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Associations between trajectories of depressive symptoms and cognitive performance in Chinese adolescents

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Abstract

Subclinical depressive symptoms and the associated risk of cognitive deficits have been overlooked. We aimed to investigate depressive symptom trajectories and the effect of depressive symptoms on cognitive performance among Chinese adolescents. The research population of our study was 1314 adolescents aged 10–15 years old from the China Family Panel Studies. The Center for Epidemiologic Studies Depression Scale was used to assess the depressive symptoms of adolescents. Vocabulary and mathematics tests were used to test fluid intelligence. Memory and number series tests were used to test crystal intelligence. The 6-year depressive symptom trajectories of adolescents were identified by the latent class mixed model. Linear regression models and Generalized Estimating Equation models were applied to test the associations between depressive symptom trajectories and cognitive performance. We identified three distinct trajectories of depressive symptoms: (a) low depressive symptom trajectory (88.51%), (b) remitting depressive symptom trajectory (5.86%), (c) decreasing depressive symptom trajectory (5.63%). We found that decreasing depressive symptom trajectory predicted worse fluid intelligence (β: -0.51, 95% *CI*: -0.88, -0.13) and crystal intelligence (β: -2.09, 95% *CI*: -3.78, -0.41) compared with low depressive symptom trajectory. Gender-stratified analysis showed that the negative association between depressive symptoms trajectory and crystal intelligence was only found in males. Depressive symptom episodes in early adolescence were associated with worse cognitive performance later. Performing mental health screenings, especially during the sensitive windows of cognitive development, is critical to reducing the negative impact of depressive symptoms.

Keywords Depressive symptoms, Cognitive performance, Adolescents, Cohort study

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Introduction

Depression is a common medical condition, with a global prevalence of about 4.4% and a lifetime prevalence of 10–15%. A person with depression may suffer from low quality of life, sleep disorders, academic failure, marital conflicts, and even suicide [1]. A crucial aspect worth mentioning is that cognitive deficits are a key feature of depressive disorder [2]. Cognitive deficits in attention, memory, learning, process speed and executive function have been observed in people who have experienced depression [3–5].

Childhood and adolescence were thought to be the onset of depression and the occurrence of depression rises dramatically during adolescence [6, 7]. The 12-month prevalence of major depressive disorder among adolescents assessed was reported to be about 13% [8]. For those adolescents at a sensitive time of brain development [9], studies have shown that adolescents with major depressive disorder have deficits in sustained attention and motor processing speed [10, 11]. Cognitive development during adolescence plays a pivotal role in shaping individuals' future physical and mental health, as well as their academic and economic outcomes [12, 13]. This is particularly salient for Chinese adolescents, who experience heightened academic pressure due to highly competitive educational environment, including college entrance examinations. Such pressures may exacerbate depressive symptoms and negatively impact cognitive development, making this population particularly vulnerable [14]. However, the existing research on the association between depression and cognitive performance in adolescents exhibits several weaknesses. Former studies mostly focused on adolescents with clinically diagnosed depression such as major depressive disorder [10, 11], while ignoring the potential and high-risk young people who had subclinical depressive symptoms without diagnosis. Depressive symptoms are a major manifestation of depressive disorder [15]. The global prevalence of aggravated self-reported depressive symptoms among adolescents is 34% [16]. Early screening for depressive symptoms can be useful to identify patients who may need further help.

Additionally, most studies have assessed depression at a single time point, which might omit the intrinsic variability of symptoms or the longitudinal course of depressive symptoms. Particularly, the courses of depressive symptoms appear to vary over time. The associations between the different courses of depressive symptoms and the later risk of dementia have been found in older adults. It has been stated that high and increasing levels of depression predict the risk of dementia [17–19]. Yet, during an essential period of biological, cognitive, and emotional development in adolescence [20], there is a paucity of data about the possible associations between the trajectories of depressive symptoms and cognitive performance. Since cognitive impairment is a long-term process, continuously assessing depression in relation to cognitive performance may provide more information than a single test.

Hence, in this study, we first investigated the depressive symptom trajectories in adolescents through a longitudinal survey. Besides, we assessed the associations between different trajectories of depressive symptoms and later cognitive performance among Chinese adolescents followed up longitudinally based on the China Family Panel Studies (CFPS).

Materials and methods

Study population and design

The research population comes from the CFPS, which is an ongoing national investigation in China. The survey covers 25 of China's 31 provinces (or municipalities), which represent 95% of the country's population. It was launched by the Institute of the Study of Social Science (ISSS) of Peking University. The baseline survey of the program was conducted in 2010 and the follow-up surveys were conducted every two years, with the most recent one in 2020. Participants' depressive symptoms were first investigated in 2012, and follow-up surveys were conducted in 2016 and 2018. The subjects in our study were adolescents aged 10–15 years old in 2012.

The investigation in 2012 was the baseline and it contained the depressive symptoms measured in adolescent participants in 2012. Of all the adolescents included in the CFPS data, 2679 adolescents between the age of 10 and 15 completed the depressive symptoms survey. In the subsequent survey in 2016 and 2018, some teens were missed from follow-up. Finally, 1314 individuals who participated in all three investigations (2012, 2016, 2018) were retained in our analysis. The details are presented in Figure S1.

The CFPS study involving human participants has been ethically approved by the Peking University Biomedical Ethics Review Committee (Approval number: IRB00001052-14010). Written informed consent was obtained from the parents or legal guardians of all participants, and assent was obtained from the adolescents themselves prior to their participation in the study [21].

Measures

Depressive symptoms

The Center for Epidemiologic Studies Depression Scale (CES-D) was used to assess the depressive symptoms of adolescents. The CES-D is a 0–3 points Likert scale which can be ranged from 0 (less than 1 day a week) to 3 (5–7 days a week) [22]. The prior study has shown that Cronbach's α coefficient of this scale is 0.73–0.88

[23], and it has been widely used in China to screen for depressive symptoms in a variety of settings [9, 24].

