higher risk of anxiety, and the RR adolescents had a higher risk of stress, which were mainly due to more screen time. Additionally, the higher anxiety among RR and RU students was partly attributed to lower family income and parental education (online supplemental table S2).

### Associations between mental health symptoms and EDF

After adjusting for confounders, all three types of mental health symptoms were significantly associated with EDF, with ORs being 3.22 (95% CI 1.38 to 7.52), 2.68 (95% CI 1.62 to 4.44) and 1.72 (95% CI 1.07 to 2.75) for depression, anxiety and stress, respectively (table 2).

### Moderating effect of urban–rural subgroup

Although we did not find a significant association between urban–rural subgroup and EDF (online supplemental table S1), we observed a marginal interactive effect of RR group and depression (p=0.089) as well as RR group and anxiety (p=0.084) on EDF (figure 2, online supplemental table S3). In further simple analysis, we showed that the UU adolescents with depression (OR 6.74, 95% CI 3.75 to 12.12) and anxiety (OR 5.56, 95% CI 1.86 to 16.66) had a much higher risk of EDF than RR adolescents with depression (OR 1.93, 95% CI 0.91 to 4.12) and anxiety (OR 1.80, 95% CI 1.39 to 2.33) (table 3, online supplemental table S4). We also compared the results of complete-case and multiple-imputation analysis, and no much changes were found (online supplemental table S5–S7).

## DISCUSSION

To our knowledge, this is the first study to investigate the moderating effect of urban–rural subpopulation on the association between mental health and EDF among general adolescents. We found that mental health symptoms were common in our sample, and their prevalence rates in the RR and RU subgroups were significantly higher than those in the UU subgroup, mainly due to having more screen time. Furthermore, we observed that mental health symptoms were significantly associated with EDF across all subgroups. Moreover, there were also marginal interactive effects of urban–rural subgroup with depression and anxiety on EDF, specifically the UU adolescents with depression and anxiety issues had a much higher EDF risk than their RR peers.

Mental health symptoms were common in our sample, that is, 25.4%, 52.8% and 19.6% for depression, anxiety and stress, respectively, which appear to be higher than rates among Hong Kong adolescents (19.1%, 22.9% and 14.3%).[27] Meanwhile, the mean score of the depression dimension in our dataset (8.5) was higher than that reported among adolescents in Spain (6.0),[28] about the same as that of a study conducted in Australia (8.4),[29] but less than scores reported in America (10.4).[30] The mean anxiety score (10.8) was also higher than that of a study conducted in Australia (7.0).[29]

Our finding that RR and RU adolescents had worse mental health symptoms than their UU peers was in line with prior studies conducted in China[31] and in other countries (eg, Korea[32] and Australia).[33] Certain behavioural and sociodemographic differences between the urban–rural subgroups explained most of the disparities, which corresponded with the results of a previous study.[34] For example, our study indicated that the significant urban–rural differences of adolescent mental health problems were mainly attributed to screen time, which previous researches have linked it to less face-to-face communication with peers and families, less outdoor physical activity and receiving plenty of potentially inappropriate information.[35] Another possible reason for these differences may be that the lower parental education levels and family income among rural adolescents lead to less mental health support.[36] On all accounts, the large share of rural adolescents experiencing more mental health problems is concerning and should receive more attention from policymakers in future adolescent health actions, such as establishing adolescent mental health and hygiene infirmary, and strengthening the publicity and education of the adolescent mental health knowledge in school and community, as well as mobilising adolescents' enthusiasm of participating in outdoor activities to reduce their media exposure time, because the government policies have the potential to change many of these determinants.

Across all three subgroups in our sample, mental health symptoms were consistently associated with EDF. That is, poor mental health associated with EF impairment even among general adolescents, supporting one recent study with nonclinical-based samples.[10] Studies from clinical patients indicated that the potential mechanism may be attributed to the dysregulation of the hypothalamic–pituitary axis with hyper activity[37] and neural-immune crosstalk with elevated cytokine production.[38] When these occurred in the central nervous system, brain architecture, morphology and functional activity may be altered, thereby reducing an adolescent's EF.[2 39] More studies on the mechanisms behind the association between mental health and EF in general adolescents should be conducted in the future.