In the 2012 wave, the 20-item (CES-D20), full of the scale was used. However, due to the low acceptance among the respondents, a simplified 8-item version (CES-D8) was used in 2016 and 2018. At the same time, to effectively compare depression scores between rounds, 1/5 of the respondents were selected to continue using CES-D20 and the remaining 4/5 were selected to use CES-D8 in 2016 [25]. The CFPS project team then used a percentile equalization method to generate scores that are comparable to the 20 items in 2016 and 2018. The higher the depressive scores, the greater level of depressive symptoms [26].

Cognitive function assessment

The CFPS has established four types of cognitive tests: vocabulary tests, mathematics tests, memory tests, and number series tests. To reduce the length of the interview, the team divided the four types of cognitive tests into two groups and used them sequentially according to the survey rounds. Cognitive ability is generally considered to be made up of "crystal intelligence" and "fluid intelligence". In 2014 and 2018, mathematics tests and vocabulary tests were used to evaluate "crystal intelligence", which refers to the skill acquired through the accumulation of prior knowledge and experience [27]. The program used two-word recall tasks (immediate recall and delayed recall) to measure the participants' short-term and long-term memory [28]. Based on the prototype of the Health and Retirement Study (HRS), these memory tests and number series tests were used to estimate "fluid intelligence", which refers to the ability to reason and solve difficulties in certain special situations [9]. The cognitive variables included in this study were selected based on their established relevance to adolescent cognitive development and their use in prior studies. These variables have been validated in Chinese populations and are sensitive to the cognitive changes associated with depressive symptoms [29, 30]. As for the four types of tests, the higher scores indicate greater cognitive ability.

Covariates

We considered the characteristics of adolescents, parents, and household characteristics as covariates. Adolescents' characteristics included age and gender, and parents' characteristics included parental age, occupational status, educational level, and whether parents have lived with the adolescent for more than 8 months in the past year. Household characteristics include net income in the last year and the living place (urban/rural). Then in the sensitivity analysis, we included parents' cognitive ability and depressive scores in 2012. Another 5 variables which may be associated with early childhood cognition were included as follows: (1) the gestational age of the child, (2) the age children begin to walk, (3) the age children can speak complete sentences, (4) the age children can count from 1 to 10, (5) the age children can urinate independently.

Statistical analysis

First, a descriptive analysis was adopted to summarize and explore the variables. The quantitative variables were expressed by using mean and standard deviation ($M \pm SD$) and qualitative variables were expressed by using counts or percentages. One-way analysis of variance (ANOVA) and repeated-measures data ANOVA were adopted to compare the depression scores of different trajectory classifications in the same year and the depression scores of the same trajectory in 2012, 2016, and 2018.

The latent class mixed model (LCMM) was performed to identify the class of adolescent trajectories of depression symptoms over time. The LCMM consisted in assuming that the population is heterogeneous and composed of G latent classes of subjects characterized by G mean profiles of trajectories. To choose the best number of classes, LCMM with different class numbers (2 to 5) were evaluated and compared in the following aspects: (1) the minimum Bayesian Information Criterion (BIC), (2) whether the entropy was closer to one, (3) the posterior probabilities by class (>0.7) and class size ($\geq 2\%$) [18, 31]. The model was performed by using the package "lcmm" in R software [31].

We then tested the associations between different depressive symptom trajectories and adolescent cognitive development by using linear regression models. Besides, the Generalized Estimating Equation (GEE) models were applied to test the longitudinal associations between depressive symptom trajectories and cognitive performance. GEE is suitable for longitudinal data analysis where missing data can exist [32, 33]. In both the linear regression models and GEE models, we adjusted the adolescents' age and gender in the crude models and the parental and household characteristics were included in fully adjusted models. We also analyzed the gender-specific effects that differ between males and females in the fully adjusted GEE models.

Except the fully adjusted models, we conducted four sets of sensitivity analyses to test the robustness of our results in GEE models, additionally. We added respectively, (1) parents' cognitive performance in 2012, (2) parents' depressive scores in 2012, and (3) five variables which may be associated with early childhood cognition. All analyses were based on SPSS 23.0.

Results

Depressive symptoms trajectories of adolescents

In this study, a total of 1314 adolescents who had participated in three tests of depressive symptoms were included in the analysis. The characteristics of 1314 individuals and their parents in the baseline are displayed in Table 1. The average age of 1314 adolescents in 2012 was 12.42 ± 1.70 years and 47.6% of them were girls. The adolescents' cognitive ability during toddlerhood was displayed in Table 1. Table S1 displays the distribution of characteristics of children excluded and involved in this study. We did not observe a statistically significant difference in the distribution of depressive symptom scores between the two groups. In comparison to the children encompassed in this study, the excluded children were older (12.77 years vs. 12.42 years), had a larger proportion of mothers with an education of six years or less (63.5% vs. 59.0%), a higher percentage of fathers living together with children for more than 8 months per year (52.0% vs. 48.0%), but a lower percentage of mothers living with their children for more than 8 months per year (63.9% vs. 73.5%).

Figure 1 displays the depressive symptom trajectories of 1314 adolescents from 2012 to 2018. Based on the LCMM, the 3-trajectory solution for depressive symptoms was optimum and provided a good overall classification with posterior probabilities of 0.79, 0.96, and 0.80. The 3-class model solution consisted of (a) low depressive symptom trajectory characterized by persistent low depression scores (1163[88.51%]), (b) remitting depressive symptom trajectory (77[5.86%]) referred to as an acute rise and then recovery trajectory of depressive symptoms, (c) decreasing depressive symptom trajectory (74[5.63%]) characterized by high depression scores in early adolescence but then decreased slowly. The fit parameters of the latent class mixed model are shown in Table S2, with the best-fitting model bolded in the table.

One-way ANOVA showed that mothers of the adolescents with remitting depressive symptom trajectory had fewer years of education compared with the adolescents with low depressive symptoms trajectory (≥ 10 years of schooling: 1.9% vs. 13.8%). Repeated-measures data ANOVA showed that the depression scores of different trajectory classes in the same year showed statistical difference. Mean score of depressive symptoms differed across waves of 3-class depressive symptom trajectories. The results of the ANOVA were displayed in Tables S3-S4.

Associations of cognitive performance and depressive symptom trajectories of adolescents

The results of linear regression analysis are displayed in Table 2. In the adjusted model, the decreasing depressive symptom trajectory was associated with lower immediate word recall scores in 2012 compared to the low depressive symptom trajectory (β: -0.69, 95% CI: -1.16, -0.23). While the remitting depressive symptom trajectory was associated with lower number series test scores in 2016 (β: -10.47, 95% CI: -18.83, -2.10). In the vocabulary test and mathematics test, the decreasing depressive symptom trajectory was negatively associated with vocabulary test scores in both years 2014 (β: -2.77, 95% CI: -4.50, -1.54) and 2018 (β: -2.00, 95% CI: -3.29, -0.70). The GEE model showed longitudinal associations between depressive symptoms trajectory and cognitive ability among adolescents and the results are displayed in Table 3. In both the crude model and adjusted model, the GEE model showed that decreasing depressive symptom trajectory was associated with lower immediate word recall scores and vocabulary test scores compared with low depressive symptom trajectories.

In addition, we conducted four sets of sensitivity analyses and the results were displayed in Table S5. The above correlations were generally robust after adjusting for adolescents' cognitive ability during toddlerhood, parental cognitive ability, and depression in 2012 respectively.

Gender-Stratified associations between depression class and adolescent's cognitive ability

The results of gender-stratified associations between depression class and adolescents' cognitive ability are displayed in Table 4. The gender-stratified association analysis showed that the associations between depressive symptoms trajectory and cognitive ability were significant in males which was consistent with the primary analysis. In males, the decreasing depressive symptoms trajectory was associated with lower cognitive ability, including immediate word recall scores (β: -0.68, 95% CI: -1.17, -0.19), vocabulary test scores (β: -2.68, 95% CI: -5.11, -0.25) and mathematics test scores (β: -1.95, 95% CI: -3.79, -0.12). The remitting depressive symptoms trajectory was associated with lower delayed word recall scores in males (β: -0.59, 95% CI: -1.16, -0.02) and number series test scores in females (β: -12.83, 95% CI: -22.83, -3.13).

Discussion

In this study, we identified three distinct trajectories of depressive symptoms characterized by low, decreasing, and remitting and assessed the associations between depressive symptom trajectories and cognitive performance among adolescents based on a nationwide cohort study. We underlined the age-sensitivity of the detrimental effects of depressive symptoms on later cognitive performance. Depressive symptoms in early adolescence could predict worse fluid and crystallized intelligence for later. The associations between different classifications of

Table 1 The characteristics of the 1314 participants

Characteristics	M ± SD /Percentages	Low symptoms (*n* = 1163)	Remitting symptoms (*n* = 77)	Decreasing symptoms (*n* = 74)
Adolescents' characteristics				
Age in 2012	12.42 ± 1.70	12.45 ± 1.70	12.29 ± 1.85	12.12 ± 1.51
Gender (female)	625 (47.6%)	556 (47.8%)	39 (50.6%)	30 (40.5%)
Parent's characteristics				
Father's age in 2012				
≤ 35	154 (11.7%)	135 (13.1%)	10 (14.3%)	9 (12.9%)
36–40	473 (36.0%)	423 (41.2%)	21 (30.0%)	29 (41.4%)
41–45	359 (27.3%)	312 (30.4%)	24 (34.3%)	23 (32.9%)
≥46	181 (13.8%)	157 (15.3%)	15 (21.4%)	9 (12.9%)
Occupational status of the father				
Yes	887 (67.5%)	781 (76.0%)	57 (81.4%)	49 (70.0%)
No	280 (21.3%)	246 (24.0%)	13 (18.6%)	21 (30.0%)
Years of schooling of father				
≤ 6 years	536 (40.8%)	468 (45.6%)	34 (48.6%)	34 (6.3%)
7–9 years	396 (30.1%)	349 (34.0%)	24 (34.3%)	23 (32.9%)
≥ 10 years	235 (17.9%)	210 (20.4%)	12 (17.1%)	13 (18.6%)
Mother's age in 2012				
≤ 35	277 (21.1%)	244 (23.0%)	14 (20.0%)	19 (27.1%)
36–40	507 (38.6%)	451 (42.5%)	25 (35.7%)	31 (44.3%)
41–45	315 (24.0%)	278 (26.2%)	23 (32.9%)	14 (20.0%)
≥ 46	102 (7.8%)	88 (8.3%)	8 (11.4%)	6 (8.6%)
Occupational status of the mother				
Yes	774 (58.9%)	684 (64.7%)	44 (62.9%)	46 (65.7%)
No	424 (32.3%)	374 (35.3%)	26 (37.1%)	24 (34.3%)
Years of schooling of mother				
≤ 6 years	708 (53.9%)	610 (57.5%)	53 (75.7%) *	45 (64.3%)
7–9 years	339 (25.8%)	305 (28.7%)	14 (20.0%) *	20 (28.6%)
≥ 10 years	154 (11.7%)	146 (13.8%)	3 (1.9%) *	5 (7.1%)
The father lived together with the children for more than 8 months in the last year, 2012	782 (59.5%)	692 (62.4%)	44 (58.7%)	46 (64.8%)
The mother lived together with the children for more than 8 months in the last year, 2012	922 (70.2%)	816 (73.6%)	54 (72.0%)	52 (73.2%)
Household characteristics				
Living place				
City	534 (40.6%)	682 (58.8%)	45 (59.2%)	48 (64.9%)
Rural	775 (59.0%)	477 (89.3%)	31 (40.8%)	26 (35.1%)
Net household income in the last year, 2012				
< 15,000 RMB	305 (23.2%)	271 (23.9%)	13 (17.6%)	21 (28.8%)
15,000–30,000 RMB (not contain 30000)	312 (23.7%)	273 (24.0%)	14 (18.9%)	25 (34.2%)
30,000–45,000 RMB (not contain 45000)	240 (18.3%)	213 (18.8%)	18 (24.3%)	9 (12.3%)
≥45,000 RMB	426 (32.4%)	379 (33.4%)	29 (6.8%)	18 (24.7%)
Adolescent's early cognitive ability for sensitive analysis[#]				
Gestational age of the child (months)	9.32 ± 0.57	9.33 ± 0.57	9.26 ± 0.53	9.22 ± 0.54
The age begins to walk (months)	14.57 ± 4.79	14.49 ± 4.72	13.85 ± 3.53	16.68 ± 6.26*
The age to speak complete sentences (months)	20.75 ± 8.23	20.77 ± 8.14	18.82 ± 7.81	22.43 ± 9.76
The age can count from 1–10 (months)	35.45 ± 15.18	35.31 ± 15.07	33.74 ± 16.30	39.32 ± 15.37*
The age the child can urinate independently (months)	34.17 ± 13.55	34.08 ± 12.27	32.14 ± 12.27	37.70 ± 13.55*