Although we only found a marginal interactive effect of urban–rural subgroup with depression and anxiety, we observed that among adolescents with depression and anxiety symptoms, the UU adolescents had a much higher EDF risk than RR counterparts. While urban regions offer a higher standard of living and a higher quality of healthcare and educational resources than

**Table 2** Associations between mental health symptoms and executive dysfunction

| | Executive dysfunction | | | | | |
|---|---|---|---|---|---|---|
| | **Model a unadjusted** | **Model a adjusted*** | **Model b unadjusted** | **Model b adjusted*** | **Model c unadjusted** | **Model c adjusted*** |
| Mental health symptoms | | | | | | |
| Depression, score ≥14 | **3.29 (2.6, 4.15)†** | **3.22 (1.38, 7.52)‡** | / | / | / | / |
| Anxiety, score ≥10 | / | / | **2.88 (2.26, 3.67)†** | **2.68 (1.62, 4.44)†** | / | / |
| Stress, score ≥19 | / | / | / | / | **1.80 (1.39, 2.32)†** | **1.72 (1.07, 2.75)§** |
| Urban–rural subgroup | | | | | | |
| UU | / | Ref. | / | Ref. | / | Ref. |
| RU | / | 0.72 (0.49, 1.05) | / | **0.70 (0.50, 0.98)** | / | 0.74 (0.46, 1.17) |
| RR | / | 0.78 (0.34, 1.79) | / | 0.74 (0.34, 1.58) | / | 0.78 (0.35, 1.76) |
| Sociodemographics | | | | | | |
| Age, years | / | 0.95 (0.81, 1.10) | / | 0.95 (0.80, 1.11) | / | 0.95 (0.82, 1.10) |
| Sex, female | / | 0.95 (0.75, 1.20) | / | 0.90 (0.67, 1.22) | / | 0.95 (0.75, 1.21) |
| Parental education, ≥high school | / | **0.64 (0.51, 0.79)†** | / | **0.69 (0.57, 0.85)†** | / | **0.66 (0.53, 0.81)†** |
| Family income, ≥RMB50000 | / | **0.62 (0.40, 0.95)§** | / | **0.63 (0.39, 1.00)§** | / | **0.61 (0.38, 0.99)§** |
| Individual behaviours | | | | | | |
| Screen time | | | | | | |
| Passive screen time, ≥2 hours | / | 1.06 (0.77, 1.44) | / | 1.12 (0.79, 1.58) | / | 1.15 (0.76, 1.74) |
| Interactive screen time, ≥2 hours | / | **1.41 (1.24, 1.61)†** | / | **1.27 (1.11, 1.45)†** | / | **1.41 (1.26, 1.58)†** |
| Night sleep duration, short | / | **0.75 (0.58, 0.97)§** | / | **0.71 (0.54, 0.95)§** | / | **0.74 (0.57, 0.95)§** |
| Physical activity | | | | | | |
| Low | / | Ref. | / | Ref. | / | Ref. |
| Moderate | / | 0.85 (0.50, 1.45) | / | 0.83 (0.55, 1.26) | / | 0.83 (0.55, 1.26) |
| High | / | 0.86 (0.53, 1.40) | / | 0.90 (0.57, 1.44) | / | 0.88 (0.54, 1.42) |

The bold words represent p values less than 0.05.
*Adjusted for sociodemographic characteristics (ie, age, sex, parental education level and gross family income) and individual behaviours (screen time, night sleep duration and physical activity).
†P <0.001.
‡P<0.01.
§P <0.05.
RR, rural hukou and rural school group; RU, rural hukou and urban school group; UU, urban hukou and urban school group.