[#] Retrospective data about early childhood cognition were from the 2010 investigation. * Different from the low symptoms

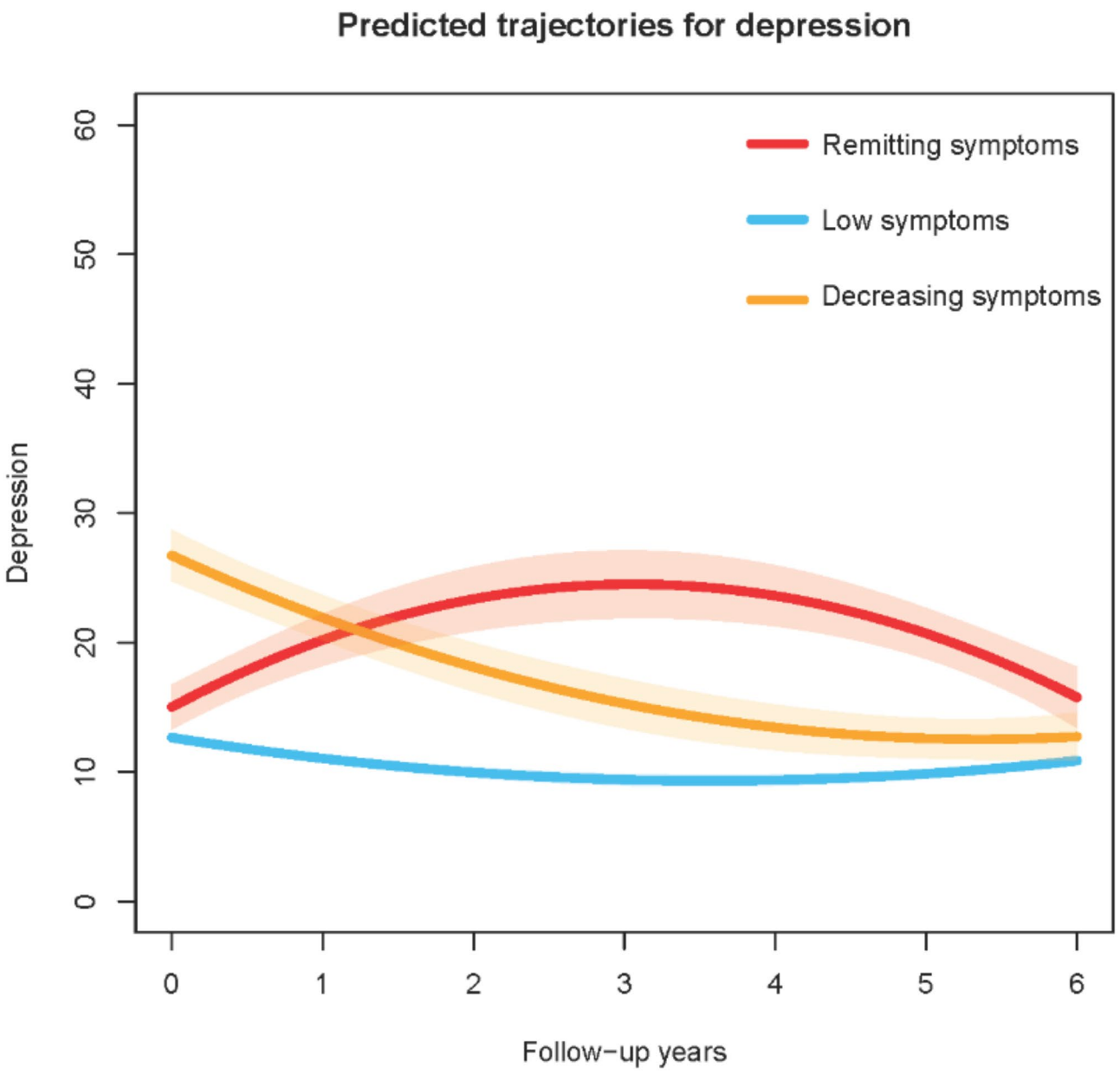

Fig. 1 Trajectories of depressive symptoms from 2012–2018

depressive symptom trajectories and later cognitive performance varied in males and females.

Our results suggested that the long-term courses of adolescents' depressive symptoms were highly variable. The adolescents with decreasing and remitting depressive symptom trajectories experienced transient episodes of high depressive symptoms. Some studies have presented that the onset of depression that remits subsequently in adolescents is relevant to transient stressors, such as academic difficulties, family stress, and victimization [34]. Prospective community studies reported that only 60% of adolescent depression persisted into early adulthood, which suggested that one-off depressive episodes during adolescence are not uncommon [35]. However, limited by the follow-up duration, we were unable to assert whether the adolescents experienced a subsequent relapse of depressive symptoms, and a longer follow-up study is warranted. In the Chinese context, socioecological factors, such as academic pressure, familial expectations and cultural stigma surrounding mental health, may contribute to the onset and course of depressive symptoms in adolescents [36]. For example, the intense focus on academic achievement in China may lead to chronic stress, which has been linked to both depressive symptoms and cognitive impairments. These factors could explain why depressive symptoms in Chinese adolescents exhibit

Table 2 Linear regression analysis of depression class and adolescent's cognitive ability

	Crude model[a](95% *CI*)			Adjusted model[b](95% *CI*)		
	Low symptoms	Remitting symptoms	Decreasing symptoms	Low symptoms	Remitting symptoms	Decreasing symptoms
Year 2012						
Immediate word recall coefficient	Ref.	-0.33 (-0.75, 0.09)	**-0.56 (-1.00, -0.12)***	Ref.	-0.26 (-0.72, 0.20)	**-0.69 (-1.16, -0.23)****
Delayed word recall coefficient	Ref.	-0.15 (-0.61, 0.32)	-0.19 (-0.67, 0.30)	Ref.	-0.07 (-0.58, 0.45)	-0.31 (-0.83, 0.21)
Number series test coefficient	Ref.	**6.59 (0.01, 13.16)***	-5.00 (-12.21, 2.20)	Ref.	5.62 (-1.91, 13.14)	-7.70 (-15.45, 0.06)
Year 2016						
Immediate word recall coefficient	Ref.	-0.36 (-0.73, 0.01)	-0.34 (-0.71, 0.04)	Ref.	-0.12 (-0.54, 0.30)	-0.26 (-0.66, 0.14)
Delayed word recall coefficient	Ref.	**-0.82 (-1.36, -0.27)****	-0.23 (-0.78, 0.33)	Ref.	-0.56 (-1.17, 0.05)	-0.18 (-0.77, 0.41)
Number series test coefficient	Ref.	-6.38 (-14.06, 1.30)	-6.08 (-13.89, 1.73)	Ref.	**-10.47 (-18.83, -2.10)***	-2.94 (-11.00, 5.12)
Year 2014						
Vocabulary test coefficient	Ref.	0.28 (-1.29, 1.84)	**-2.58 (-4.19, -0.96)****	Ref.	0.88 (-0.80, 2.57)	**-2.77 (-4.50, -1.04)****
Mathematics test coefficient	Ref.	-0.05 (-1.28, 1.18)	**-1.39 (-2.67, -0.12)***	Ref.	0.58 (-0.71, 1.87)	-1.23 (-2.56, 0.10)
Year 2018						
Vocabulary test coefficient	Ref.	0.49 (-0.76, 1.72)	**-2.10 (-3.32, -0.84)****	Ref.	0.75 (-0.66, 2.15)	**-2.00 (-3.29, -0.70)****
Mathematics test coefficient	Ref.	-0.87 (-2.43, 0.70)	**-2.26 (-3.80, -0.71)****	Ref.	-1.08 (-2.83, 0.68)	-1.39 (-3.00, 0.23)

Note: $^{*}P<0.05$, $^{**}P<0.01$

[a] Adjusted for adolescents' age and gender

[b] Adjusted for adolescents' age, gender, parental age, occupational status, years of schooling, whether parents have lived together with the children for more than 8 months in the last year, living place, and net household income in the last year

Table 3 The GEE model showed longitudinal associations between depressive symptoms trajectory and cognitive ability among the adolescents

Cognitive ability of adolescents	Coefficient (95% CI)	
	Crude model [a]	Adjusted model [b]
Immediate word recall		
Low symptoms	Ref.	Ref.
Remitting symptoms	**-0.34 (-0.64, -0.04)***	-0.20(-0.54, 0.13)
Decreasing symptoms	**-0.46 (-0.81, -0.11)***	**-0.51(-0.88, -0.13)****
Delayed word recall		
Low symptoms	Ref.	Ref.
Remitting symptoms	**-0.44 (-0.81, -0.08)***	-0.27(-0.67, 0.13)
Decreasing symptoms	-0.19 (-0.62, 0.25)	-0.30(-0.75, 0.15)
Number series test		
Low symptoms	Ref.	Ref.
Remitting symptoms	-0.18 (-6.10, 5.75)	-2.38(-8.90, 4.14)
Decreasing symptoms	-5.17 (-11.80, 1.45)	-4.19(-11.08, 2.70)
Vocabulary test		
Low symptoms	Ref.	Ref.
Remitting symptoms	0.50(-0.43, 1.42)	0.90(-0.12, 1.92)
Decreasing symptoms	**-2.22(-3.90, -0.55)****	**-2.09(-3.78, -0.41)***
Mathematics test		
Low symptoms	Ref.	Ref.
Remitting symptoms	-0.33(-1.34, 0.67)	-0.20(-1.27, 0.86)
Decreasing symptoms	**-1.66(-2.98, -0.34)***	-1.21(-2.60, 0.17)

Note: $^{*}P<0.05$, $^{**}P<0.01$

[a] Adjusted for adolescents' age and gender

[b] Adjusted for adolescents' age, gender, parental age, occupational status, years of schooling, whether parents have lived together with the children for more than 8 months in the last year, living place, and net household income in the last year

Table 4 Gender-Stratified associations between depression class and adolescent's cognitive ability

Cognitive ability of adolescents	Adjusted coefficient (95% CI) [a]	
	Male	**Female**
Immediate word recall		
Low symptoms	Ref.	Ref.
Remitting symptoms	-0.25(-0.74, 0.24)	-0.18(-0.65, 0.30)
Decreasing symptoms	**-0.68(-1.17, -0.19)****	-0.32(-0.90, 0.25)
Delayed word recall		
Low symptoms	Ref.	Ref.
Remitting symptoms	**-0.59(-1.16, -0.02)***	0.01(-0.56, 0.58)
Decreasing symptoms	-0.48(-1.03, 0.07)	-0.12(-0.89, 0.64)
Number series test		
Low symptoms	Ref.	Ref.
Remitting symptoms	7.79(-0.04, 15.63)	**-12.98(-22.83, -3.13)***
Decreasing symptoms	-8.35(-18.29, 1.59)	1.61(-6.78, 10.01)
Vocabulary test		
Low symptoms	Ref.	Ref.
Remitting symptoms	1.14(-0.38, 2.66)	0.61(-0.82, 2.04)
Decreasing symptoms	**-2.68(-5.11, -0.25)***	-1.15(-3.11, 0.82)
Mathematics test		
Low symptoms	Ref.	Ref.
Remitting symptoms	0.76(-0.66, 2.17)	-1.15(-2.66, 0.36)
Decreasing symptoms	**-1.95(-3.79, -0.12)***	0.00(-2.10, 2.09)

Note: *$P<0.05$, **$P<0.01$

[a] Adjusted for adolescents' age, gender, parental age, occupational status, years of schooling, whether parents have lived together with the children for more than 8 months in the last year, living place, and net household income in the last year

distinct trajectories compared to those in other cultural contexts. Future studies should explore these socioecological influences in greater depth to inform culturally tailored interventions.