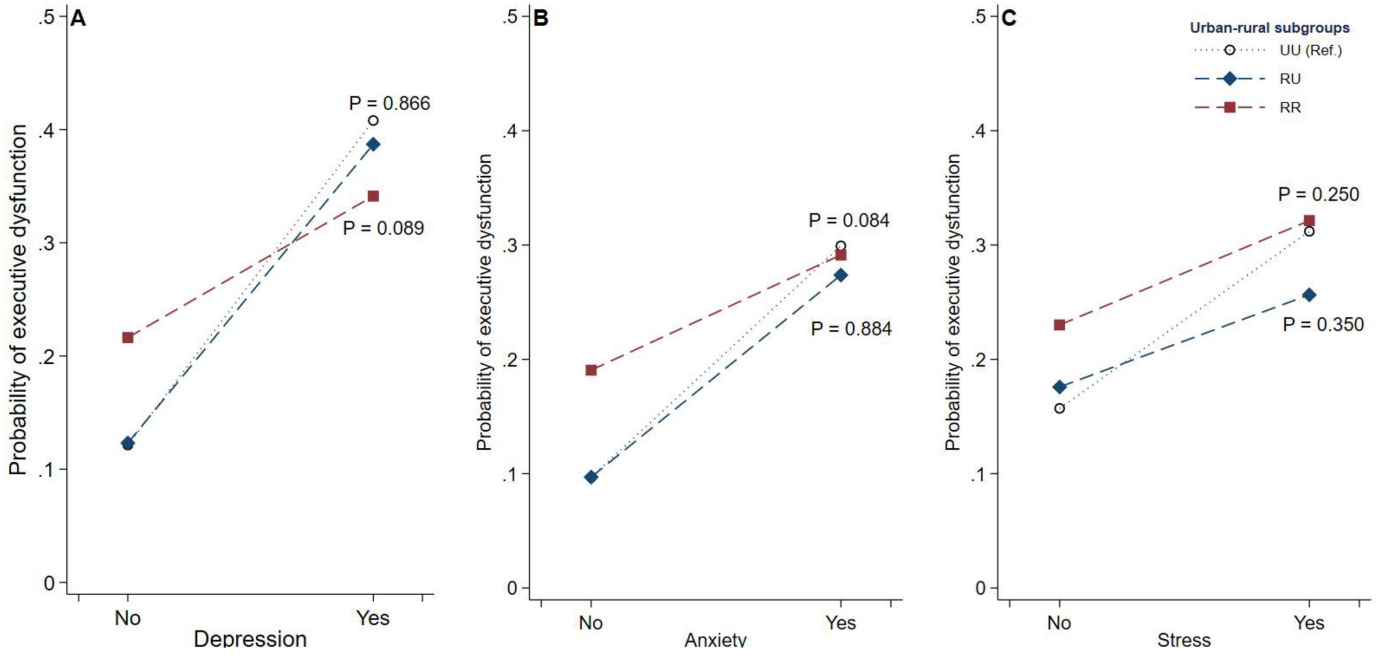


**Figure 2** Interactive effects of urban–rural subgroup and mental health symptoms on executive dysfunction. All models were adjusted for sociodemographic characteristics (ie, age, sex, parental education level and gross family income) and individual behaviours (screen time, night sleep duration and physical activity). P values indicated whether each interactive effect of urban–rural subgroups and mental health symptoms on executive dysfunction reached statistical significance. RR, rural hukou and rural school group; RU, rural hukou and urban school group; UU, urban hukou and urban school group.

rural areas, stressors in urban environments, such as high population density, noise pollution and air pollution, in addition to less access to green spaces and relatively low neighbour communication and support,[17 18 40 41] might strengthen the relationship between mental health problems and EDF, which is also an important topic in need of further empirical study. To improve adolescent mental health and EF, we suggest that the government, school and community should pay much more attention to both investment in mental health support services in rural areas as well as improving the quality of the living environment in urban areas.

This study has several limitations. First, our data were collected from one relatively low socioeconomic development city in China, and the findings might not be generalisable to the national population. Future samples in other settings with different levels of socioeconomic development should be collected. Second, we used subclinical cutoffs of EDF. Although the effect estimated was at magnitudes that may be considered subclinical in adolescents, these findings are important at the population level. Third, our measures of lifestyle behaviours were based on self-report, which may be subject to recall bias. Future studies should collect these data using more objective measurements, such as using actiwatch to assess night sleep duration and physical activity. Fourth, we did not collect the parenting and caregiving style which might influence the association between mental health and EDF. Finally, as this is a cross-sectional study, we cannot make causal claims and cannot exclude the possibility that the results may be influenced by residual and unmeasured or unknown factors.

**Table 3** Simple effects of mental health symptoms on executive dysfunction stratified by urban–rural subgroup*

| | Executive dysfunction | | |
|---|---|---|---|
| | OR (95% CI) | *Z* value | P value |
| UU group | | | |
| Depression, score ≥14 | 6.74 (3.75, 12.12) | 6.38 | **<0.001** |
| Anxiety, score ≥10 | 5.56 (1.86, 16.66) | 3.06 | **0.002** |
| Stress, score ≥19 | 3.14 (1.75, 5.61) | 3.85 | **<0.001** |
| RU group | | | |
| Depression, score ≥14 | 4.89 (1.67, 14.25) | 2.90 | **0.004** |
| Anxiety, score ≥10 | 3.46 (1.21, 9.84) | 2.32 | **0.020** |
| Stress, score≥19 | 1.65 (0.92, 2.93) | 1.69 | 0.091 |
| RR group | | | |
| Depression, score ≥14 | 1.93 (0.91, 4.12) | 1.70 | 0.088 |
| Anxiety, score ≥10 | 1.80 (1.39, 2.33) | 4.44 | **<0.001** |
| Stress, score ≥19 | 1.59 (1.12, 2.27) | 2.57 | **0.010** |

The bold words represent p values less than 0.05.
*Adjusted for sociodemographic characteristics (ie, age, sex, parental education level and gross family income) and individual behaviours (screen time, night sleep duration and physical activity).
RR, rural hukou and rural school group; RU, rural hukou and urban school group; UU, urban hukou and urban school group.

## CONCLUSION

The prevalence of mental health symptoms was significantly higher among rural origin adolescents when compared with their urban peers, and such disparities

were primarily explained by excessive screen exposure. Adolescents with mental health symptoms were more likely to have EDF regardless of urban–rural, and urban adolescents with depression and anxiety had a much higher EDF risk than their rural peers. The results indicate the need to improve mental health issues prevention and treatment in both urban and rural areas, where adolescents may be exposed to different kinds of risk factors that may exacerbate the impact of mental health problems on their EF in daily life.

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