Consistent with our findings, previous studies have identified the associations between depression and cognitive impairment [37]. The longitudinal and meta-analysis studies have shown that cognitive impairment increases after the onset of depression, which might remain after the resolution of depressive symptoms [38, 39]. Our findings align with previous longitudinal studies demonstrating that depressive symptoms are associated with cognitive impairments, even after symptom remission. For example, a meta-analysis by Rock et al. found that individuals with a history of depression exhibited persistent deficits in executive function and memory [40]. Our study extends this literature by demonstrating that even short-term episodes of depressive symptoms during adolescence can have long-term negative effects on cognitive performance, particularly in the domains of fluid and crystallized intelligence. This underscores the importance of early intervention to mitigate the cognitive consequences of depression. Many theories have been proposed regarding why episodes of depression might be detrimental to cognitive function: for example, hypercortisolemia causing hippocampal dysfunction or inflammation leading to residual damage [41]. In addition, increased cortisol secretion might be responsible for cognitive deficits in depressed patients [42, 43]. In our study, the adolescents with decreasing depressive symptom trajectories showed greater cognitive impairment than those with remitting depressive symptom trajectories. This is likely due to the fact that adolescents with decreasing depressive symptom trajectories experienced more severe episodes of depressive symptoms in early adolescence. Evidence suggests that patients with a more severe, recurrent illness might have greater cognitive impairment when remitted [44]. Moreover, the results of this study suggested that even short-term episodes of depressive symptoms could have a long-term negative effect on adolescents' cognitive performance.

More importantly, our results highlighted the age-sensitivity detrimental impact of depressive symptoms on later cognitive performance. Depressive symptoms in early adolescence could lead to worse fluid and crystallized intelligence compared to middle and late adolescence. The occurrence of subclinical depressive symptoms in adolescents has been frequently noted in recent studies [45]. Considering the course of brain development is gradual and protracted, the effect of depressive symptoms on cognitive performance may depend on the stage at which the symptomology occurred [46]. Adolescents are at a critical period in their lives when facing the pressures of school exams and interpersonal relationships, and their academic success during adolescence will have an impact on their careers in adulthood.

Therefore, early identification and treatment of mental disorders in adolescents is essential to promote long-term success. Our findings have important implications for parents, practitioners, and policymakers. For parents, the results underscore the need to be vigilant about early signs of depressive symptoms in their children, as even short-term episodes can have long-term cognitive consequences. For practitioners, our findings highlight the importance of integrating mental health screenings into routine adolescent health assessments. Early identification of depressive symptoms, particularly during critical developmental windows, can facilitate timely interventions to mitigate cognitive impairments. For policymakers, our study provides a strong rationale for investing in mental health services and educational programs that address the unique needs of adolescents.

The gender-stratified association analysis showed that depressive symptom trajectories were correlated with cognitive performance both fluid intelligence and crystal intelligence in males. However, we found that only decreasing depressive symptom trajectories were negatively associated with girls' fluid intelligence rather than crystal intelligence. Previous studies have identified that the levels of depression and the associations between depression and cognitive performance differ between males and females [47]. However, the existing findings were contradictory. A cross-sectional multicohort study involving 13,841 children suggested that cognitive performance was more strongly affected in boys than in girls given comparable levels of psychopathology [48]. Masten et al. found gender differences in cross-sectional associations between academic achievement and internalizing symptoms [49]. While some studies didn't find gender differences in associations between cognitive performance and depression [50, 51]. The gender differences in associations between different depressive trajectories and cognitive development are potentially important, especially in the context of the widely acknowledged higher rate of depression in females and the emergence of associated gender differences in adolescence [52]. Although the reasons for these gender differences are not clear, more efforts are needed to screen depressive symptoms, particularly in boys to minimize impairment of cognitive development. Future research should explore these gender differences in greater depth, especially considering the higher rates of depressive symptoms in females during adolescence. Gender-tailored interventions may be necessary to address these disparities and mitigate the cognitive consequences of depression.

The main strength of our study is its nationwide and longitudinal sample of Chinese adolescents. Secondly, we did a series of sensitivity analyses taking the parents' cognitive ability and depressive scores of the parents at baseline into account. The associations remained robust after we adjusted for five variables that may be associated with early childhood cognition in the models. Thirdly, we divided adolescents' cognitive performance into two components, including fluid intelligence and crystal intelligence, and repeated the measures in different years. Our results more strongly support the negative effect of depressive symptoms on cognitive development.

This study has some limitations. Firstly, we adopted self-reported depressive symptoms among the adolescents, and therefore the reporting bias is inevitable. Secondly, more than half of adolescents identified in 2012 were incrementally lost over the 6 years of follow-up. However, the attrition rate of CFPS between 2 consecutive surveys was less than 30%. More efforts were needed to reduce the loss of follow-up. Finally, our conclusions were limited by the short follow-up duration. We did not observe whether the adolescents subsequently experienced a recurrence of depressive symptoms, which had a greater impact on their cognitive performance. Therefore, a longer follow-up study is necessary to demonstrate the actual association between depressive symptoms and cognitive performance.

Conclusion

In conclusion, depressive symptom episodes in early adolescence were associated with worse cognitive performance for later. Even though the adolescents remitted from depressive symptoms, cognitive impairment still existed. Age sensitivity of the detrimental effects of depressive symptoms on later cognitive performance was underlined. The results highlighted that performing mental health screenings, especially during the sensitive windows of cognitive development, is critical to reducing the negative impact of depressive symptoms on adolescent cognitive development. Additionally, tailored mental health interventions and gender-specific screenings are recommended to address the diverse needs of adolescents, especially in contexts like China, where academic pressures may exacerbate the onset and course of depression.

Supplementary Information

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Supplementary Material 1

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Author contributions

Z. X. and P. X.: Formal analysis, Writing - original draft, Writing - review & editing. HX.W., KH. Z.,Q. J., and YN. F.: Investigation, review & editing. RR. S. and H. X.: Investigation, Supervision, Writing - review & editing. All authors reviewed the manuscript.

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Data availability
The datasets generated and analyzed during the current study were derived from the China Family Panel Study (CFPS). Researchers who want to use these data can visit: http://www.isss.pku.edu.cn/cfps/.

Declarations

Ethics approval and consent to participate
The CFPS study involving human participants has been ethically approved by the Peking University Biomedical Ethics Review Committee, with all participants signing informed consent. All study procedures involving human participants follow the 1964 Declaration of Helsinki and its subsequent amendments.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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References

1. Sepehrmanesh Z, Fahimi H, Akasheh G, Davoudi M, Gilasi H, Ghaderi A. The effects of combined Sertraline and aspirin therapy on depression severity among patients with major depressive disorder: A randomized clinical trial. Electron Physician. 2017;9(11):5770–7.
2. Roca M, Monzón S, Vives M, López-Navarro E, Garcia-Toro M, Vicens C, Garcia-Campayo J, Harrison J, Gili M. Cognitive function after clinical remission in patients with melancholic and non-melancholic depression: a 6 month follow-up study. J Affect Disord. 2015;171:85–92.
3. Frampton JE. Vortioxetine: A review in cognitive dysfunction in depression. Drugs. 2016;76(17):1675–82.
4. Gotlib IH, Joormann J. Cognition and depression: current status and future directions. Annu Rev Clin Psychol. 2010;6:285–312.
5. Gohier B, Ferracci L, Surguladze SA, Lawrence E, El Hage W, Kefi MZ, Allain P, Garre J-B, Le Gall D. Cognitive Inhibition and working memory in unipolar depression. J Affect Disord. 2009;116(1):100–5.
6. Liu Y. The joint effects of body mass index and MAOA gene polymorphism on depressive symptoms. Psychiatry Invest. 2015;12(3):408–10.
7. Kessler RC, Amminger GP, Aguilar-Gaxiola S, Alonso J, Lee S, Ustün TB. Age of onset of mental disorders: a review of recent literature. Curr Opin Psychiatry. 2007;20(4):359–64.
8. Kalin NH. Anxiety, depression, and suicide in youth. Am J Psychiatry. 2021;178(4):275–9.
9. Li Z, Qin W, Patel V. Associations of parental depression during adolescence with cognitive development in later life in China: A population-based cohort study. PLoS Med. 2021;18(1):e1003464.
10. Han G, Klimes-Dougan B, Jepsen S, Ballard K, Nelson M, Houri A, Kumra S, Cullen K. Selective neurocognitive impairments in adolescents with major depressive disorder. J Adolesc. 2012;35(1):11–20.
11. Favre T, Hughes C, Emslie G, Stavinoha P, Kennard B, Carmody T. Executive functioning in children and adolescents with major depressive disorder. Child Neuropsychology: J Normal Abnorm Dev Child Adolescence. 2009;15(1):85–98.
12. Gerhard DM, Meyer HC, Lee FS. An adolescent sensitive period for threat responding: impacts of stress and sex. Biol Psychiatry. 2021;89(7):651–8.
13. Schalbetter SM, von Arx AS, Cruz-Ochoa N, Dawson K, Ivanov A, Mueller FS, Lin HY, Amport R, Mildenberger W, Mattei D, et al. Adolescence is a sensitive period for prefrontal microglia to act on cognitive development. Sci Adv. 2022;8(9):eabi6672.
14. Ma A, Tan S, Chen J, Lou H. Stress events and stress symptoms in Chinese secondary school students: gender and academic year characteristics of the relationship. Front Public Health. 2024;12:1360907.
15. Xie Y, Ma M, Wu W, Zhang Y, Zhang Y, Tan X. Dose-response relationship between intergenerational contact frequency and depressive symptoms amongst elderly Chinese parents: a cross-sectional study. BMC Geriatr. 2020;20(1):349.
16. Shorey S, Ng ED, Wong CHJ. Global prevalence of depression and elevated depressive symptoms among adolescents: A systematic review and meta-analysis. Br J Clin Psychol. 2022;61(2):287–305.
17. Fu X, He J, Zheng D, Yang X, Wang P, Tuo F, Wang L, Li S, Xu J, Yu J. Association of endocrine disrupting chemicals levels in serum, environmental risk factors, and hepatic function among 5- to 14-year-old children. Toxicology. 2022;465:153011.
18. Mirza SS, Wolters FJ, Swanson SA, Koudstaal PJ, Hofman A, Tiemeier H, Ikram MA. 10-year trajectories of depressive symptoms and risk of dementia: a population-based study. Lancet Psychiatry. 2016;3(7):628–35.
19. Kaup AR, Byers AL, Falvey C, Simonsick EM, Satterfield S, Ayonayon HN, Smagula SF, Rubin SM, Yaffe K. Trajectories of depressive symptoms in older adults and risk of dementia. JAMA Psychiatry. 2016;73(5):525–31.
20. Wang RAH, Davis OSP, Wootton RE, Mottershaw A, Haworth CMA. Social support and mental health in late adolescence are correlated for genetic, as well as environmental, reasons. Sci Rep. 2017;7(1):13088.
21. Zhang Y, Li Z, Wei J, Zhan Y, Liu L, Yang Z, Zhang Y, Liu R, Ma Z. Long-term exposure to ambient NO2 and adult mortality: A nationwide cohort study in China. J Adv Res 2022.
22. Adams LM, Wilson TE, Merenstein D, Milam J, Cohen J, Golub ET, Adedimeji A, Cook JA. Using the center for epidemiologic studies depression scale to assess depression in women with HIV and women at risk for HIV: are somatic items invariant? Psychol Assess. 2018;30(1):97–105.
23. Yang W, Xiong G, Garrido LE, Zhang JX, Wang MC, Wang C. Factor structure and criterion validity across the full scale and ten short forms of the CES-D among Chinese adolescents. Psychol Assess. 2018;30(9):1186–98.
24. Chin WY, Choi EP, Chan KT, Wong CK. The psychometric properties of the center for epidemiologic studies depression scale in Chinese primary care patients: factor structure, construct validity, reliability, sensitivity and responsiveness. PLoS ONE. 2015;10(8):e0135131.
25. Gu J. Physical activity and depression in adolescents: evidence from China family panel studies. Behav Sci (Basel Switzerland) 2022, 12(3).
26. Lei P, Feng Z. Age-friendly neighbourhoods and depression among older people in China: evidence from China family panel studies. J Affect Disord. 2021;286:187–96.
27. Wang T, Cao S, Li D, Chen F, Jiang Q, Zeng J. Association between dietary patterns and cognitive ability in Chinese children aged 10–15 years: evidence from the 2010 China family panel studies. BMC Public Health. 2021;21(1):2212.
28. Huang G, Xie Y, Xu H. Cognitive ability: social correlates and consequences in contemporary China. Chin Sociol Rev. 2015;47(4):287–313.
29. Li Z, Chen L, Li M, Cohen J. Prenatal exposure to sand and dust storms and children's cognitive function in China: a quasi-experimental study. Lancet Planet Health. 2018;2(5):e214–22.
30. Ren T, Yu X, Yang W. Do cognitive and non-cognitive abilities mediate the relationship between air pollution exposure and mental health? PLoS ONE. 2019;14(10):e0223353.
31. Lévêque E, Lacourt A, Philipps V, Luce D, Guénel P, Stücker I, Proust-Lima C, Leffondré K. A new trajectory approach for investigating the association between an environmental or occupational exposure over lifetime and the risk of chronic disease: application to smoking, asbestos, and lung cancer. PLoS ONE. 2020;15(8):e0236736.
32. Saari T, Hallikainen I, Hintsa T, Koivisto AM. Neuropsychiatric symptoms and activities of daily living in Alzheimer's disease: ALSOVA 5-year follow-up study. Int Psychogeriatr. 2020;32(6):741–51.
33. Ehrenstein JK, van Zon SKR, Duijts SFA, van Dijk BAC, Dorland HF, Schagen SB, Bültmann U. Type of cancer treatment and cognitive symptoms in working cancer survivors: an 18-month follow-up study. J Cancer Surviv. 2020;14(2):158–67.
34. Thapar A, Collishaw S, Pine DS, Thapar AK. Depression in adolescence. Lancet. 2012;379(9820):1056–67.
35. Patton GC, Coffey C, Romaniuk H, Mackinnon A, Carlin JB, Degenhardt L, Olsson CA, Moran P. The prognosis of common mental disorders in adolescents: a 14-year prospective cohort study. Lancet. 2014;383(9926):1404–11.
36. Chen TJ, Dong B, Dong Y, Li J, Ma Y, Liu D, Zhang Y, Xing Y, Zheng Y, Luo X, et al. Matching actions to needs: shifting policy responses to the changing health needs of Chinese children and adolescents. Lancet. 2024;403(10438):1808–20.

37. Mollon J, David AS, Zammit S, Lewis G, Reichenberg A. Course of cognitive development from infancy to early adulthood in the psychosis spectrum. JAMA Psychiatry. 2018;75(3):270–9.
38. Meier MH, Caspi A, Reichenberg A, Keefe RS, Fisher HL, Harrington H, Houts R, Poulton R, Moffitt TE. Neuropsychological decline in schizophrenia from the premorbid to the Postonset period: evidence from a population-representative longitudinal study. Am J Psychiatry. 2014;171(1):91–101.
39. Semkovska M, Quinlivan L, O'Grady T, Johnson R, Collins A, O'Connor J, Knittle H, Ahern E, Gload T. Cognitive function following a major depressive episode: a systematic review and meta-analysis. Lancet Psychiatry. 2019;6(10):851–61.
40. Rock PL, Roiser JP, Riedel WJ, Blackwell AD. Cognitive impairment in depression: a systematic review and meta-analysis. Psychol Med. 2014;44(10):2029–40.
41. Bauer IE, Pascoe MC, Wollenhaupt-Aguiar B, Kapczinski F, Soares JC. Inflammatory mediators of cognitive impairment in bipolar disorder. J Psychiatr Res. 2014;56:18–27.
42. Belanoff JK, Gross K, Yager A, Schatzberg AF. Corticosteroids and cognition. J Psychiatr Res. 2001;35(3):127–45.
43. de Kloet ER, Joels M, Holsboer F. Stress and the brain: from adaptation to disease. Nat Rev Neurosci. 2005;6(6):463–75.
44. Porter RJ, Douglas KM. Cognitive impairment in people remitted from major depression. Lancet Psychiatry. 2019;6(10):799–800.
45. Bertha EA, Balazs J. Subthreshold depression in adolescence: a systematic review. Eur Child Adolesc Psychiatry. 2013;22(10):589–603.
46. Reppermund S, Ising M, Lucae S, Zihl J. Cognitive impairment in unipolar depression is persistent and non-specific: further evidence for the final common pathway disorder hypothesis. Psychol Med. 2009;39(4):603–14.
47. Van der Ende J, Verhulst FC, Tiemeier H. The bidirectional pathways between internalizing and externalizing problems and academic performance from 6 to 18 years. Dev Psychopathol. 2016;28(3):855–67.
48. Blok E, Schuurmans IK, Tijburg AJ, Hillegers M, Koopman-Verhoeff ME, Muetzel RL, Tiemeier H, White T. Cognitive performance in children and adolescents with psychopathology traits: A cross-sectional multicohort study in the general population. Dev Psychopathol 2022:1–15.
49. Masten AS, Roisman GI, Long JD, Burt KB, Obradovic J, Riley JR, Boelcke-Stennes K, Tellegen A. Developmental cascades: linking academic achievement and externalizing and internalizing symptoms over 20 years. Dev Psychol. 2005;41(5):733–46.
50. Englund MM, Siebenbruner J. Developmental pathways linking externalizing symptoms, internalizing symptoms, and academic competence to adolescent substance use. J Adolesc. 2012;35(5):1123–40.
51. Vaillancourt T, Brittain HL, McDougall P, Duku E. Longitudinal links between childhood peer victimization, internalizing and externalizing problems, and academic functioning: developmental cascades. J Abnorm Child Psychol. 2013;41(8):1203–15.
52. Weeks M, Wild TC, Ploubidis GB, Naicker K, Cairney J, North CR, Colman I. Childhood cognitive ability and its relationship with anxiety and depression in adolescence. J Affect Disord. 2014;152–154:139–45.

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